ASSESSMENT OF RISK ASSOCIATED WITH HEAVY METAL CONTAMINATION IN SOIL AND ITS REMEDIAL MEASURES: A REVIEW

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Abstract:
Heavy metals in soil pose a severe environmental problem due to their tremendous toxicity. Arsenic, cadmium, mercury, and other metals have all been linked to serious health hazards. Because of human activities, the types and amounts of heavy metals in soil have increased, severely harming the ecosystem. The increase of heavy metal contamination coincides with the development of the world economy. Therefore, the primary objectives of this study are to identify the sources of heavy metals in soil, highlight any potential risks posed by their presence, and investigate effective remediation strategies. By focusing on these goals, we want to gain a thorough understanding of heavy metal contamination, its ramifications, and eventually solutions to lessen its negative impacts. The findings of this study demonstrate that human activities, such as industrial processes, mining operations, and the use of agrochemicals, significantly contribute to the contamination of soil with heavy metals. Significant amounts of heavy metals are discharged into the environment as a result of these activities, where they eventually accumulate in soil. The study's conclusion emphasises the significance of heavy metal contamination in soil as a critical environmental issue that requires immediate action variety of remediation techniques like phytoremediation, phytoextraction, phytostabilization, and phytofiltration.

Keywords: Heavy metals, Remediation techniques, Biological toxicity, Concentration

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1. Introduction

Leaded paints, petrol, animal waste, sewage byproducts, pests, irrigation waste, coal byproducts, petrochemical spills, mine tailings, atmospheric deposition, and emissions from rapidly expanding industrial areas are all possible sources of soil contamination that is aided by heavy metals. (S.Khan 2008) (2010) M.K. Zhang Nickel (Ni), cadmium (Cd), zinc (Zn), copper (Cu), mercury (Hg), arsenic (As), chromium (Cr), and lead (Pb) are the heavy metals that are most commonly detected in contaminated areas. (1997, GWRTAC) An extensive group of inorganic chemical hazards includes heavy metals. The bulk of metals do not disintegrate by chemical or microbiological processes, and even when they are introduced into the soil, their presence there lasts for a very long time. Contrarily, organic pollutants are converted into carbon (IV) oxide by bacteria. (2006) T. A. Kirpichtchikova The heavy metals that these anthropogenic activities emit into the environment are primarily absorbed by soils. (Adriano, 2003, "Trace Elements in Terrestrial Environments: Biogeochemistry, Bioavailability and Metal Risks"). They might change in terms of their chemical make-up and bioavailability, though. (2000) P. Maslin and R. M. Maier The presence of heavy metals in the soil can seriously hinder the biodegradation of organic contaminants. Soil contamination with regard to heavy metals can be brought on by direct intake, contact with contaminated soil, the food chain, drinking contaminated ground water, a decline in food quality (safety and marketability) brought on by phytotoxicity, or other processes. (2000) B. A. M. J. McLaughlin (W. Ling 2007),(Alam & Singh, 2023) and (R. E. M. J. McLaughlin 2000). Immobilisation, soil purification, and phytoremediation procedures are some of the best proven available technologies (BDAT) that are frequently mentioned when dealing with heavy metal- contaminated sites. (GWRTAC 1997) Field uses have only been documented in industrialised nations, despite the accessibility and environmental friendliness of these technology. These technologies have not yet gained widespread acceptance in the majority of developing countries due to ignorance about their advantages and operating principles. The scientific community has been more driven to seek methods to repair damaged areas as higher authorities and the general public have become more aware of the effects of heavy metal contaminated soils on human and plant health. November 2008 (N. S. Bolan). Around the world, different locations and nations have shown varying degrees of soil pollution with heavy metals (Su et al., 2014). For instance, heavy metal contamination affects 10% of China's agricultural soils, and roughly 82.8% of polluted soils worldwide are made up of inorganic contaminants, primarily heavy metals (Kou et al., 2018). According to Su et al. (2014), cd-contaminated soils are a threat in nations including France, Spain, India, and the United States. Cu, Pb, and Zn levels in urban soils have reached dangerous contamination levels in Naples, Italy, as well as Mexico City (Imperato et al., 2003; Morton-Bermea et al., 2009). Unfortunately, the problem of soil heavy metal contamination keeps getting worse on a global scale, posing serious threats to the environment and human health that necessitate quick attention and efficient mitigation methods.

