



REVIEW ARTICLE

Prevalence, Types, Risk and Remediation Strategies of Heavy Metals Present in Soils

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ABSTRACT

Significant amount of metals adds to soils and water due to intensification in industrialization and disintegration of heavy metals from rocks in hilly areas, and spreading on plane soil. Contamination of water, soil and sediments through industrial and natural processes is a global problem. Millions ton of materials are producing contaminated with radionuclide's like U and various heavy metals like Ni, Pb and Cd. Heavy metals cannot degrade naturally like organic pollutants and could pollute ecosystem and accumulate in various parts of food chain, so are considered as real threat to environment. These heavy metals are toxic for organism, affect their morphology, biochemical activities and reduce biomass. Because of their wide use heavy metals are great concern with environment, especially their toxicity for biosphere and human being. However few of the elements are essential at low concentration for living organism. Mostly heavy metals are transition elements having densities (>5 g cm⁻³). The most abundant heavy metals found in soil are As, Hg, Cu, Cd, Zn, Cr and Pb. Few of the heavy metals are essential (i.e. Fe, Zn), while some other are toxic (e.g. Mercury (Hg), Cadmium (Cd)). They have hostile consequence on human physiology and other biological system. Heavy metals reduce crop production due to the risk of bio magnification and bioaccumulation in food chain. They cause superficial as well as groundwater contamination. The present study reviewed the prevalence, toxicity, and remediation technique of seven heavy metals, i.e. As, Hg, Cu, Cd, Zn, Cr and Pb, which are frequently exist in soil. This review summarizes the current literature to produce awareness and update the epidemiology of heavy metals in soil.

KEY WORDS: Contamination, remediation strategies, heavy metals, soils, food chain.

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INTRODUCTION

Water, soil and sediment contamination through heavy metals by industrial and natural processes is a global problem. Millions ton of materials contaminated with radionuclides like U and various heavy metals such as Ni, Pb and Cd are producing [1].

As like organic pollutants heavy metals cannot be degraded naturally and could pollute ecosystem and accumulate in various parts of food chain, so are considered as real threat to the environment[2]. These heavy metals are toxic for organism, affect their biochemical activities, morphology and reduce biomass and its variety[3]. Bacteria are among the most abundant organism present on earth. Genes for heavy metals tolerance mechanism are present both on plasmid and chromosome in bacteria on the basis of which they tolerate them [4]. Bacteria also play an important role in biogeochemical cycle such as nitrogen, phosphorus, carbon and sulfur cycle. It also decomposes organic matter such as leaves and straw and increase soil fertility [5]. Normally soil contain low level of heavy metals, however when industrial, agricultural, municipal, and land wastes applied as fertilizer, the quantity of heavy metals may be increased. Increase amount of heavy metals are toxic for man, plant and animal. Most organism particularly bacteria have the ability to detoxify heavy metals (i.e. immobilization/or transformation, mineralization of pollutants) [6]. In polluted soil the survival of microorganism depend on structural properties, intrinsic biochemical, physiological and genetic adaptation including cell morphological properties as well as environmental modification of metal speciation [7]. The quantitative composition of microbial communities are effecting due to the presence of high level of heavy metals. Various studies stated that heavy metals harming microorganism by disrupting their morphology, growth, biochemical activities and cause reduction in their diversity and biomass [8, 9,10]. A bacterium occurs everywhere on

earth and is the most abundant organism. Due to several anthropogenic and natural processes heavy metals are abundantly found in microbial habitats. Therefore microbes develop mechanism to tolerate heavy metals by either complexation, efflux, to use them as terminal electron acceptors in anaerobic respiration or reduction of metal ions [11].

