Vidya (2020) Vol : 15(1)

Review Paper

ISSN: 2321-1520

Cause and Effect of Heavy Metal Pollution in the Landscape: A Reivew

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Received Date: 30-10-2019

Published Date: 15-03-2020

Abstract

Most pollutants are introduced into the environment as sewage, waste, involuntary discharge and compound used to protect plants such as pesticides and animals. The most common heavy metals found at contaminated sites, in order of abundance are Pb, Cr, As, Zn, Cd, Cu, and Hg. Heavy metal concentrations in the soil can lead to enhanced crop uptake and negative outcome on plant growth. At higher concentrations, they interfere with metabolic processes and inhibit growth, sometimes leading to plant death. Zinc is required by large number of enzymes and its toxicity often leads to leaf chlorosis. Excess copper in the growing medium can restrict root growth. Lead can cause serious injury to the brain, nervous system, red blood cells, and kidneys. Arsenic exposure to human, results in the degenerative, inflammatory and neoplastic change of skin, respiratory system, blood, lymphatic system, nervous system and reproductive system. Cd is one of the big three heavy metal poisons and is not known for any essential biological function. Mercury Exposure can permanently damage the brain, kidneys, and developing foetuses. Accumulation of heavy metal by human causesmulty organ failure, Reaction to skin, affect the nervous system or other biological systems in the human body. This metal contamination is prevented by phytoremediation which is low cost and eco-friendly in nature.

Keywords: Biomagnifications, Bioaccumulation, Heavy metal, Human health, Soil, Plant health, Toxicity

Introduction

Human activities like scattering and discarding of industries and municipal wastes are the problem and major environmental concern that contaminate water, soil and aquatic ecosystem like Ground water, land, Fertile soil etc. Pollution occurs when a manufactured goods addition to our natural environment adversely affects nature's ability to dispose it off(Wuana1 and Okieimen, 2011). A pollutant is something which adversely interferes with health, comfort, property or environment of the people. Most pollutants are introduced in the environment as sewage, waste, unintentional discharge and compound used to protect plants such as pesticides and animals. There are many types of pollution such as air pollution, soil pollution, water pollution and oil pollution. A wide range of inorganic and organic compounds cause contamination especially in rainy season, its decomposition produces noxious odour constituting a health hazard (Wuana and Okieimen,2011).

Human evolution has led to immense scientific and technological progress. Global development, however, raises new challenges, especially in the field of environmental protection and conservation the demand for a country's economic, agricultural and industrial development outweighs the demand for a safe, pure, and natural environmental. Ironically, it is the economic, agricultural and industrial developments that are often linked to polluting the environment (Jadia and Fulekar, 2009) Immobilization, soil washing, and phytoremediation techniques are frequently listed among the best demonstrated available technologies (BDATs) for remediation of heavy metal-contaminated sites (Wuana and Okieimen,2011).

Those metals are significant since they are capable of decreasing crop production due to the risk of bioaccumulation and biomagnifications in the food chain. There's also the risk of superficial and groundwater contamination. Knowledge of the basic chemistry, environmental and associated health effects of these heavy metals is necessary in understanding their speciation, bioavailability, and remedial options. The fate and transport of a heavy metal in soil depends significantly on the chemical form and speciation of the metal. Once in the soil, heavy metals are absorbed by initial fast reactions, followed by slow adsorption reactions (days, years) and are redistributed into different chemical forms with varying bioavailability, mobility, and toxicity. This distribution is believed to be controlled by reactions of heavy metals in soils such as (I) mineral precipitation and dissolution, (II) ion exchange, adsorption, and desorption, (III) aqueous complication, (IV) biological immobilization and mobilization, and (V) plant uptake (Wuana1 and Okieimen, 2011).

Properties of Heavy Metals

They occur near the bottom of the periodic table, Have high densitie, Toxic in nature, Non degradable. However Arsenic is not actually a metal but is a semi metal i.e. its properties are intermediate between those of metals and non-metals (Rajeswari and sailaja,2014).

Sources of Metal Contamination

Heavy metals occur naturally in the soil environment from the pedogenetic processes of weathering of parent materials at levels that are regarded as *trace* (<1000mg kg^{-1}) and rarely toxic.Soil has being bio accumulated by most heavy metals like Fe, Pb, Ni, Cr, Cd etcresulting to serious disease infection to crops, animals and human beings. Soil pollution by heavy metals such as cadmium, lead, chromium, copper and zinc is a problem of concern. Although heavy metals are naturally present in soil contamination and comes from local sources: mostly industry (non-ferrous industries, but also power plants and iron, steel and chemical industries) (O.A. Ekpete et al, 2013).

Access Direction of Heavy Metal

Heavy metals go in plant, animal and human tissues via air inhalation, diet and manual handling. Motor vehicle emissions are a major source of airborne contaminants including arsenic, cadmium, cobalt, nickel, lead, antimony, vanadium, zinc, platinum, palladium and rhodium. Plants are exposed to heavy metals through the uptake of water; animals eat these plants; ingestion of plant- and animalbased foods are the largest sources of heavy metals in humans. Plants are exposed to heavy metals through the uptake of water; animals eat these plants; ingestion of plant- and animal based foods are the largest sources of heavy metals in humans (Rajeswari and sailaja,2014).