2. SOURCES OF HARMFUL HEAVY METALS IN SOIL

In the soil environment, parent materials naturally weather, releasing trace (1000 mg/kg) and infrequently dangerous levels of heavy metals. The majority of soils on earth are capable of absorbing one or more of the aforementioned heavy metals, and background concentrations of these metals are frequently high enough to pose threats to not just the environment, but also to the health of humans, plants, animals, and other living things. (J. J. D'Amore 2005) This is because the naturally occurring geochemical cycle of metals has been disrupted and accelerated by human activity. Because of the following factors, heavy metals effectively transform into pollutants in soil ecosystems: They are produced at rates quicker than those of nature through artificial cycles, and they are released from mines into uncontrolled regions where there is a higher risk of direct exposure. (J. J. D'Amore 2005).

2.1 Contamination of soil by Fertilizers

Agriculture has historically been the first significant human influence on the land (A. Scragg 2006). Naturally occurring heavy metals (HMs) in soils include cadmium (Cd), mercury (Hg), arsenic (As), chromium (Cr), and lead (Pb). However, overusing fertilisers makes the problem worse by lowering the pH of the soil. The acidity of this environment promotes the release and availability of HMs in the soil, making it simpler for plants to absorb them and perhaps putting the environment and human health in jeopardy (Khan et al. 2018). Essential micronutrients are required for a plant to develop and finish its life cycle in addition to macronutrients (Ca, N, K, S, P, and Mg). Since some soils contain lower concentrations of specific heavy metals (Zn, Ni, Mo, Mn, Fe, Cu, and Co), which are essential for healthy plant development, crops must be provided with these elements through the soil (Lasat 2000). Cu is occasionally added to the soil for crops produced on soils low in the element; Mn can also be used for cereal and root crops. In intensive agricultural systems, a lot of fertiliser is applied to the soil on a regular basis to make sure the soil has enough P, N, and K for crop growth and production. (1981 Jarvis) The materials utilised to give these nutrients contain trace levels of heavy metals (such Cd and Pb), which are pollutants. Following repeated fertiliser applications, their concentration in the soil may swiftly increase. Two examples of metals that are known to have no physiological effects are lead and cadmium. Cadmium and other potentially dangerous metals including iron, mercury, and lead are unintentionally introduced to the soil when various phosphatic fertilisers are applied. (1998, P. H. Raven)

2.2 Contamination of soil by Pesticides

In terms of chemical synthesis, the broad collection of molecules known as pesticides is constantly evolving. Some of the more modern chemicals, such as acylalanines, dinitroanilines, chloroacetamides, and dicarboximides, are thought to be safer for the environment. However, it is noteworthy that these seemingly safer pesticides can accumulate in soils in significant proportions. The widespread application of these compounds in agriculture and other applications contributes to their presence in soil, raising concerns about their potential environmental threat and long-term effects on soil quality (Gonçalves& Alpendurada, 2005).

Several conventional insecticides that were historically widely used in horticulture and agriculture contained significant amounts of metals. For instance, Zn, Pb, Mn, Hg, or Cu were the main ingredients in 10% of the pesticides recently licenced for use as fungicides and insecticides in the UK. These insecticides include copper fungicidal sprays like Bordeaux combination (copper sulphate) and copper oxychloride (Jarvis 1981). Lead arsenate has been used to eradicate parasite insects from apple orchards for a very long time. There are many abandoned sites with soil that contains Cu and Cr in concentrations above background levels as a result of these elements having been utilised in formulations to preserve wood. In Australia and New Zealand, arsenic-containing substances were often employed to get rid of pests on bananas and parasites on animals. Problems could arise from this contamination, especially if land is developed for other agricultural or non-agricultural uses. These substances have been applied more specifically than fertilisers, or with more particular crops.
(R. E. M. J. McLaughlin 2000).

2.3 Contamination of soils by Biosolids and Manure

In agricultural practises, livestock manure and biosolids are typically collected and used as fertilisers. The possible spread of viruses and heavy metals has traditionally been the main environmental danger associated with applying these organic materials to soil. The negative consequences of such application on soil, groundwater, and existing plants have received significant attention in studies evaluating the overall safety and sustainability of using manures or sludge as soil additives. It is essential to strictly supervise and oversee these practises in order to limit any harmful effects and ensure the protection of the environment and human health. (Walker et al.1997).