Research on entophytic fungi are in early stage, stated that fungi have the ability to restrain toxic heavy metals by either bio sorption, insoluble metal oxalate formation or chelation onto melanin like polymers and in various situation such fungi do competition with endogenous bacterial micro flora. The practice of filamentous fungi may deliver compensation over bacterial bio augmentation[12]. Numerous fungi like *Aspergillus*, *Trichoderma* and Arbuscular mycorrhizial fungi (AMF) displayed prospective to phytoremediation in metal contaminated soil. Mostly Arbuscular mycorrhizial fungi (AMF) related to hyper and non-hyper accumulating plants have been frequently studied for their roles in phytoremediation. It was find out that Brassicaceae family is one of the known hyper accumulators belonging to non mycorrhizial plant[13]. Fungal endophytes of Brassica plant are critical for phytoremediation of heavy metal contaminated soils. Yet, a little information is available about fungal endophytes isolated from plants grown in heavy metal contaminated soil on the phytoremediation of these soils[14]. In microorganism generally there are two types of metal accumulation process, i.e. bio sorption and bioaccumulation [15]. Bioaccumulation occurs through growing and living cells, while bio sorption occurs through non-growing or non-living biomass. Bio sorption of heavy metal by non-growing or non-living cells has widely studied[16]. Bioaccumulation of heavy metal by actively growing microorganism from single or particularly multi metal system has been rarely studied [17].

Basic Soil Chemistry and Potential Risks of Heavy Metals because of their wide use heavy metals are great concern with environment, especially their toxicity to biosphere and human being. However few of the elements are essential at low concentration for living organism. Mostly heavy metals are transition elements having densities ($>5 \text{ g cm}^{-3}$) [18].

The most abundant heavy metals found in soil are As, Hg, Cu, Cd, Zn, Cr and Pb[19]. Heavy metals reduce crop production due to the risk of bio magnification and bioaccumulation in the food chain. They cause both superficial as well as groundwater contamination. Chemical form and speciation of heavy metal affect the fate and transport of heavy metals in soil [20].

It is believed that the distribution and transport of heavy metals in soil is controlled by such as (1) ion exchange, desorption and adsorption (2) mineral dissolution and precipitation (3) biological mobilization and immobilization (4) aqueous complexation (5) plant uptake [21].

HEAVY METALS AS SOIL POLLUTANTS

Few of the heavy metals are essential elements (i.e. Fe, Zn) while some other are toxic (e.g. Mercury (Hg), Cadmium (Cd)). They have hostile consequence on human physiology and other biological system[22, 23]. Heavy metals show a great affinity for various elements like sulphur, disrupting enzyme function in living cells by forming bonds with this group. Lead, mercury and cadmium ions disrupt cell transport process by binding with cell membranes [22, 24]. Heavy metals produce oxidative stress in a cell by stimulating the formation of free radical and reactive oxygen species[25]. Heavy metals are non-biodegradable and through bio concentration tend to accumulate in living organism tissue[22, 23]. Soil pH, water, carbonate, oxide contents, organic and redox potential influence metal mobility and speciation from biological activity adsorption and complexation like interaction remove some ions [25, 26]. Chelated captions are slightly mobile, while complex and simple captions are more motile. After weathering and oxidation metals become mobile [27].

Soil is a complex mixture of mineral (e.g. clay) and biological substances (e.g. humic), gaseous and aqueous components. It's a vigorous systems with variations in pH, redox potential conditions and moisture content, interfere metals form and availability[18]. Interaction of heavy metals with soil can be understood by surface adsorption, ion exchange and chelation reactions. On the basis of their functional groups humic substances have the ability to form complexes with heavy metals. Reduction of heavy metals in soil can also be depend on pH, ionic strength, type of competing cations, functional group and type of clay minerals[18].

Lead

Lead is an important metal which is belonging to period 6 and group IV of periodic table having atomic number 82, mass number 207.2, density 11.4 g cm^{-3} , melting and boiling point 327.4°C and 1725°C respectively. Lead is a bluish gray naturally occurring metal found mostly as mineral combined with various other elements like oxygen (PbCO_3), or sulphur (i.e., PbS , PbSO_4), and in earth's crust ranges from 10 to 30 mg kg^{-1} [28].

In industrial production of metals, lead is the fifth behind Fe, Cu, Al, and Zn. The Pb used in U.S., about half of them are coming from manufacturing Pb storage batteries. Other uses of Pb include bearings, solders,

ammunition, caulking, cable covers and plumbing pigments, etc. [29]. The general form of lead released in the surface water, ground water and soil are Lead oxides, hydroxides and ionic lead (II), and lead metal oxyanion complexes. Ingestion and inhalation are the two routes of Pb exposure and from both the effects are same. Accumulation of Pb in the body organs (i.e. brain) may cause poisoning and may lead to death. Its presence can also affect the central nervous system, kidneys and gastrointestinal tract. Exposure of children to lead is at risk for poorer IQ, reduced development, mental deterioration and hyperactivity. Under the age of six children are at a more substantial risk. Pb exposure to adult can cause insomnia, nausea, memory loss, weakness of joints and anorexia [30].