<u>Historical Converse and Metal Toxicity in Plant</u>

Soils may become contaminated by the accretion of heavy metals and metalloids through emissions from the rapidly mounting industrial areas, mine tailings, disposal of high metal wastes, leaded gasoline and paints, land application of fertilizers, animal manures, sewage sludge, pesticides, wastewater irrigation, coal combustion residues, spillage of petrochemicals, and atmospheric deposition. The presenceof toxic metals in soil can severely inhibit the biodegradation of organic contaminants (Maslin and Maier, 2000). Heavy metal contamination of soil may pose risks and hazards to humans and the ecosystem through direct intake or contact with contaminated soil, those metals are important since they are capable of decreasing crop production due to the risk of bioaccumulation and biomagnifications in the food chain the food chain(Wuana and Okieimen, 2011).

Schmidt (2003) reported that elevated heavy metal concentrations in the soil can lead to enhanced crop uptake and negative effect on plant growth. At higher concentrations, they interfere with metabolic processes and inhibit growth, sometimes leading to plant death. Excessive metals in human sustenance can be toxic and can cause heightened and unceasing diseases(Jadia and Fulekar, 2009).The adequate protection and restoration of soil ecosystems that have been contaminated by heavy metals require their characterization and remediation (Wuana and Okieimen, 2011).

Zinc is a transition metal with the following characteristics: period 4, group IIB, atomic number 30, atomic mass 65.4, density 7.14 g cm$^{″3}$, melting point 419.5æ%C, and boiling point 906æ%C. Zinc occurs naturally in soil (about70mg kg″1 in crustal rocks) (Davies and Jones,1988) but Zn concentrations are rising unnaturally, due to anthropogenic additions. Most Zn is added during industrial activities, such as mining, coal, and waste combustion and steel processing. Many foodstuffs contain certain concentrations of Zn. Drinking water also contains certain amounts of Zn, which may be higher when it is stored in metal tanks. Industrial sources or toxic waste sites may cause the concentrations of Zn in drinking water to reach levels that can cause health problems.Zinc is a trace element that is essential for human health.Zinc shortages can cause birth defects. The world's Znproduction is still on the rise which means that more andmore Zn ends up in the environment (Wuana and Okieimen, 2011). Zinc toxicity often leads to leaf chlorosis, High levels of zinc inhibit the uptake of iron, and it is common to find symptoms of severe iron deficiency induced by zinc toxicity. Iron deficit is characterised by a pale yellow to white interveinal chlorosis on the younger leaves, and may ultimately lead to necrosis of the leaf blades and increasing point.(Jadia and Fulekar, 2009).

Copper (Cu) is a transition metal which belongs to period 4 and group IB of the periodic table with atomic number 29, atomic weight 63.5, density 8.96 g cm$^{˝3}$, melting point 1083æ%C and boiling point 2595æ%C. The metal's average density and concentrations in crustal rocks are 8.1 × 103 kgm$^{˝3}$ and 55mg kg$^{˝1}$, respectively. Excess copper in the growing medium can restrict root growth by burning the root tips and thereby causing excess lateral root growth. High levels of copper can compete with plant uptake of iron and sometimes molybdenum or zinc(Davies and Jones, 1988; Mishra et al,2019). Copperis essential micronutrient for plants. Copper contributes to several physiological processes in plants including photosynthesis, respiration, carbohydrate distribution, nitrogen and cell wall metabolism, seed production including also disease resistance(Jadia and Fulekar,2009). Excess copper exposure can be potentially toxic to plants causing phytotoxicity by the formation of reactive oxygen radicals that damage cells or by the interaction with proteins impairing key cellular processes, inactivating enzymes and disturbing protein structure. Effect of Cu on root hair proliferation suggests that reductions in growth due to nutrient deficiency or inhibition of nodulation may occur at lower Cu concentrations(Sheldon and Menzies, 2005,Mishra et al, 2018).

Leadis a metal belonging to group IV and period 6 of the periodic table with atomic number 82, atomic mass 207.2, density 11.4 g cm$^{˝3}$, melting point 327.4$^{æ\%}$C, and boiling point 1725$^{æ\%}$C. It is a naturally occurring, bluish gray metal usually found as a mineral combined with other elements, such as sulphur (i.e.,PbS, $PbSO_4$), or oxygen ($PbCO_3$), and ranges from 10 to 30mg kg$^{˝1}$ in the earth's crust (USDHHS,1999). Typical mean Pb concentration for surface soils worldwide averages 32mg kg$^{˝1}$ and ranges from 10 to 67mg kg˝1It is well known to be toxic and its effects have beenmore extensively reviewed than the effects of other trace metals. The Pb present in the soil solution is absorbed by the plant roots. Aa large proportion of Pb^{2+} is retained in plant roots in precipitated form, The growth of aerial part of plants and roots are inhibited by the low concentration of Pb. If the Pb content is higher in the growing medium, the inhibition is strongly seen on root growth(Srivastava et al,2015). Lead can cause serious injury to the brain, nervous system, red blood cells, and kidneys (Baldwin and Marshal, 1999).

