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REVIEW ARTICLE **OPEN ACCESS**

Multidisciplinary Approaches to Clean up Heavy Metal Contaminated Soil: A Review

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ABSTRACT

Due to their melting and movement, heavy metals such as Ld., Ch, Zn, Cd, and Cu can be hazardous to anthropological health. Metal contamination has become a significant environmental concern on a global scale as heavy metal's foundations are both natural and natural systems. All kinds of debris, such as dirt, water, air, and soil liquid are found in iron ore. Deviant human activities are rapidly evolving soil preparation and consolidation also resulting in environmental pollution. Heavy metal nowadays has to be very air friendly. As soon as heavy metals are accumulated in many places in several parts of the troposphere, they try to get caught in the danger of humans, creatures and vegetation. Other metals such as Lead, Hg, Cu, Cd, As, Cr are highly toxic to the environment and affect the metabolism of the ecosystem. Metals are made up of soil, water and air are very stressful because they affect the food we eat, the water we drink and the air we breathe. The most appropriate types of soil preparation methods depend on the characteristics of the site, the concentration, the type of chemicals removed and the final use of contaminant methods. Systematic repairs to precious metals are usually based on physical, chemical, and biological methods; to achieve good results, individual methods of cleaning the atmosphere must be costly and inefficient. In this review, soil re-demonstrating abilities, for example, soil division and control, soil washing and data cleaning, electro energy planning, phyto-volatilization, phyto-extraction, phyto-adjustment information

Keywords: Heavy metals, toxicity, remediation methods, electro-kinetics, soil washing, phyto-extraction, phyto-stabilization, phyto-volatilization

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INTRODUCTION

The state is made up of air, liquid, and earth as a composite component. The term "essential metals" refers to a group of toxic substances that are necessary for biological and industrial purposes [75]. All of this is due to rapid urbanization, increased traffic, organic and fertilizer use, and agricultural insecticide spraying [31]. Heavy metal waste is actually one of the many environmental issues that have the greatest potential to damage the environment and human health [46]. These days, Earth's natural resources are mixed with a range of human activities [30].

Because of the possibly harmful effects of heavy metal, there is a worldwide concern that heavy agricultural land containing iron and plants grown in this dust should not surpass permissible regulatory limits [12]. Natural and anthropogenic sources of essential minerals are found loose in the soil [25]. The organization of underground cities in developing countries is known to be put to the test by cold population, growth, and modernization [28].

The key explanations for their extensive research are the growth and determination of precious metals in remote parts of the world, their numerous discoveries, and potential harm [40]. Not only is the world's obsession with metals a waste of time, but so are the particulars of organisms and the subtleties that offer a new understanding of matter dissolution and exploration [68].

The extraction of iron in the solid process into soil solutions and problems concerning the types of minerals in the soil parts decide the behavior of the metal in the soil and the biological impact of producing its presence in the upper layer [74]. The types of metals not currently available in earth solutions are moderately larger than the large quantities of solids in the solid phase that cause biotic pollutants in soil biota, limiting metal acceptance by heavy flora [79]. Table 1.

Table 1. Classification of heavy metals with examples

Class of heavy metals	Examples
Macro-nutrients elements	Cobalt, Iron
Micro-nutrients elements	Copper, Nickle, Chromium, Iron, Manganese, Molybdenum
Highly toxic elements	Mercury, Cadmium, Lead, Palladium, Bismuth, Arsenic, Platinum, Selenium, Tin, Zinc
Precious elements	Platinum, Silver, Gold, Palladium, Ruthenium
Radio elements	Uranium, Thorium, Radium, Cerium, Praseodymium

Source: Awashthi [6]

METALS AS ENVIRONMENTAL POLLUTANTS

The precious metals obey a logic that originates on the other side of the globe. People enjoy events such as initiation, establishment, and manufacturing through the use of metals and metallic compounds used for local and agricultural applications, and critical metal waste is produced as an equally common waste [9]. Natural behind volcanic eruptions or pillars survival or periodic formation at sea is a significant metal present in natural and anthropogenic resources in the atmosphere [15]. Anthropogenic sources such as waste processing, heat melting process removal, brick kilns, composting, pesticides and chemicals used in agriculture all contribute significantly to polluting our troposphere and disrupting biodiversity [14].