Heavy metals unintentionally build up in the soil when different biosolids (including sewage sludge, household trash, and livestock manure) are applied to land (N. T. Basta and R. Gradwohl 1998) Applying some animal wastes, such as chicken and cattle manure, to crops and pastures using solids or slurries is a widespread activity in agriculture. Through the pig and poultry industries, copper, zinc, and as, which are added to diet as growth accelerators and are present in poultry health products, may also be able to contaminate the soil (Sumner 2000). The manures produced by animals fed on these diets include high concentrations of arsenic, copper, and zinc, and if these manures are routinely applied to tiny plots of land, a significant amount of these metals may eventually accumulate in the soil.

2.4 Contamination of soils by Wastewater

Municipal, industrial, and associated pollutants have been applied to the soil for hundreds of years in various parts of the world. It is estimated that waste water is used to irrigate close to a quarter million hectares of land worldwide. According to researches, irrigation of wastewater is used in agriculture to produce roughly 50% of the vegetables that are supplied to cities in few of the continents on the globe. (Bjuhr 2007) Basically, farmers are very much focused on growing their crops and profits than they are on the benefits or threats associated with the environment. Even though wastewater effluents normally include modest levels of metal, long-term irrigation of land with them may eventually cause a significant deposit of metal in the soil.

2.5 Contamination of soils by Industrial and Mining Slurries

Due to the mining and processing of metal ores in tandem with commercial activities, metal contaminants in soil have been discovered in many different countries. As a result of mining, substantial amounts of heavy metals are discharged into the environment, and the majority of these metals are absorbed and deposited in soils. (Kirpichtchikova et al. 2006). The heavy, large particles, known as tailings, that have collected at the bottom of the flotation cell throughout mining are immediately dumped in neighbouring marshes and other natural depressions where they may collect in great quantities (P. S. DeVolder 2003). The environment and human health are at danger due to the extensive mining and smelting of lead and zinc ore. Many of the costly, time-consuming restoration techniques applied to these sites could be unable to increase soil production. Bioavailability is related to the environmental risk that heavy metals in soil pose to humans. (N. T. Basta and R. Gradwohl 1998) Examples of absorption processes include the oral bioavailability of polluted soil or ingesting plant components that were ingested through the food chain. Only a few companies manufacture extra parts, including those that manufacture insecticides, petrochemicals from oil spills from daily use or use of petroleum-based products, textile, petrochemicals from petrochemical facilities, and pharmaceutical facilities. Despite the fact that some are released on land, some of them are beneficial for forestry or agricultural purposes. Many are also infrequently, if ever, applied to the land and may be toxic because to the presence of heavy metals (such as chromium, lead, and zinc) or hazardous organic compounds. Others are incapable of improving soil or offer very little in the way of plant nutrients. (Sumner 2000).

1.1 Contamination of soil by Air-Borne sources

Metals may be released into the environment by fugitive emissions from storage areas or rubbish heaps, air, gas or vapour stream emissions from stacks or ducts, or both. Metals from airborne sources are frequently released as gas stream particles. According to recent studies, lead and cadmium contents in soil and vegetation have significantly increased (tvös et al. 2003; Wheeler & Rolfe, 1979). This rise in pollution is tied to traffic, notably the burning of exhaust gases and the usage of leaded fuel. Among the metals that can volatilize when subjected to high temperatures are as, cadmium, and lead. These metals can change into oxides and condense as tiny particles if a reducing atmosphere is not maintained. Before wet or dry precipitation processes remove the emissions from the gas stream, natural air currents can disperse stack emissions across a wide area. Fugitive emissions are often spread across a much smaller area since they are frequently created near to the ground. Compared to stack emissions, fugitive emissions frequently have lower pollutant concentrations.

Since most fossil fuels contain heavy metals, this kind of contamination has been prevalent since the start of the industrial revolution. Every solid component of industrial chimney emissions, including fire smoke, eventually finds its way to the surface of the land or the sea. For instance, plants and soils close to smelting operations have been discovered to contain exceptionally high levels of cadmium, lead, and zinc. The burning of fuel containing tetraethyl lead results in the aerial release of lead, which is another substantial source of soil pollution. As a result, lead levels in urban soils and soils close to busy roads are significantly greater than they would be otherwise. In addition, lubricating fluids and tyre tread may contribute Zn and Cd to soils close to roads.(USEPA, Recent Developments for In Situ Treatment of Metals contaminated Soils 1996)

2. RISKS LINKED WITH HEAVY METALS THAT ARE PRESENT IN THE SOIL

Because of their potential to reduce agricultural output through bioaccumulation and biomagnification in the food chain, heavy metals pose a substantial risk. Their presence can have a deleterious effect on cattle, crops, and food quality in general.