Arsenic has the following properties: atomic number 33, atomic mass 75, density 5.72 g cm$^{\text{"}3}$, melting point 817$^{\text{æ\%}}$C, and boiling point 613$^{\text{æ\%}}$C, and exhibits fairly complex chemistry and can be present in several oxidation states ("III, 0, III, V)(Smith et al, 1995). In aerobic environments, As (V) is dominant, usually in theform of arsenate (AsO4$^{3\text{"})}$ in various protonation states:H_3AsO_4, $H_2AsO_4^{\text{"}}$, $HAsO_4^{2\text{"}}$, and $AsO_4^{3\text{"}}$.Arsenate andother anionic forms of arsenic behave as chelates andcan precipitate when metal cations are present (Bodek et al,1988).Arsenic exposure to human results in degenerative, inflammatory and neoplastic changes of skin, respiratory system, blood, lymphatic system, nervous system and reproductive system. There is no particular remedial action for chronic arsenic poisoning(Singh et al, 2007). Arsenic is to disturb biochemical and metabolic pathways such as impeded nutrient absorption, the negative effect on photosynthetic apparatus, the disruption of plant water status, interaction with the functional groups of enzymes and replacement of essential ions from adenosine triphosphate (ATP) in plants growing in As-contaminated soils(Abbas et al, 2017)

Chromiumis a first-row *d*-block transition metal of group VIB in the periodic table with the following properties: atomic number 24, atomic mass 52, density 7.19 g cm$^{\text{"}3}$, melting point 1875$^{\text{æ\%}}$C, and boiling point 2665$^{\text{æ\%}}$C. It is one of the less common elements and does not occur naturally in elemental form, but only in compounds. Chromium is mined as a primary ore product in the formof the mineral chromite, $FeCr_2O_4$(Wuana and Okieimen,2011).Its exposure can cause damage to liver, kidney circulatory and nerve tissues, as well as skin irritation (Martin and Griswold, 2009). Cr also causes deleterious effects on plant physiological processes such as photosynthesis, water relations and mineral nutrition. Metabolic alterations by Cr exposure have also been described in plants either by a direct effect on enzymes or other metabolites or by its ability to generate reactive oxygen species which may cause oxidative stress(Shanker et al,2005, Mishraet al, 2019).

Cadmium is located at the end of the second row of transition elements with atomic number 48, atomic weight 112.4, density 8.65 g cm$^{\text{"}3}$, melting point 320.9*æ%*C, and boiling point 765*æ%*C. Together with Hg and Pb, Cd is one of the big threeheavy metal poisons and is not known for any essential biological function (Wuana and Okieimen,2011).Ingesting high levels rigorously irritates the stomach, leading to vomiting and diarrhea AND Cd-induced effects include oxidative stress, genotoxicity, inhibition of the photosynthetic apparatus, and inhibition of root metabolism (Martin and Griswold, 2009).

Mercury belongs to same group of the periodic table with Zn and Cd. It is the only liquid metal. It has atomic number 80, atomic weight 200.6, density 13.6 g cm$^{\prime\prime 3}$, melting point ″13.6$^{æ\%}$C, and boiling point 357$^{æ\%}$C and is usually recovered as a by-product of ore processing. Exposure to Hg can also reduce photosynthesis, transpiration rate, and water uptake and chlorophyll synthesis(Smith et al, 1995). Mercury in soil and water is converted by microorganisms to methyl mercury, a bio accumulating toxin. The nervous system is very sensitive to all forms of mercury. Exposure can permanently damage the brain, kidneys, and developing foetuses. Effects on brain functioning may result in irritability, shyness, tremors, *89-changes in vision or hearing, and memory problems. Short-term exposure to high levels of metallic mercury vapours may cause lung damage, nausea, vomiting, diarrhea, increases in blood pressure or heart rate, skin rashes, and eye irritation (Martin and Griswold, 2009). Hg have been related to seed injuries and reducing seed viability. Exposure to Hg can also reduce photosynthesis, transpiration rate, and water uptake and chlorophyll synthesis. Both organic and inorganic Hg have been showed to cause loss of potassium, magnesium, and manganese and accumulation of iron (Azevedoand Rodriguez, 2012)

Potential for Human Exposure of Metal

Heavy metals are known to cause toxicities around the world. Accumulation of heavy metal by human cause many dieses like organ failure, Reaction to Skin, Affect the nervous System or other Biological system in Human body (Jadia and Fulekar, 2009). Toxic metals can bio accrues in the body and in the food chain. A common attribute of toxic metals is the chronic nature of their toxicity (Rajeswari and sailaja, 2014).

Table 1: Clinical Aspects of Chronic Toxicities Metal (Mahurpawar, 2015)

Metal	Target Organs	Primary Sources	Clinical effects
Arsenic	Pulmonary Nervous System, Skin	Industrial Dusts, Medicinal Uses Of Polluted Water	Perforation of Nasal Septum, Respiratory Cancer, Peripheral Neuropathy: Dermatomes, Skin, Cancer
Cadmium	Renal, Skeletal Pulmonary	Industrial Dust And Fumes And Polluted Water And Food	Proteinuria, Glucosuria, Osteomalacia, Aminoaciduria, Emphysemia
Chromium	Pulmonary	Industrial Dust And Fumes And Polluted Food	Ulcer, Perforation of Nasal Septum, Respiratory Cancer
Manganese	Nervous System	Industrial Dust And Fumes	Central And Peripheral Neuropathies
Lead	Nervous System, Hematopoietic System, Renal	Industrial Dust And Fumes And Polluted Food	Encephalopathy, Peripheral Neuropathy, Central Nervous Disorders, Anemia.
Nickel	Pulmonary, Skin	Industrial Dust, Aerosols	Cancer, Dramatis
Tin	Nervous , Pulmonary System	Medicinal Uses, Industrial Dusts	Central Nervous System Disorders, Visual Defects And EEG Changes, Pneumoconiosis.
Mercury	Nervous System, Renal	Industrial Dust And Fumes And Polluted Water And Food	Proteinuria