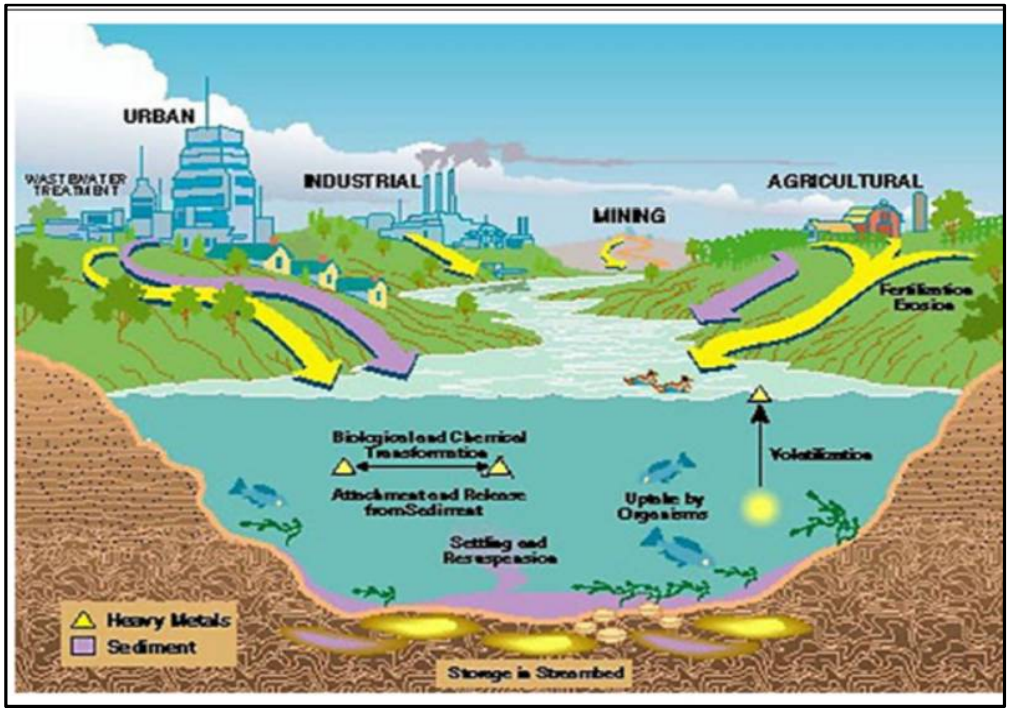

Fig. 1 Potential sources of heavy metals in the environment Source: doi: 10.3389/fenvs.2019.00066

HEAVY METALS DISTRIBUTION IN ENVIRONMENT

NATURAL SOURCES

Heavy Metals in Rocks

Isomorphic exchanges incorporate large metals in a quartz matrix with main crystals [29]. Despite the fact that the mud is cool, differences in normal weather conditions cause the body in the rocks to deteriorate and break up into units, allowing water, air, and grease to reach the flowers [5]. Active species or organic responses increase the abnormalities of existing calcite in the deposit. Ni, Co, Mn, Li, Zn, Cu, Mo, Se, V, Rb, Ba, Pb, Ga, Sr, F, and other essential metals found in the rock include Ni, Co, Mn, Li, Zn, Cu, Mo, Se, V, Rb, Ba, Pb, Ga, Sr, F, and others [10].

Heavy rocks weaken the earth's good elements, which would otherwise be degraded by ice, liquid, temperature, and other influences [35]. Since the earth and the scale of the metal relationships absorb humorous and diverse features, the earth medium is the main container otherwise carrying media for large metals [11]. Soil is the gateway to the key, and anthropogenic death is used by heavy metal outside

the troposphere. Metals may be absorbed, reacted to, interacted with, stimulated, delayed, or slowed by the earth's crust [54]. Other variables that affect this process include pH, liquid, temperature, material distribution, metal flowers, and clay content. Natural resources that are still unresolved are separated into suitable alternatives [34]. Metals and metalloids from iron, petrol, animal waste, slush, wasted irrigation water, special confession, and other sources have polluted the lands. The key impurities in the earth's precious metals are converted to the following purposes: (1) a fast-paced community with a complete sequence, (2) my experience gained from transport from the mine to the tropics, and (3) high iron positions, among other things.