Recent Developments for In-Situ Treatment of Metals-Contaminated Soils, USEPA, 1996 There is also a chance of surface and groundwater pollution. Once in the soil, heavy metals are redistributed by first fast (within minutes or hours) and then slowly (within days) adsorption processes (days, years) into a variety of chemical forms with varied availability, mobility, and toxicity. (2002) (J. Shiowatana) The distribution of heavy metals in soil is thought to be influenced by processes such mineral dissolution and precipitation, desorption, ion exchange, adsorption, aqueous complexation, biological immobilisation and mobilisation, and plant absorption.. (Buekers 2007)

2.1 Risks Associated with Lead (Pb)

The effects of exposure through inhalation and ingestion are identical. Pb accumulates in human tissues, including the brain, and this can result in poisoning (plumbism), which can be fatal. The central nervous system, gastrointestinal tract, and kidneys are all impacted by lead.

Infants are at a notably increased risk of developing slower, with lower IQs, shorter attention spans, hyperactivity, and brain deterioration from lead exposure. Adults who have been exposed to lead frequently have memory loss, anorexia, nausea, and joint weakness. (NSC 2009) Lead is not a required ingredient. Its effects have drawn more attention than those of other trace elements because of its well-known toxicity. Lead can have major damage to the kidneys, RBC, nerve system, neurological system, and brain. (Marshall 1999) Lead exposure varies greatly in the biological effects it can have based on the amount and duration of exposure. More sensitive than adults, developing infants and new-borns experience a wide spectrum of effects at varied doses. Consuming garden vegetables produced on soils with total lead amounts as high as 300 ppm has long been regarded as harmless. As the lead content in the soil exceeds this limit, there is an increased danger of lead poisoning in the food chain. Even at soil concentrations above 300 ppm, lead contamination in the soil or dust deposits on plants pose a greater risk than lead uptake by plants. (Rosen 2002)

2.2 Risks associated with Chromium (Cr)

Chromium (3) is the main type of chromium at a lower pH of (4). Cr^{3+} forms compounds with F, Cl, OH, and soluble organics. Cr is the more lethal and transportable form of the element (VI). (P. Chrostowski 1991) Both soluble and precipitated forms of chromium are capable of being carried by surface runoff into surface waterways. Both soluble and non- absorbable chromium compounds can leak into groundwater from the soil. Cr (VI) leachability increases together with a rise in soil pH. (A. Smith 1995) The majority of Chromium that are let off into natural streams, however, is particle-associated and eventually settles in the sediment. Cr is associated with allergies. (A. Scragg 2006)

2.3 Risks associated with Arsenic (As)

Arsenic (As) is a toxic element frequently detected in soil environments. It can originate from natural lithogenic processes or be a byproduct of mining and feritilizer production activities (González et al. 2017; Li et al. 2017). The enrichment of arsenic (As) in agricultural soils presents a dual threat. Firstly, it jeopardizes food security by exerting phytotoxic impact on crops, potentially reducing their yield and quality. Secondly, it poses a risk to food safety as it can bioaccumulate in crops, making them potentially hazardous for human consumption (Cui et al. 2018).

Arsenic exhibit chelating behaviour and are able to precipitate in the presence of metallic cations. Many arsenic compounds strongly adsorb to soils, barely passing through groundwater and surface water momentarily. Arsenic has been linked to circulation issues, skin deterioration, and an increased risk of cancer. Arsenic has been linked to circulation issues, skin deterioration, and an increased risk of cancer. (A. Scragg 2006)

2.4 Risks associated with (Cd)

Cadmium is known to have an effect on a variety of enzymes in the body. The Jintsu River Valley's cadmium poisoning was caused by irrigated rice that was tainted by an upstream mine that produced Pb, Zn, and Cd. Chronic renal failure, which is brought on by buildup in the kidneys, is the biggest threat to human health. Consuming food and smoking are the two main ways that Cd enters the body. Itai itai illness, which is pronounced "ouch, ouch" in Japanese, was present in the patients. Painful osteomalacia, a disorder of the bones, and kidney dysfunction are the causes of the symptoms. The irrigated rice that was contaminated by an upstream mine that produced Pb, Zn, and Cd was the source of the cadmium poisoning in the Jintsu River Valley. The biggest danger to human health is chronic renal failure, which is caused by accumulation in the kidneys. The two main routes that Cd enters the body are through food consumption and tobacco use. (Manahan 2003)