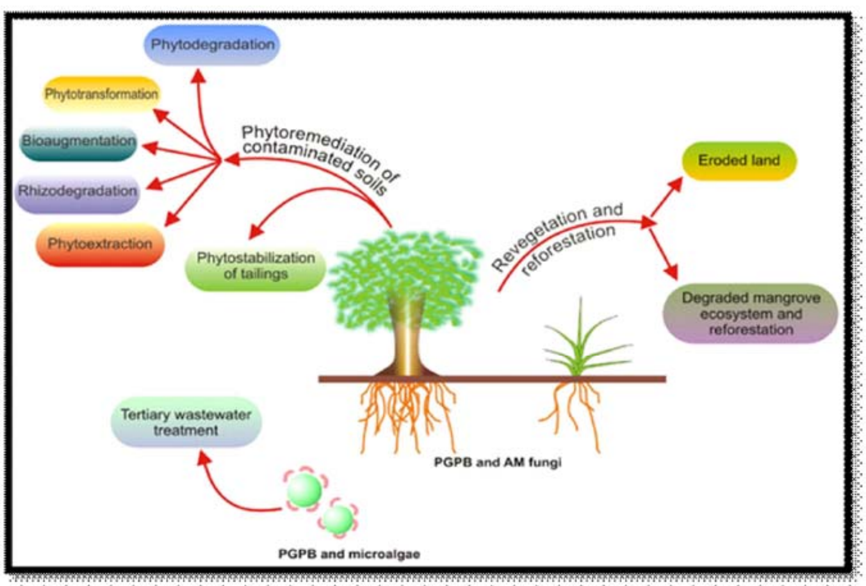
Remediation of Soil Using Plants

Phytoremediation is a bioremediation process that uses various types of plants to remove, transfer, stabilize, and/or destroy contaminants in the soil and groundwater. **Plants** use photosynthesis to extract chemicals from the soil and to put down them in the on high part of their bodies, or to convert them to a less contaminated form. These **plants** can then be harvested and treated, removing the pollutants(JayBoi , 2015;Mishra et al,2018).The study and development of phytoremediation for metal-contaminated soils was taking place about 40 years ago, and the phytoremediation for organic pollutants are more recent. Phytoremediation has gained extensively attention and much progress in remediation of inorganic and organic contaminants, and the means for enhanced phytoremediation. Phytoremediation are expected to be used as a vital tool in sustainable management of contaminated soils. Contaminated site managers should consider phytoremediation when evaluating remedial alternatives(Oh et al, 2014)

Plants Used For Phytoremediation

- *Brassica juncea L* (Indian mustard) (Info*: Brassica juncea (L.)* Czern. – Indian Mustard....
- Salix species (Willow)
- Populus deltoides (Poplar tree)
- Sorghastrum nutans (Indian grass)
- Helianthus Annuus L (Sunflower) ,
- Helianthus annuus L. (common sunflower)(Jay Boi , 2015)

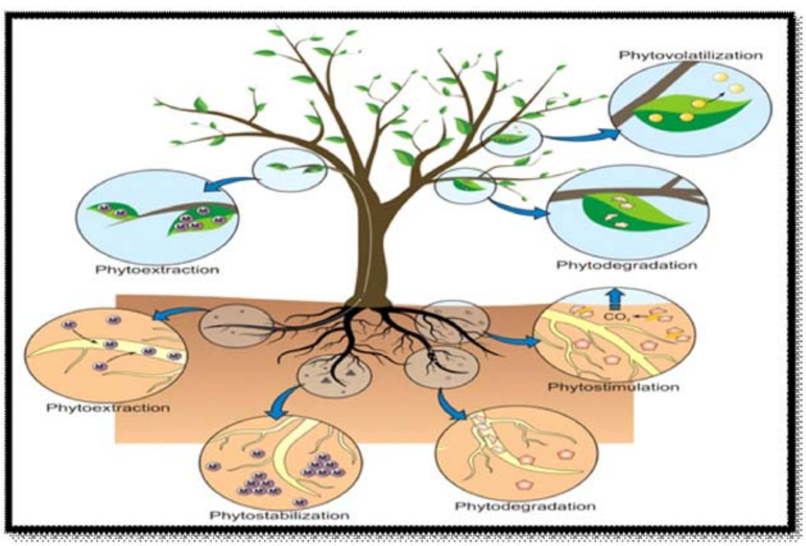
Fig: 1 Phytoremediation of soil (Solke H De Boer, 2001)



Mechanism of Phytoremediation

There are several ways by which plants clean up or remediate contaminated sites. The uptake of contaminants in plants occurs primarily through the root system, in which the principal mechanisms for preventing toxicity are found (Subhashini and Swamy , 2013). The root system provides an enormous surface area that absorbs and accumulates the water and nutrients essential for growth along with other non-essential contaminants (Vamerali et al,2010).Plant roots cause changes at the soil-root interface as they release organic and inorganic exudates in the rhizosphere. These root exudates affect the number and activity of microorganisms, the aggregation and stability of the soil particles around the root, and the availability of the contaminants (Ali and Sajad,2013). Root exudates by themselves can increase or decrease (immobilize) the availability of the contaminants in the root zone of the plants through changes in soil characteristics, release of organic substances, changes in chemical composition and/or increase in plant assisted microbial activity (Vamerali et al,2010).Phytoremediation of contaminated soils is generally supposed to take place through one or more of the following mechanisms or processes: phytoextraction, phytostabilization, phytodegradation, phytovolatilization, rhizofiltration and rhizodegradation(oh et al,2014)