Heavy Metals in Water

Metal systems in external canals, such as canals, seas, and streams, belong to the loam, rock, and liquid current types. Metals from the outside are moved to the system's back end, where they are sorted into compost or sheets [36]. Even though rainwater passes through the troposphere, it is contaminated. A variety of productive natural processes pollute water bodies [76]. After leachates for garbage disposal, liquid removal, stone production, and other purposes, sprinkled drinks become polluted.

Heavy Metals in Atmosphere

Through external destruction and colloidal damage, essential metals are more interested in air than smoke and particles of matter [1]. Air, inanimate soils, saline aquatic plants, volcanic eruptions, and forest fires all exist in vast oceans in the spring. Significant impurities in the weight of steel can also form after several manufacturing processes involving the construction of the earth's foundations, furthering these common foundations [66]. Unstable metals like Se, Hg, As, and Sb are distributed in a particular vapour system and atmosphere. Major iron deficiency can be found in a variety of spatial structures, including (1) the number and characteristics of production emissions, (2) environmental sensitivity, (3) the possibility of a natural problem, and (4) the proximity of these precious metals to humans [72].

ANTHROPOGENIC SOURCES

Heavy metal contamination exists as a result of the following activities: ore processing and removal, pesticide batteries, paper factories, tanneries, fertilizer industries, smelting, fly ash, solid waste disposal, including compost manure, garbage dumping, and automobile collisions [63]. Due to the endless supply of chemicals and food processing compost, a complete view of the big metal is right next to you with more water by entering [33]. The distribution of large metals is uneven. Pesticides have accelerated the development of vital metals in a variety of natural settings [82].

Pesticides used in agriculture absorb compounds such as Hg, As, and Pb in addition to Zn and Cd. He assumes the distribution of iron is confined to essential machine types [38]. To put it another way, the metals have been extracted so this mechanism tends to build up in the soil and incorporate natural components even after the events have ended [20]. The anthropogenic causes of iron ore were divided into five groups by Ross (1994): (1) Agriculture (Zn, As, Pb, Cd, Cu, Se, and Uranium); (2) Metalliferous removal and melting (Cd, Pb, As, and Hg); (3) Industry (Cd, Hg, As, Cr, Cu, Co, Ni, and Zn); (4) Waste Disposal (e.g., Pb, Cu, Cd, Cr, Zn, and Hg); and (5) Atmospheric Posting (e.g., Pb (As, Pb, Cr, Hg, Cu, Cd and U).

Coal Heat

Wood burning is the predominant source of huge quantities of metal in the atmosphere. It would be determined by the reinforcement of non-ferrous metals in the air and heat-producing structures.

Fertilizer

A surprising amount of large iron can be found in the spraying of a few bugs and pesticides used in farming. The key arsenate is used to treat fruit-eating rodents, and arsenic-containing compounds were used to keep livestock ticks [58].

Bio-solids and Manures

Many metals, such as As, Ch, Cd, Cu, and lead, can be found in large amounts in urban waste and computers poured directly into the earth's crust [77].