2.5 Risks associated with Copper (Cu)

Metals' detrimental effects on agricultural development and productivity result in direct dangers, whilst their entry into the human food chain and potential harm to human health result in indirect risks.Both of these risks can be brought on by trace amounts of copper metals in the soil. Even a slight decrease in crop yield could have a significant long-term impact on output and revenue. Farmers may find it more difficult to export contaminated harvests now that certain food importers are specifying permissible maximum metal quantities in food (Bjuhr 2007). The detrimental effects of excessive copper (Cu) addition to the soil environment after manure application have been highlighted in numerous research. Increased plant and animal toxicity, the development of toxic metal-resistant bacteria, persistent harm to pasture animals, and increased human exposure to this trace element through the food chain are some of these detrimental impacts. (Wong and Bradshaw, 1982;
Zervas et al. 1990; Alloway, 1995).

2.6 Risks associated with Nickel (Ni)

Nickel elements are only found in the environment at incredibly lower level and are required in fewer quantities, therefore when the maximum allowable amount is exceeded, it might be problematic. Animals may get a variety of cancers throughout their bodies as a result, especially those who dwell close to refineries. Ni is the most commonly utilised metal as a component of metal products. Nickel mining, nickel electroplating, burning fossil fuels, and metal plating businesses are the main contributors of nickel pollution in soil. Power plants and trash incinerators discharge it into the atmosphere, where it gets trapped in precipitation processes before falling to the ground. (A. P. Khodadoust 2004) Nickel often takes a while to dissipate from the atmosphere. Nickel may end up in surface waterways if it is present in wastewater streams.

3. TECHNIQUES OF REMEDIATION OF METALS FROM THE CONTAMINATED SOIL

3.1 Electro Kinetic Remediation

During the in-situ electrokinetic (EK) remediation process, electrodes buried in the soil are subjected to a low-voltage direct current (DC) that creates an electrical field in the soil matrix. Heavy metal contaminants can be mobilised using this electric field, then collected at the electrodes' end and removed from the earth containing the contaminated soil. When the electric field will be applied, it will have different effects on the water, earth containing soil, and the contaminants. Electromigration, electroosmosis, and other influences, as well as electrophoresis, can cause the pH of the system to change. Electromigration is the term used to describe the moving nature of cations and anions induced by the electrical field. These ions may gather in fluids near the electrodes or can react there, plating metals onto the electrodes or releasing gaseous materials. When an electrical field is present, water will move in large quantities through the soil due to electroosmosis, which is the movement of an ion-containing liquid with regard to a charged surface that is immobile. When the current is applied, pH changes occur due to electrolysis at electrodes. When water is oxidised at the anodic end, hydrogen (H^+) ions are generated, and these ions create an acid front to travel in the cathodic direction. A charged particle moving through a liquid as a result of an electric field is known as electrophoresis. (Alaa Zaghloul 2019)

In contrast approach, hydroxyl (OH-) ions are created and travel as a base front towards the anode when water is reduced at the cathode. In comparison to OH- ions, the H+ ions pass through the body twice as quickly. As a result, the acid front advances more quickly than the base front. The soil between the electrodes will start to turn acidic unless the soil's capacity to buffer the proton (H+ ion) transport is boosted. This acidity leads to the solubilization of contaminants because it induces the desorption and species dissolution from the soil. When contaminants are found in the soil's pore fluid in ionic form, they travel to the electrode with the opposite polarity in the presence of an electric field and/or via electroosmosis, which causes the contaminants to be extracted from the soil at the electrodes. (Zhemin, Bingxin and Wang 2008) (Yuan and C. Wu 2008)

To remove and extract the pollutants, electrodeposition might be utilised at the electrode. The quantity and effectiveness of heavy metal extraction during EK remediation are influenced by a number of subsurface variables, including the type of soil, particle size and distribution, contaminant concentration, ion mobility, total ion concentration, kind of contaminated species, and their dissolvability. Using electrokinetic therapy may be made more challenging by the presence of organic pollutants and even organic debris in the soil. (Chiang 2008)