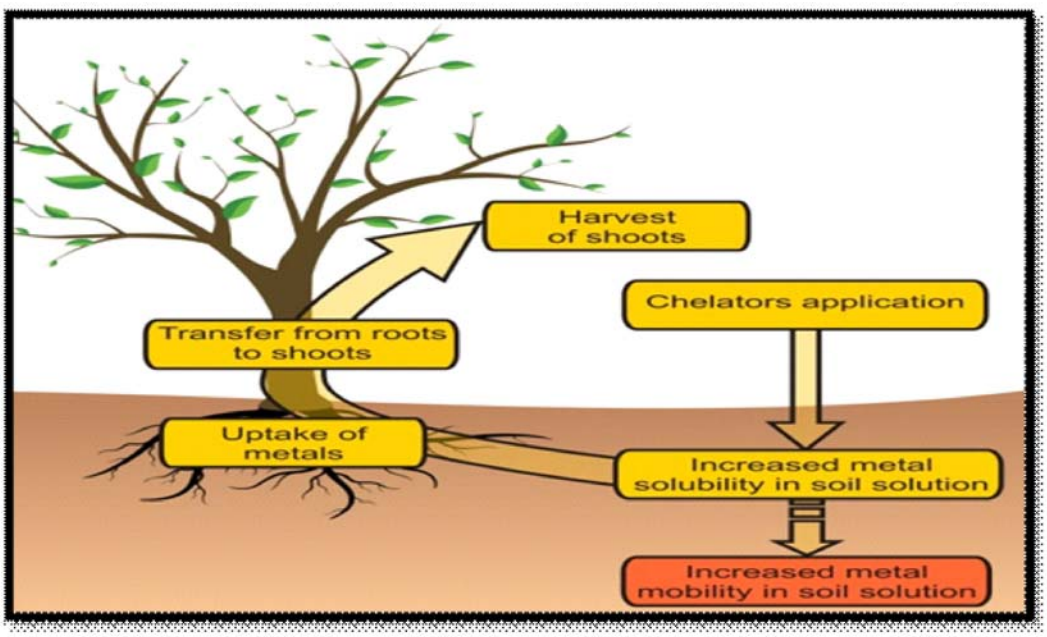
Fig:2 Mechanism of Phytoremediation(Pauloet al, 2004)



Phytoextraction

Phytoextraction also called phytoaccumulation refers to the uptake and translocation of metal contaminants in the soil by plant roots into the aboveground portions of the plants. Certain plants, called hyper accumulators, adsorb unusually large amounts of metals in comparison to other plants (Subhashini and Swamy, 2013). One or a combination of these plants is selected and planted at a particular site based on the type of metals present and other site conditions. After the growth period of the plants, they are harvested and either incinerated or composted to recycle the metal (Elekes, 2014). This procedure may be repeated if necessary, to bring soil contaminant levels down to permissible limits. If plants are incinerated, ash is disposed off in a hazardous waste landfill (Ali and Sajad,2013). The volume of ash will be less than 10% of the volume that is created, if the contaminated soil itself were dug up for treatment (Saxena et al,1999). Metals such as nickel, zinc and copper are the best candidates for removal by phytoextraction because it has been shown that they are preferred by a majority of the (approximately400) plants that uptake and absorb unusually large amounts of metals (Elekes,2014).

Fig: 3 Phytoextraction(Pauloet al, 2004)



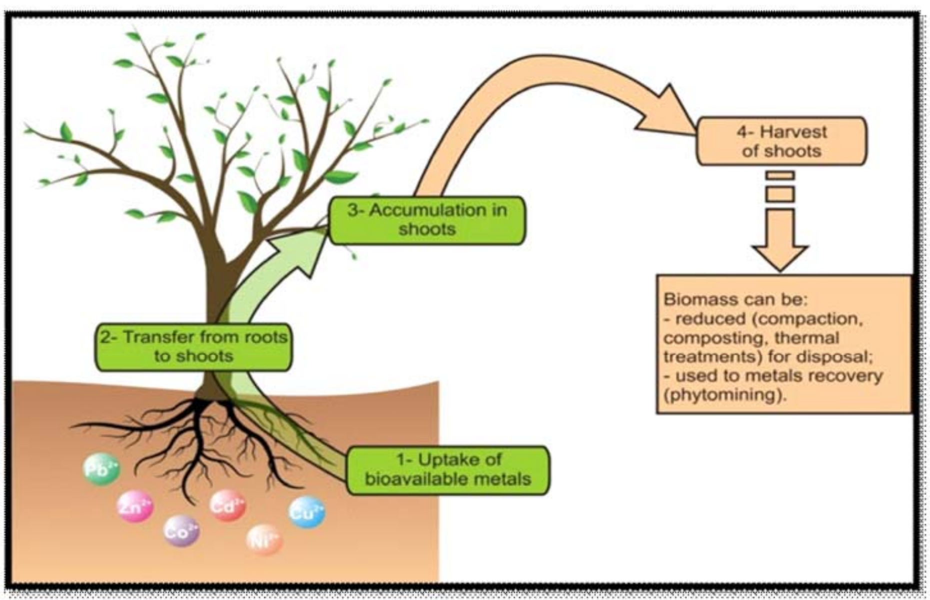
<u>Rhizofiltration</u>

Rhizofiltration (rhizo- means root) is the adsorptionor precipitation on to plant roots or absorption of contaminants in the solution surrounding the root zone. Rhizofiltration is similar to phytoextraction, but the plants are used primarily to address contaminated ground water rather than soil (Tangahu et al, 2011). The plants to be used for cleanup are raised in greenhouses with their roots in water rather than in soil (Saxena et al, 1999). To acclimatize the plants, once a large root system has been developed, contaminated water is collected from a waste site and brought to the plants where it is substituted for their water source. The plants are then planted in the contaminated area where the roots take up the water and the contaminants along with it. As the roots become saturated with contaminants, they are harvested.