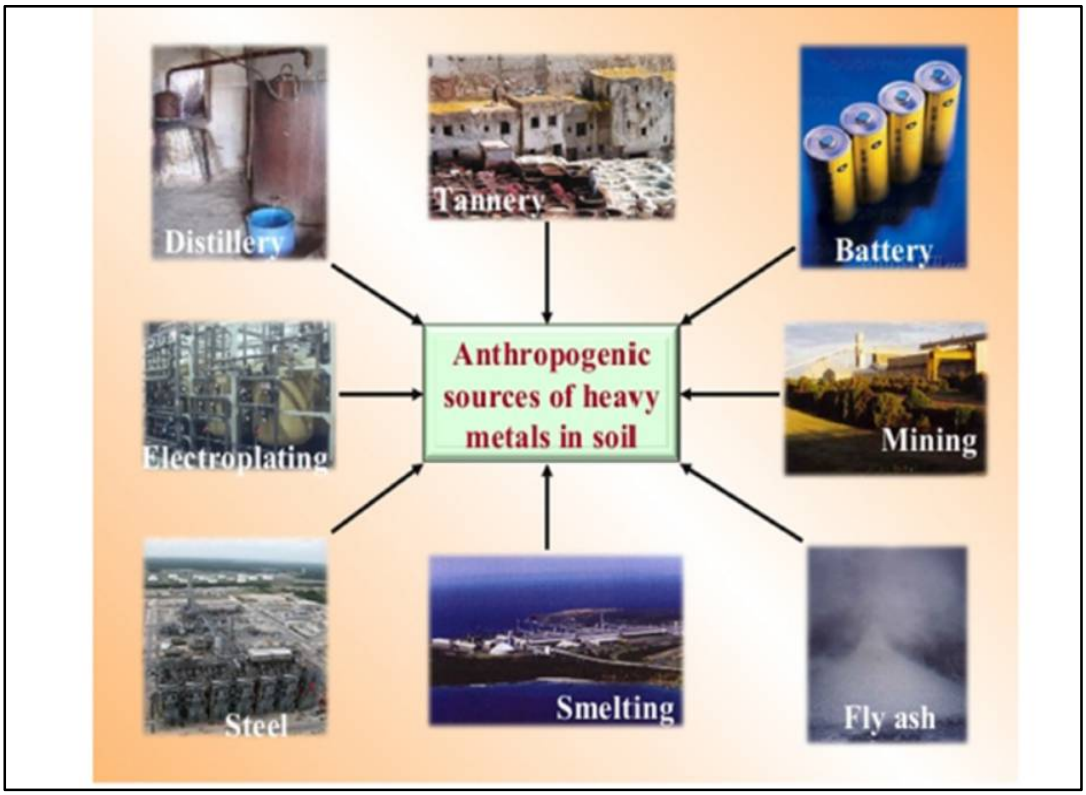

Fig. 2 Anthropogenic sources of heavy metals.
(Source:https://www.slideshare.net/tutan2009/heavy-metal-pollution-in-soil-and-its-mitigation-aspect-by-dr-tarik-mitran).

This is a wet world, and the earth is a normal planet with normal resources. High levels of fluid in the world compete with crop yields and put the intermediate areas of humanoids, plants, and flowers at risk of humidity. It's important to keep metals out of the atmosphere as much as possible [7]. This heavy metal contamination in the soil has also been characterized as environmental degradation because it disrupts the food chain, lowers food quality due to photo toxicity, and reduces soil fertility, among other things [70]. This situation of extreme mental hazards caused by heavy waste can be due to industrial incompetence in the form of direct waste disposal in space, disaster, which means difficult guidance for government agencies in developing countries to protect the environment, and the unreliability of currently located remedial programmes and major applications [45].
Heavy metal cannot be absolutely eradicated at this time. When iron is imported and pollutes the atmosphere, depending on the type of metal and the soil [79], it can last for a long time [69].
Many modified knowledges, including body, biochemical, and biotic, have been used over the years, including soil adjustment, soil subdivision, vitrification, electro kinetic system balance, soil washing, and soil cleaning, among others, and often disrupts soil resources[24]. After heavy metals, scientists are likely to have introduced new methods of dust reduction, such as phytoremediation and bioremediation. Phyto-stabilization, phyto-filtration, phyto-extraction, phyto-volatilization, and phyto-degradation are some of the techniques used in phytoremediation [13].

SOIL PREPARATION METHODS
Soil preparation methods can be broadly divided into three categories i.e., chemical, biological and physical (Fig.3).