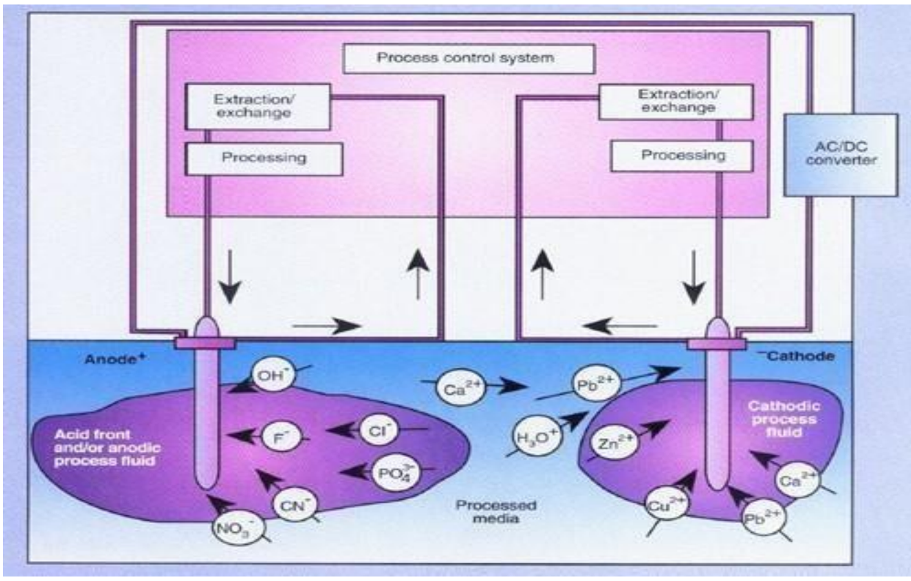

Fig:1 Transport of ions in the presence of electric field

3.2 Phytoremediation

Due to the significant costs associated with site restoration, it is essential to develop and enhance inventive, inexpensive environmental cleaning methods. Improvements in soil remediation are assisting in our growing understanding of the various methods through which plants can minimise environmental contamination. (B. 2003) This realisation has stimulated research in a new field of study that uses particular plants with a built-in ability to absorb heavy metals as a low-cost way of environmental rehabilitation. This procedure, sometimes referred to as phytoremediation or plant-assisted remediation, has the advantage of assisting in site restoration even when intermediate action is being conducted. Phytoremediation offers a number of advantages over alternative remediation techniques such land filling, chemical treatment, and soil extraction. It works on a variety of poisons, can disinfect large areas, and can be done with little environmental damage. When plants absorb contaminated waters, off- site migration can be stopped and the topsoil can be recovered for agricultural use while still being in acceptable condition. (E. Lombi 2001) (B.D Ensley 2000) (Fulekar, Phytoremediation of heavy metals: recent techniques 2009)

3.2.1 Phytoextraction

Plant roots use a procedure known as phytoextraction to move metal contaminants in the soil into the tissues above the soil's surface. The plant that is being utilised for phytoremediation needs to be resistant to metals, grow quickly with a high biological mass output per hectare, accumulate metals in the foliar regions of the plant effectively, have a strong root system, and be capable of biological accumulation. Phytoextraction is an aesthetic (green) remediation technique that cannot be disputed. Two approaches, first being natural phytoextraction and secondly, chemically supported phytoextraction—have been proposed for the phytoextraction of heavy metals. A feasible alternative to more traditional methods of increasing soil remediation is the Chelant-enhanced phytoextraction of metals from polluted soils. When the chelating agent is introduced to the soil, metal-chelants are produced. The majority of these complexes are absorbed by the plant through a different extracellular pathway. Extracellular transport is further constrained by the high cationic exchange capacity of cell walls unless the metal ion is given as a noncationic chelate. Chelators, which are important for the uptake and detoxification of heavy metals, have been found in plants. One of the tried-and-true mobilisation additives for scarce metals like lead is EDTA. (B. Nowack 2006) (B. 2003) (J. W. Huang 1997)