Phytostabilization

Phytostabilization is the use of certain plant species to immobilize contaminants in the soil and ground water through absorption and accumulation by roots, adsorption on to roots, or precipitation within the root zone of plants (rhizosphere) (Alkorta et al,2004). This process reduces the mobility of the contaminant and prevents migration to the ground water, and it reduces bio-availability of metal In to the food chain. This technique can also be used to reestablish vegetation cover at sites where natural vegetation fails to survive due to high metals concentrations in surface soils or physical disturbances to surface materials (Tangahu et al, 2011). Metal-tolerant species is used to restore vegetation at contaminated sites, thereby decreasing the potential migration of pollutants through wind erosion and transport of exposed surface soils and leaching of soil contamination to groundwater (Alkorta et al, 2004).

Fig 4:Phytostabilization(Paulo et al, 2004)



Phytovolatilization

Phytovolatilization This involves the use of plants to take up contaminants from the soil, transforming them into volatile forms and transpiring them into the atmosphere(Paz-Ferreiro et al, 2014) . Phytovolatilization also involves contaminants being taken up into the body of the plant, but then the contaminant, a volatile form thereof, or a volatile degradation product is transpired with water vapour from leaves (Dushenkov et al, 1995). Phytovolatilization may also entail the diffusion of contaminants from the stems or other plant parts that the contaminant travels through before reaching the leaves (Tangahu et al, 2011).Phytovolatilization can occur with contaminants present in soil, sediment, or water. Mercury is the primary metal contaminant that this process has been used for. It has also been found to occur with volatile organic compounds, including trichloro ethene, as well as inorganic chemicals that have volatile forms, such as selenium, and arsenic (Dushenkov et al,1995). The advantage of this method is that the contaminant, mercuric ion, may be transformed into a less toxic substance like elemental Hg (Paz-Ferreiro et al,2014). The disadvantage to this is that the mercury released into the atmosphere is likely to be recycled by precipitation and then redeposited back into lakes and oceans, repeating the production of methyl mercury by anaerobic bacteria (Paz-Ferreiro et al, 2014).

Indexs of Phytoremediation

There are some index that helps to calculate efficiency of phytoremediation and assessment of plant ability in up taking and translocation or mobilization (Kisku et al., 2000) of metallic elements. these index use for collecting hyper accumulator plant species (McGrath and Zhao, 2003).

Bio concentration factor (BF)

The ratio of concentration of metallic elements in plants tissue (roots, shoots) to that in contaminated site (Tu et al., 2002),it also termed as bio concentration factor (BCF) (Marchiol et al., 2004).

Enrichment Coefficient (EC)

It termed as degree of metallic elements accumulation in plants (shoot, roots) to concentration of metallic elements at contaminated site (Kisku et al., 2000). It also termed as biological accumulation coefficient (BAC).

$$EC = \frac{\text{concentration of metallic elements in roots or shoots}}{\text{concentration of metallic elements at contaminated site}}$$

Translocation (mobilization) factor (TF)

This factor calculated to determine the translocation of metallic elements from the root of plant to shoot (McGrath and Zhao, 2003). where; TF in hyper accumulator species is more than one

$$TF = \frac{\text{concentration of metallic elements in plant shoots}}{\text{Concentration of metallic elements in roots}}$$

Relative treatment efficiency index (RTEI)

Introduced by (Marchand et al., 2010)which is based on comparing control treatment metal removal with influent metal concentration and effluent treatment metal removal ,meanwhile previous index are suitable now .

Conclusion

The pollution of soil and water with heavy metals is an majorenvironmental concern. Metals and other inorganiccontaminants prevalent forms ofcontamination found at waste sites, and their remediationin soils and sediments are among the most technically difficult. Heavy metals affect the plant health and human health. Contamination of soil and water with heavy metal decrease the quality of it. The most common heavy metals found at contaminated sites, in order of abundance are Pb, Cr, As, Zn, Cd, Cu, and Hg. Zn is an essential trace nutrient to all high plants and animals.Zinc toxicity often leads to leaf chlorosis. Cuis essential micronutrient for plants, but it can be toxic at higher concentrations. Exposure to Hg,Ar,Crand Pb can also reduce photosynthesis, transpiration rate, and water uptake and chlorophyll synthesis. This Metal contamination can be prevented by Phytoremediation which is low cost and ecofriendly in nature.

Acknowledgement

Financial help received from the **Gujarat pollution control board**, Gujarat,Gandhinagar, India is gratefully acknowledged.

References

Alkorta, I., Hernández-Allica, J., Becerril, J.M., Amezaga, I., Albizu, I. and Garbisu, C., 2004. Recent findings on the phytoremediation of soils contaminated with environmentally toxic heavy metals and metalloids such as zinc, cadmium, lead, and arsenic. *Reviews in Environmental Science and Biotechnology*, *3*(1), pp.71-90.