Generally Pb is not accumulated by plants. However soil having high concentration of lead, may be possible to uptake from soil. From various studies it is concluded that lead does not accumulate in the fruiting parts of fruit crops (beans, apples, strawberries, tomatoes, squash, beans etc) and vegetables. Higher concentrations of lead are found in surface of root crops (e.g. carrots) and leafy vegetables (e.g. lettuce). Generally plants do not take up large quantities of soil lead, and considered that it is safe to produce garden in soil having lead concentration up to 300 ppm. Lead contamination higher than 300 ppm is a risk for plant survival [31].

Chromium

In periodic table chromium is group VIB first-row *d*-block transition metal, having atomic number 24, mass number 52, density 7.19 g cm⁻³, melting and boiling point 1875°C and 2665°C respectively. Naturally chromium is not occurring in elemental form, only in compound state they can exist. It is one of the less common elements. Chromium is a primary ore product in mine. They are extracted from mined in the form of chromite (FeCr₂O₄). Sources of contamination of chromium include disposal of Cr containing wastes and electroplating processes [33]. Chromium has two forms, i.e. Chromium (VI) and Chromium III. In shallow aquifers where the aerobic condition exists, Chromium (VI) is the dominant form of Cr. Under anaerobic condition soil organic matter convert Chromium (VI) into Cr (III) by soil organic matter, S²⁻ and Fe²⁺ ions often meet in deeper ground water. Chromate and dichromate also have the ability to absorb on the surface of soil. At low pH (<4) Chromium (III) is the dominant form of Cr. Cr³⁺ formulates complexes with OH⁻, NH₃, SO₄²⁻, CN⁻, F⁻, Cl⁻ and soluble organic ligands [32]. On soil sorption characteristic mobility of chromium depend, i.e. iron oxide content, clay content and amount of organic matter present in soil [33]. Chromium can cause allergic dermatitis in human beings [34].

Arsenic

Arsenic is a metalloid present in group VA and period 4 of periodic table. In minerals it occurs in wide range, mostly it occurs in the form of As₂O₃. During extraction of As mostly Pb, Au, Cu, Ag and Zn are also tracking down from ores. During coal combustion it also present in ashes. For arsenic the atomic number is 33, mass number 75, density 5.72 g cm⁻³, melting and boiling point 817°C and 613°C respectively. Arsenic can exist in several oxidation states (-III, 0, III, V) [33]. As (V) is dominant in aerobic environment, usually it present in the form of (AsO₄³⁻) in different protonation states: H₂AsO₄⁻, AsO₄³⁻, H₃AsO₄, H₂AsO₄⁻ [51]. As(III) dominates under reducing condition, prevailing as arsenate (AsO₃³⁻) and protonated forms for it is HAsO₃²⁻, H₂AsO₃⁻ and H₃AsO₃. Arsenic biotransformation produce methylated derivatives of arsine, like di methyl arsine As (CH₃)₂ and tri methyl arsine As(CH₃)₃ both are extremely volatile. Mostly arsenic present in the form of anion, with simple anions like SO₄²⁻ and Cl⁻ it does not form complexes. Arsenic is associated to increase risk of cancer, skin damage and circulatory system problems [34].

Zinc

Zinc is a transition metal situated at period 4 and group IIB of periodic table. Its atomic number is 30, mass number 65.4, density 7.14 g cm⁻³, melting and boiling point 419.5°C and 906°C respectively. Naturally zinc occurs in soil (in crustal rocks about 70 mg kg⁻¹) [35], unnaturally Zn concentrations are rising due to anthropogenic addition. Mostly during industrial activities Zn is adding, such as coal, mining, steel processing and waste combustion. Various foodstuffs contain certain quantity of Zn, and the quantity may be higher when water stored in metal tanks.