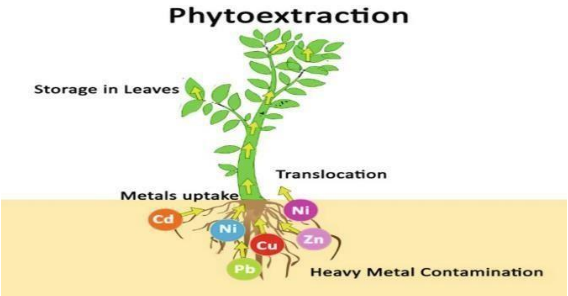

Fig:2 Phytoextraction of heavy metals

3.2.2 Phytostabilization

Utilizing particular plants to immobilise soil sludge and silt is the fundamental objective of phytostabilization, sometimes known to as in-place inactivation. (USEPA, Introduction to phytoremediation 2000). Either taken up by the roots and retained there, adsorbed onto the roots, or precipitated in the rhizosphere are metal pollutants. In contrast, this reduces or even stops pollutant mobility, restricting emigration into the air or groundwater, as well as pollutant bioavailability, stopping transmission down the food chain. Plants should be able to: (i) lessen the amount of water that percolates through the soil matrix; (ii) act as a barrier to prevent direct contact with the contaminated soil; and (iii) halt soil erosion and the spread of the toxic metal to other areas in order to prevent the formation of a hazardous leachate. Phytostabilization can be caused through sorption, precipitation, complexation, or metal valence reduction. Lead, arsenic, cadmium, chromium, copper, and zinc can all be eliminated with this method. In areas where heavy metal contamination has damaged plant communities, it can also be utilised to rebuild those communities. If a community of tolerating plants has grown, the likelihood of wind erosion (and the pollutant's future spread) is decreased, and the leaching of toxins from the soil is also diminished. Because hazardous materials or biomass don't need to be disposed of, phytostabilization is useful. It also performs effectively when immediate immobilisation is required to safeguard groundwater and surface waters. (USEPA, Introduction to phytoremediation 2000)

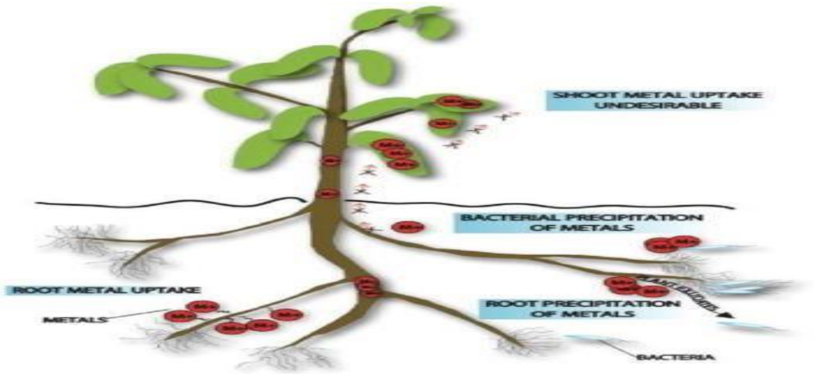

Fig3: Phytostabilization mechanism

4.2.3 Phytofiltration

Similar in concept to phytoextraction, phytofiltration employs plant roots (rhizofiltration) to absorb pollutants from groundwater, typically metals, as opposed to repairing damaged soils. (1997, GWRTAC) Rhizosphere refers to the region of soil immediately below a plant's root surface, which is typically up to a few millimetres deep. The contaminated metals either deposit on the surface of the plant's roots or absorb into them. Before being used, rhizofiltration plants must become acclimated to the contaminant. Plants are genetically produced in pure water as opposed to dirt until they have a strong root system. Once a significant root has developed, the water source is changed to contaminated water to aid in the plant's adaptation. The plants are then placed in the polluted area after acclimating, where the roots take up the tainted water and its pollutants. When the roots begin to get damp, they are carefully removed and thrown away. Sunflowers were grown in radioactively contaminated pools at Chernobyl as an example of how repeated treatments can lessen contamination to bearable levels. (Scragg, A. 2006)

4. CONCLUSION

In order to create effective mitigation strategies, it is essential to understand the causes and dangers of toxic heavy metals in polluted soils. Remediation of heavy metal-polluted soil is crucial for lowering risks, restoring soil fertility for agricultural use, guaranteeing food security, and addressing issues with land ownership. Immobilisation, soil washing, and phytoremediation have proven to be the most successful methods for reducing heavy metal contamination in soils among the available options. The fact that wealthy nations have been the focus of the majority of studies on these strategies highlights the need for additional research and adaptation to other socio-economic and geographic contexts. Nevertheless, given their proven efficacy, these technologies are strongly recommended for practical implementation in real-world field scenarios. Continued research and exploration of alternative approaches will contribute to the development of sustainable and efficient strategies for soil remediation, facilitating long-term environmental and agricultural sustainability.

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