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

Baldwin, D.R. and Marshall, W.J., 1999. Heavy metal poisoning and its laboratory investigation. *Annals of Clinical Biochemistry*, *36*(3), pp.267-300.Bodek, I., 1988. *Environmental inorganic chemistry: properties, processes, and estimation methods*.

Pergamon.Borasiya HB, Shah MP 2016 Recent Trends in Waste Water Microbiology. J Bioremediat Biodegrad 7:e177. doi: 10.4172/2155-6199.1000e177Chen, Z.S., 2000.

Relationship between heavy metal concentrations in soils of Taiwan and uptake by crops (p. 15). Food and Fertilizer Technology Center.Dabke, S. V 2013 Vermi-remediation of heavy metal-contaminated soil. Journal of Health and Pollution, 3(4), 4-10.

Davies, B.E. and Jones, L.H.P., 1988. Micronutrients and toxic elements. *Russell's Soil Conditions and Plant Growth*, *11*, pp.780-814.

Dushenkov, V., Kumar, P.N., Motto, H. and Raskin, I., 1995. Rhizofiltration: the use of plants to remove heavy metals from aqueous streams. *Environmental science & technology*, *29*(5), pp.1239-1245.

Ekpete, O.A. and Festus, C., 2013. Heavy metal distribution in soil along Iwofe Rumuolumeni road. *International Journal of Science and Technology*, *8*(1), pp.450-455.

Elekes, C.C., 2014. Eco-technological solutions for the remediation of polluted soil and heavy metal recovery. In *Environmental Risk Assessment of Soil Contamination*. InTech.

Favas, P.J., Pratas, J., Varun, M., D'Souza, R. and Paul, M.S., 2014. Phytoremediation of soils contaminated with metals and metalloids at mining areas: potential of native flora. In *Environmental risk assessment of soil contamination*. InTech.

He, Z., Shentu, J., Yang, X., Baligar, V.C., Zhang, T. and Stoffella, P.J., 2015. Heavy metal contamination of soils: Sources, indicators and assessment.

Jadia, C.D. and Fulekar, M.H., 2009. Phytoremediation of heavy metals: recent techniques. *African journal of biotechnology*, *8*(6).

Jiao, X., Teng, Y., Zhan, Y., Wu, J. and Lin, X., 2015. Soil heavy metal pollution and risk assessment in Shenyang industrial district, Northeast China. *PloS one*, *10*(5), p.e0127736.

Kapagunta, C and Datt, S. 2017 Bioremediation is an effective remedy for environmental pollution.

Karigar, C.S. and Rao, S.S., 2011. Role of microbial enzymes in the bioremediation of pollutants: a review. *Enzyme research*, *2011*.

Mahurpawar, M., 2015. Effects of heavy metals on human health. *International Journal of Reseacrh-Granthaalayah, ISSN-23500530*, pp.2394-3629.

Martin, S. and Griswold, W., 2009. Human health effects of heavy metals. *Environ Sci Technol Brief Cit*, *15*, pp.1-6.

Maslin, P. and Maier, R.M., 2000. Rhamnolipid-enhanced mineralization of phenanthrene in organic-metal co-contaminated soils. *Bioremediation Journal*, *4*(4), pp.295-308.

Mishra A., Shukla. D, Vaghela K. And Saraf M.(2019) "Copper: Its Biologicalrole And Toxicity" J. Indian Bot. Soc.98 (1) 2019 : 27

Mishra A., Shukla. D and Saraf M. (2018) "A Review on Plant Growth Promoting Halophiles" Vidyavrut, Proceeding of Conference: Synthetic Biology Approaches in drug Discovery and Microbial Biotechnology

A. Mishra, D. Shukla, Z. Rathod, R. JainAnd M. Saraf.(2019) "Multi Facilitated Activation Of Endophytic Bacteria Isolated From Macroalgae" Advance in Bioresearch: In process

Nazir, R., Khan, M., Masab, M., Rehman, H.U., Rauf, N.U., Shahab, S., Ameer, N., Sajed, M., Ullah, M., Rafeeq, M. and Shaheen, Z., 2015. Accumulation of heavy metals (Ni, Cu, Cd, Cr, Pb, Zn, Fe) in the soil, water and plants and analysis of physico-chemical parameters of soil and water collected from Tanda Dam kohat. *Journal of Pharmaceutical Sciences and Research*, *7*(3), pp.89-97.

Number, W.A., Ma, C., Kingscott, J. and Evans, M., 1997. Recent developments for in situ treatment of metal contaminated soils.

Parekh,H. Patel, M. and Tiwari, K. 2016 A detailed study of heavy metal accumulation across highway plant species. Research Journal of Agriculture and Environmental Management, 5(1), 032-036

Paz-Ferreiro, J., Lu, H., Fu, S., Méndez, A. and Gascó, G., 2014. Use of phytoremediation and biochar to remediate heavy metal polluted soils: a review. *Solid Earth*, *5*(1), p.65.

Rahman, S.H., Khanam, D., Adyel, T.M., Islam, M.S., Ahsan, M.A. and Akbor, M.A., 2012. Assessment of heavy metal contamination of agricultural soil around Dhaka Export Processing Zone (DEPZ), Bangladesh: implication of seasonal variation and indices. *Applied sciences*, *2*(3), pp.584-601.

Saini, P. 2016 Assessment of Soil Contamination due to Heavy Metals: A Case Study of Rakhial Industrial Area. Internation Journal of Advance Research and Innovative Ideas in Education, 2(3), 273-278.