Toxic waste and industrial sources may increase the concentration of Zn in drinking water which can cause many health problems. Zn is a trace element which also has positive aspects on human health, i.e. its shortage can cause birth defects [36].

Cadmium

Cadmium is a transition elements present in second row having atomic number 48, mass number 112.4, density 8.65 g cm⁻³, melting and boiling point 320.9°C and 765°C respectively. Along with Hg and Pb, Cd is one of the great three heavy metal poisons and has no known biological functions. In compound state Cd present as divalent Cd (II) ion. In periodic table it present bellows Zn, so has chemical similarity to Zn. For both plant and animal Zn is an essential micronutrient [37]. Ni/Cd batteries are the most important use of Cd, which are rechargeable or secondary power sources providing high output, low maintenance,

long life and high tolerance to electrical and physical stress. Cadmium is also used for coating on vessels and vehicles to provide corrosion, resistance, especially in high stress environment such as aerospace and marine environment. Other cadmium uses are alloys and electronic compounds, stabilizers for polyvinyl chloride (PVC). Cadmium is also present as impurity in various products, i.e. detergents, refined petroleum products and phosphate fertilizers [37]. In mammalian body cadmium disrupts various enzymes. It is believed that kidney damage, which results proteinuria is due to Cd, which adversely affecting enzymes responsible for protein reabsorption in kidney tubules [38].

The most revealed and remarkable prevalence of cadmium poisoning due to cadmium contaminated diet by people in the Jintsu river valley, near Fuchu, Japan. Victims were suffering from *itai* disease, means *ouch, ouch* in Japanese. The symptoms are due to painful osteomalacia (bone disease) shared with kidney malfunction. In Jintsu River Valley the cadmium poisoning was due to irrigated rice contaminated from mines situated at upstream location producing Cd, Zn, and Pb. Tobacco smoking and intake food are the main routes of Cd intake and its accumulation in kidneys lead to kidney dysfunction [38].

Copper

Copper is a transition metal situated in group IB and period 4 of periodic table. Its atomic number is 29, mass number is 63.5, density 8.96 g cm⁻³, melting and boiling point are 1083°C and 2595°C respectively. In the world copper is the most used metal. For both animals and plants copper is the essential micronutrient for growth. Copper helps blood hemoglobin production in humans, while in plants it helps in seed production, water regulation and disease resistance [38].

Although copper is essential but still in high concentration it cause kidney damage, liver damage, intestinal and stomach irritation, anemia. At pH 5.5 the solubility of Cu increased considerably. The pH of farmland is about 6.0–6.5 [39].

Copper and Zn are two essential important elements for humans, animals, plants and microorganism. The metal uptake of plant, from contaminated soil, and water is determined from chemical and physical factors of soil as well as crops physiological properties. Contamination of soil through trace metals may cause direct as well as indirect threats. Direct threat of metals include effects on crop yield and growth, while indirect threat is, entering of heavy metals to food chain, produce negative impact on human health [40].

Mercury

Mercury is situated in same group of periodic table with Cd and Zn. Mercury is the only liquid metals. Its atomic number is 80, mass number 200.6, density 13.6 g cm⁻³, melting and boiling point–13.6°C and 357°C respectively. Mercury is recovering as byproduct of ore processing [33].

The major source of Hg contamination is coal combustion. Another Hg contamination is release from manometers at pressure determining positions along gas/oil pipelines. When mercury release to the environment, they exist in mercurous (Hg²⁺), mercuric (Hg²⁺), alkylated form (methyl/ethyl mercury), or elemental (Hg⁰). The pH and redox potential of the system find out the stable form of Hg. Under oxidizing condition mercuric and mercurous are more oxidizing condition. Inorganic and organic Hg may be reduce to elemental Hg when slightly reducing condition exist. Elemental Hg may be converted to alkylated form by abiotic and biotic process. In alkylated form mercury is most toxic which are volatile in air and soluble in water [33].