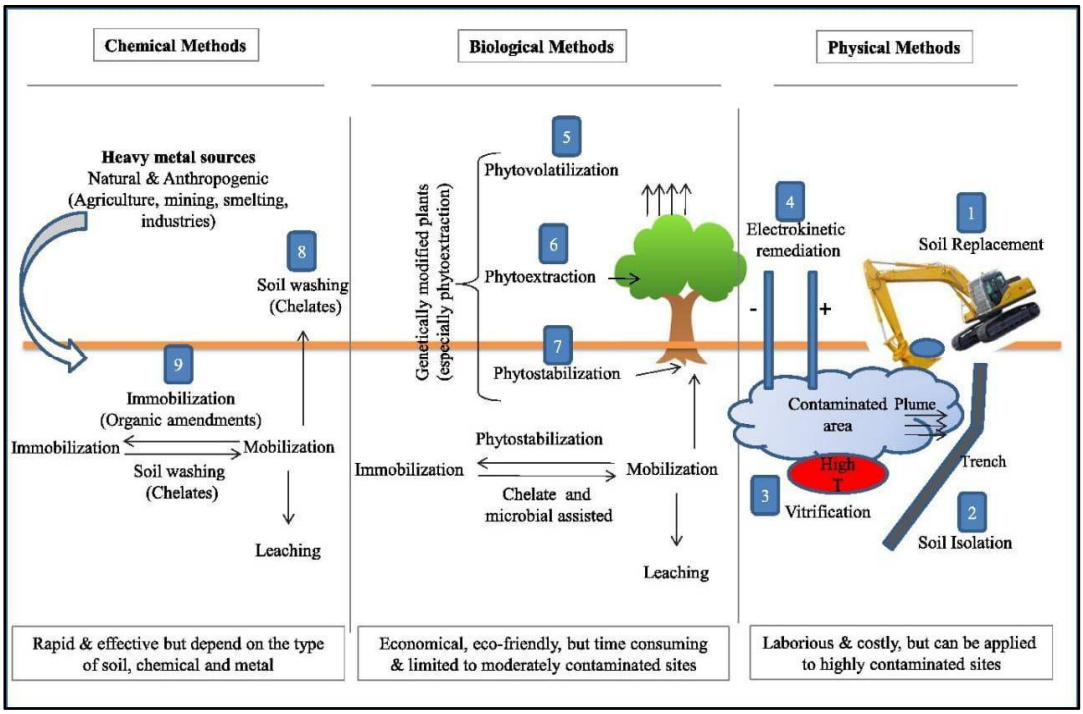

Fig. 3 Comparison of different soil cleanup methods
(Source: https://dx.doi.org/10.1016/j.gexplo.2016.11.021)

PHYSICAL METHODS

Soil replacement

Soil replacement is the method of removing or partly replacing soil that has been polluted [53]. Light soils, soft clay, or soils with high carbon content below or near the construction site can be unaffected and replaced in good phases at a higher level to preserve stability or prevent unreasonable structure approval. Soil restitution techniques minimize heavy metal absorption in the soil, increasing soil quality [80]. Heavy metals are often removed from restorative soils, or they are disposed of elsewhere in some situations. Soil replacement can also be accomplished by (1) soil loading and (2) the import of fresh soil. It extends deeper into the earth, accomplishing the objective of metal refining. The addition of new soil to heavy metal soils is known as new soil implantation. To minimize iron absorption, additional soil may be covered or mixed. Soil recycling efficiently separates soil from contaminated environments, reducing environmental effects [27]. However, because of Laboure's high efficiency, this method is costly, and it is only suitable for highly contaminated soils with limited room. Mass excavation, short-term storage, and disposal costs range from 15000 to 25000 rupees per tonne. Transporting excavated land over a long distance can be expensive. Furthermore, since the soil is damaged, this approach cannot operate on planted sites. Furthermore, since soil fertility is harmed, this approach will not operate on planted sites [4].

Soil isolation

Soil replacement refers to removing or partially polluted soil, light soils, soft clay, or highly carbon-based soils below or near construction that are unchanged and replaced in good phases at a higher level to preserve stability or prevent unequal structure approval. Soil restitution techniques minimize heavy metal absorption in the soil, increasing soil quality [80]. Heavy metals are often removed from restorative soils, or they are disposed of elsewhere in some situations. Soil replacement can also be accomplished by (1) soil loading and (2) the import of fresh soil [73]. It extends to deeper areas in the ground, achieving the goal of metal processing. The term "new soil implantation" refers to the addition of new soil to heavy metal soils. To minimize iron absorption, more soil may be covered or mixed in. Soil recycling can effectively separate soil from a contaminated atmosphere, lowering its environmental impact [55]. However, because of Labor's high efficiency, this method is costly, and it is only suitable for highly contaminated soils with limited space. Mass excavation, short-term storage, and disposal costs range from 15000 to 25000 rupees per ton. Transporting excavated land over a long distance can be expensive. Furthermore, since soil fertility is harmed, this approach will not operate on planted sites [4].