Saxena, P. K, KrishnaRaj, S, Dan, T, Perras, M. R, & Vettakkorumakankav, N. N 1999 Phytoremediation of heavy metal contaminated and polluted soils. In Heavy metal stress in plants Springer Berlin Heidelberg pp. 305-329.

Schmidt, U., 2003. Enhancing phytoextraction. *Journal of Environmental Quality*, *32*(6), pp.1939-1954.

Schroder, J.L., Basta, N.T., Casteel, S.W. and Evans, T.J., 2004. Validation of the in vitro gastrointestinal (IVG) method to estimate relative bioavailable lead in contaminated soils. *Journal of environmental quality*, *33*(2), p.513.

Siddiquee, S., Rovina, K., Azad, S.A., Naher, L., Suryani, S. and Chaikaew, P., 2015. Heavy metal contaminants removal from wastewater using the potential filamentous fungi biomass: a review. *Journal of Microbial and Biochemical Technology*, *7*(6), pp.384-393.

Singh, N., Kumar, D. and Sahu, A.P., 2007. Arsenic in the environment: effects on human health and possible prevention. *Journal of Environmental Biology*, *28*(2), p.359.

Singh, R., Gautam, N., Mishra, A. and Gupta, R., 2011. Heavy metals and living systems: an overview. *Indian journal of pharmacology*, *43*(3), p.246.

Smith, L.A., 1995. *Remedial options for metals-contaminated sites*. Lewis Publ..

Solke H De Boer "Environmental Applications of Plant Growth-Promoting Bacteria of the Genus Azospirillum" Chapter · January 2001DOI: 10.1007/978-94-010-0003-1_12 In book: Plant Pathogenic Bacteria, pp.68-74

Subhashini, V. and Swamy, A.V.V.S., 2013. Phytoremediation of Pb and Ni Contaminated Soils Using Catharanthus roseus (L.). *Universal Journal of Environmental Research & Technology*, *3*(4).

Tangahu, B.V., Sheikh Abdullah, S.R., Basri, H., Idris, M., Anuar, N. and Mukhlisin, M., 2011. A Review on heavy metals (As, Pb, and Hg) uptake by plants through phytoremediation. *International Journal of Chemical Engineering*, *2011*.

Tariq, S.R., Shafiq, M. and Chotana, G.A., 2016. Distribution of heavy metals in the soils associated with the commonly used pesticides in cotton fields. *Scientifica*, *2016*.

Tchounwou, P.B., Yedjou, C.G., Patlolla, A.K. and Sutton, D.J., 2012. Heavy metal toxicity and the environment. In *Molecular, clinical and environmental toxicology* (pp. 133-164). Springer Basel.

Vamerali, T., Bandiera, M. and Mosca, G., 2010. Field crops for phytoremediation of metal-contaminated land. A review. *Environmental Chemistry Letters*, *8*(1), pp.1-17.

Vediya & Patel, Contamination of toxic metals in Vastral lake, Ahmadabad, 2011INTERNATIONAL JOURNAL OF PHARMACY & LIFE SCIENCES.

Wuana, R.A. and Okieimen, F.E., 2011. Heavy metals in contaminated soils: a review of sources, chemistry, risks and best available strategies for remediation. *Isrn Ecology*, *2011*.

Yadav, A., Yadav, P.K. and Shukla, D.N., 2013. Investigation of heavy metal status in soil and vegetables grown in urban area of Allahabad, Uttar Pradesh, India. *International Journal of Scientific and Research Publications*, *3*(9), pp.1-7.

https://land8.com/5-best-plants-for-phytoremediation/

Bindu, G. H. IMPACT OF TOXIC METALS, MINERALS, SOLVENTS, E-WASTE AND PLASTICS LEADING TO ENVIRONMENTAL POLLUTION. *Journal of Chemical and Pharmaceutical Sciences ISSN*, *974*, 2115.

Sheldon, A. R., & Menzies, N. W. (2005). The effect of copper toxicity on the growth and root morphology of Rhodes grass (Chloris gayana Knuth.) in resin buffered solution culture. *Plant and soil*, *278*(1-2), 341-349

Divya Srivastava, Ajeet Singh and Mamta Baunthiyal(2015) LEAD TOXICITY AND TOLERANCE IN PLANTS, www.opensciencepublications.com (2)

Divya Srivastava, Ajeet Singh and Mamta Baunthiyal

Edao, H. G. (2017). Heavy metals pollution of soil; toxicity and phytoremediation techniques. *Indian J. Adv. Eng. Resc.*, *1*(1), 2456-9992.

Kisku G, Barman S, Bhargava S (2000). Contamination of soil and plants with potentially toxic elements irrigated with mixed industrial effluent and its impact on the environment. Water, air, and soil pollution, 120(1-2): 121-137.

Marchand L, Mench M, Jacob D, Otte M (2010). Metal and metalloid removal in constructed wetlands, with emphasis on the importance of plants and standardized measurements: a review. Environmental pollution, 158(12): 3447-3461.

Abbas, G., Murtaza, B., Bibi, I., Shahid, M., Niazi, N. K., Khan, M. I.,& Hussain, M. (2018). Arsenic uptake, toxicity, detoxification, and speciation in plants: physiological, biochemical, and molecular aspects. *International journal of environmental research and public health*, *15*(1), 59.

Shanker, A. K., Cervantes, C., Loza-Tavera, H., & Avudainayagam, S. (2005).Chromium toxicity in plants. *Environment international*, *31*(5), 739-753.

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