Nickel

Nickel is a transition element having atomic number 28 and mass number 58.69 [41]. Nickel is essential in small amount, but at high concentration (above tolerable levels) is dangerous for health. Nickel can cause different types of cancer in various sites within animal's bodies, mainly those which live near refineries. The most common application of Ni is an ingredient of steel and other metal products. The important source of Ni contamination in the soil are electroplating, nickel mining, combustion of fossil fuels and metal plating industries [42].

Nickel also suffers the growth of microorganism but in the presence of it, microorganism usually develops resistance. It is not known that nickel are accumulating in plant and animal body and it has not been found that nickel bio magnify up food chain [38].

REMIEDIATION OF HEAVY METAL-CONTAMINATED SOILS

Generally remediation is subject to an array of regulatory requirements, based on human health assessments and ecological risks where no established standard exist. Normally the regulatory authorities accept remediation strategies that reduce availability of metal to reduce risk [43].

Immobilization Techniques

For remediation of metal contaminated soil in situ and ex situ immobilization technique is a practical approach. For highly contaminated soil ex situ remediation technique is applied, in which soil are removed from it place of origin. Advantages of ex situ remediation are: (i) fast and easy applicability (ii) relatively low costs of investment and operation, while Disadvantages of ex situ remediation include (1)

the byproduct need to store in a special landfill site (2) high invasively to the environment (3) generation of a significant amount of solid wastes (4) for stored wastes permanent control is required (5) for release of additional contaminants a serious danger is present in case of changing physiochemical condition in its surrounding or side product. In situ remediation method have advantages, e.g. (1) rapidity and simplicity (2) low invasively (3) high public acceptability (4) only a small amount of wastes are produced (5) relatively inexpensive (6) cover a broad spectrum of inorganic pollutants, disadvantage include (1) permanent monitoring is necessary (2) the activation of pollutants may occur when soil physiochemical properties change (3) it is only a temporary solution (4) only to the upper layer of soil reclamation process is applied [44].

Solidification/Stabilization (S/S)

Solidification includes the addition of binding substances to a contaminated material to communicate dimensional/physical stability to contain contaminants in a solid product and decrease access by exterior substance through combination of chemical reaction, reduce permeability and encapsulation. Stabilization involves the addition of reagents of contaminated soil to produce more chemically stable constituents. In many countries of the world conventional S/S is established as a treatment technology for contaminated soil and hazardous wastes [45].

Solidification/stabilization may not suitable for sites containing wastes in the form of organic, mostly if volatile organics are present. Heating and mixing related to blinder hydrogen may discharge organic clouds. Pretreatment, e.g. incineration or stripping may be used to remove the organics and formulate the waste for metal Solidification/stabilization [33].

For ex situ S/S treatment fixed and mobile treatment plant are available. Smaller pilot scale plant can treat up to 100 tons of contaminated soil per day while larger portable plants can treat up to 500-1000 tons per day [33]. In situ S/S is less energy intensive and less labor than ex situ process that requires transport, excavation and treated material disposal. In situ S/S is also preferred if volatile or semi volatile organics are present because these contaminants are exposing to air due to excavation [46].

Verification

Metal contaminants mobility can be decrease by high temperature treatment of the contaminated area, results the formation of vitreous material, usually an oxide solid. Increase temperature may volatilize organic contaminants or volatile metal species, collected from treatment or disposal. Most of the organic and inorganic contaminants are targeted in the soil during treating soil by verification. Both ex situ and in situ process are used for verification, in situ processes are preferred over ex situ because of low cost and energy requirements [47]. In ex situ verification processes typical stages include excavation, mixing, feeding, pretreatment, melting and forming or casting of the melted product. The energy used in melting is the primary factor influencing the cost of ex situ verification. For this purpose various sources of energy are used, depending on the cost of local energy. Water content of the feed and heat losses of the process should be controlled in order to minimize energy requirements. Vitrified material having various characteristics may be obtained by using additives such as clay, sand, and/or native soil. Vitrified waste may be reused as aggregate, clean fill, or other reusable material [33].

Soil Washing

Soil washing or removal of heavy metal is done on the basis of addition of various chemical to soil. This technique is performed in reactors. The adding chemical may be organic or inorganic, e.g. acetic acid and sulphuric acid, ethylenediamine tetra acetic acid (EDTA) are also used as chelating agents. After cleaning the soil is then returned to its original location. Effectiveness of the technique depends on soil characteristics [48]. Soil washing is a waste minimization treatment process. The process is done both in situ and ex situ. During soil washing various technique are applied, e.g. physical separation of contaminant from bulk soil, or contaminants are separated through aqueous chemical, or through combination of both techniques [49]. Separated contaminants are goes to hazardous waste landfill (in few cases are further treated by biological, thermal or chemical processes). After removing the contaminant from soil the treated soil are recycled to original site. Mostly Ex situ soil washing are frequently used because it ensures the rapid cleanup and completely removes the contaminants [50].

Principles of Soil Washing

Soil washing is a physical and/or chemical process in which volume reduction/waste minimization is done. During this processes contaminants are recovered through physical washing, particle grain size differences, settling velocity, surface chemical behavior, specific gravity and rarely magnetic properties. In mining industries standard mineral processing equipment is used [49]. Soil particles are cleaned by transferring the contaminated soil into solution. Heavy metals are sparingly soluble and mostly occur in sorbet state, washing the soils with water would be expected to remove very low amount of cation's in leachates, chemical agents have to be added to the washing water [51]. Cleaned soil is obtained by mixing soil samples with acids aqueous solution, e.g. surfactants, alkalis, complexants and other solvents. The

cleaned particles are then separated from resulting aqueous solution. The obtained solution is then treated for contaminants removal (e.g. by sorption on ion exchange or activated carbon) [52].

Chemical Extractants for Soil Washing

Different classes of chemicals are used for soil washing including surfactants, cyclodextrins, organic acids and chelating agents [53,54]. Soil washing extractants depend on types of contaminants at particular site. Chelating organic acids can dislodge the carbonate, exchangeable and reducible fractions to heavy metals by washing procedure. Although various chelating compounds, e.g. tartaric acid, citric acid and EDTA have been evaluated for mobilizing heavy metals, there remain uncertainties as to the optimal choice for full scale application [55].

PHYTOREMEDIATION

It is an old concept to use plants to clean environmental contaminants. For treatment of wastewater, plants were used for about 300 years ago [56]. *Viola calaminaria* and *Thlaspi caerulescens* were documented in the end of 19th century to accumulate large amount of metals in leaves [57].

Byers reported in 1935 that plant of genus *Astragalus* were capable of storing selenium in dry shoot biomass up to 0.6 % [58]. About 10 year later Minguzzi and Vergnano identified in (1948) that plants can accumulate up to 1% Ni in shoots [59]. Later on Rascio, reported in (1977) that high Zn accumulation and tolerance are occurring in shoots of *Thlaspi caerulescens* [60]. In 1991 (Baker et al.) conducted the first trial on Cd and Zn phytoextraction. Plant may degrade organic pollutants, break down or remove and stabilize metal contaminants. Phytoremediation technique is quite different from those to remediate organic contaminants from a site [61]. Modern phytoremediation technique is more advantageous than classical remediation including, (1) it is economically more feasible (2) less disruptive (3) it avoid excavation and transport of polluted media (4) disposal sites not needed (5) it is more acceptable to the public (6) it has the potential to treat more than one polluted sites. Disadvantages of phytoremediation include (1) growing condition is necessary (i.e. temperature, climate, altitude and geology) (2) contaminants may be stored in woody tissue which are used as fuel (3) large scale operations require access to knowledge and agricultural equipment (4) tolerance of plant to pollutants needed (5) contaminants stored in senescing tissues may be released back into the environment in autumn (6) solubility of contaminant may be increase causing to greater environmental damage and leaching possibility [62].

Phytoextraction (Phytoaccumulation)

Phytoextraction is the process in which plant root uptake metal contaminants from soil and translocate them to the areal part of the plant. Plant used for phytoremediation needs to tolerate heavy metals, grow rapidly and accumulate heavy metals [63]. For phytoextraction technique there are two main approaches namely, continuous or natural phytoextraction and chemically enhanced phytoextraction [64].

Continuous or Natural Phytoextraction

Continuous phytoextraction depend on the use of natural hyper accumulator plant with exceptional metal accumulating capacity. Hyper accumulator plant species can accumulate metals up to 100-fold greater than common non-accumulator plant. So, a hyper accumulator plant will concentrate more than 100mg kg⁻¹ Cd, 10mg kg⁻¹ Hg, 1000mg kg⁻¹ Co, Cr, Cu and Pb; 10 000mg kg⁻¹ Ni and Zn [65].

Chelate-assisted (induced) Phytoextraction

Chelant enhanced phytoextraction of metals from contaminated soil have received much attention as cost effective alternative to conventional techniques of improved soil remediation from contaminated soil for more than 10 years. When chelating agent is applied to soil, they form metal chelant complexes which are then taken by plant mostly through a passive apoplastic [66]. Chelators which are strongly involved in the uptake of heavy metals and their detoxification have been isolated from plant. TDTA is one of the chelating agents which are the most tested mobilizing amendments for less mobile/available metals such as Pb [67].

Phytostabilization

Phytostabilization is primarily concerned with the use of certain plants to immobilize sludge's and sediment [68]. Root absorbed and accumulates the contaminant, adsorbed onto the roots, or precipitated in the rhizosphere. This decrease or even prevents the movement of contaminants migration into air or groundwater and reduce contaminants bioavailability thus preventing spread through food chain. Plants used for phytostabilization should be able to (1) act as barrier to prevent direct contact with contaminated soil (2) prevent soil erosion and distribution of toxic metal to other areas (3) reduce water amount percolating through soil matrix which may cause formation of hazardous leachate [69]. Phytostabilization occurs through the process of precipitation, metal valence reduction or sorption. This technique is useful for cleanup of Zn, Pb, Cr, As, Cu and Cd [70].

Phytostabilization is advantageous because disposal of hazardous biomass/material is not required, and it is so much effective when rapid immobilization is needed to preserve surface and ground water [71].

Phytofiltration

Phytofiltration means the use of plant root (rhizofiltration) or seedlings (blast filtration), is similar in concept to phytoextraction, but is used to adsorb or absorb pollutants, mainly heavy metals from ground water and aqueous waste stream rather than the remediation of polluted soils[72]. Rhizosphere is the soil around the root hairs, about a few millimeters from the root surface. The contaminants are either adsorbed onto root surface or plant root. For rhizofiltration plants are not planted directly in situ but are acclimated to the pollutant first. Hydroponically plants are grown in clean water instead of soil, until a large root system has developed. When the large root system is developed the clean water supply is substituted for polluted water to accumulate plant. After the plant get adaptation they are planted in polluted area the root uptake polluted water along with contaminants. When the root becomes saturated they are harvested and disposed up safely [34].

BIOLOGICAL TECHNIQUES

Using living organism to remove heavy metals is still in its initial stages, including bio sorption, oxidation/reduction reaction and bioleaching. Either bacteria or fungi are used during bioleaching. For inorganic sulphur compound oxidation *Thiobacillus* spp are responsible(73). *Aspegillusniger* offers also a promising alternative due to gluconic acid and citric acid production. For heavy metal removal these acids can act as chelating agents (73). Another promising biochemical process is bio sorption, which are used for removal of heavy metals at low concentration [48]

CONCLUSION

Significant amount of metals adds to soils and water due to intensification in industrialization and disintegration of heavy metals from rocks in hilly areas, and spreading on plane soil. Contamination of water, soil and sediments through industrial and natural processes is a global problem. Millions ton of materials are producing contaminated with radionuclides like U and various heavy metals such as Ni, Pb and Cd. Heavy metals cannot degrade naturally like organic pollutants and could pollute ecosystem and accumulate in various parts of food chain, so are considered as real threat to the environment. These heavy metals are toxic for organism, affect their morphology, biochemical activities and reduce biomass. Mostly heavy metals are transition elements having densities (>5 g cm⁻³). The most abundant heavy metals found in soil are As, Hg, Cu, Cd, Zn, Cr and Pb. Few of the heavy metals are essential elements (i.e. Fe, Zn) while some other are toxic (e.g. Mercury (Hg), Cadmium (Cd)). They have hostile consequence on human physiology and other biological system. Remediation techniques are using in various countries to get rid from the horrors of heavy metals.

COMPETING INTEREST

The author declares that they have no competing interest.

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