Vitrification

It is a way of reinforcing / reinforcing that uses heat energy. By using high temperature output in a polluted environment that results in the formation of material, heavy metal movement inside the soil can be minimized. Other forms of iron (Hg) can be exposed to high temperatures during vitrification and must be collected for disposal or treatment [81].Vitrification is a relatively new form of metal repair. It's pretty simple to combine with other bodybuilding techniques [8]. It can be used on a wide range of carbon and biologically polluted soils. The electric current is transmitted over the soil during in vitrification by directly inserting further electrodes into the polluted field [52].It used a space heater up to 1850 degrees C to conduct in-field joule heat system vitrification of Zn and Pb tones rich ceramic waste. They found that the vitrification methods were very useful in purifying heavy metals polluted with unused waste, and that they could also be used to clean up large quantities of mine.When it comes to reducing heavy metals in soil samples, the timing of vitrification is crucial. During vitrification, toxic gases may also be generated. With the exception of chromium-contaminated soil, the full-scale application comes from arsenic and lead. This method can also be used to treat mixed waste. The system's proper operation can be hampered by a high and wet clay material [64].

Vitrification may be done in situ or ex situ, but the in-form approach is preferred because it is less expensive than living requirements. Ex situ vitrification necessitates a long lifetime in order to melt, so it is costly in certain ways [21]. Wet soils with low alkaline content can be used to dissolve in vitrification.For large areas polluted with metal, these techniques may be extended to a small solution. This approach may be very unique under field conditions or to a large degree [26].

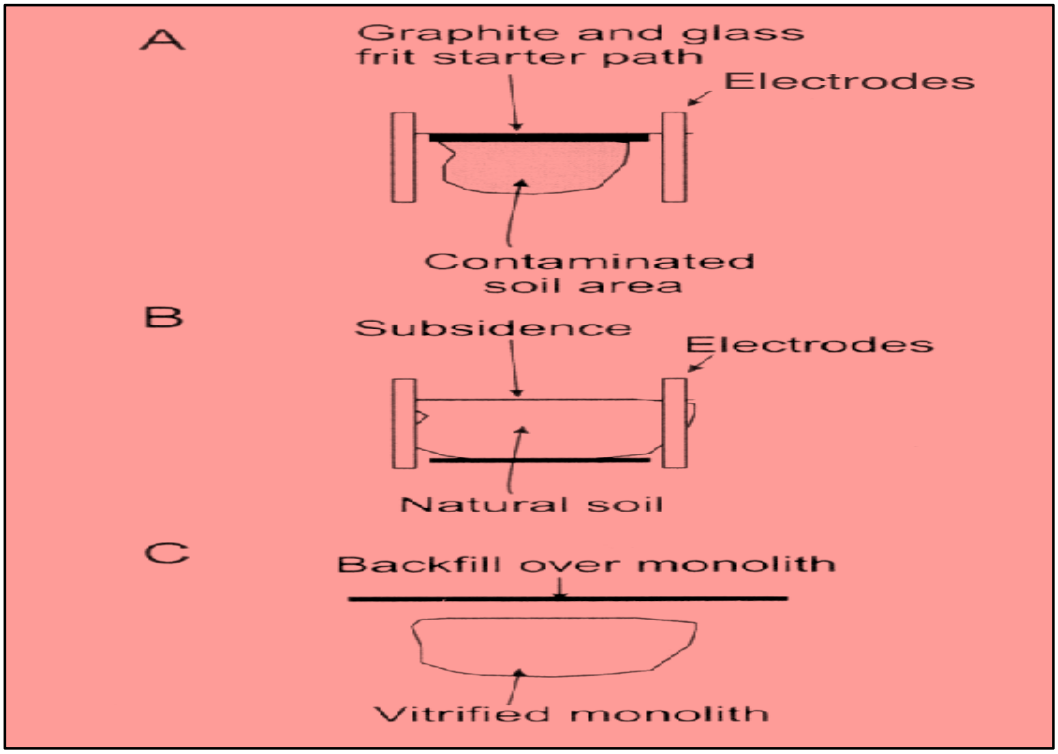

Fig. 4 Diagram showing steps in vitrification process for metal, including (a) insertion of electrodes and placement of graphite and glass frit starter path to invite vitrification, (b) subsidence of soil during vitrification and (c) placement of backfill over vitrified monolith [39]

Electrokinetic

The soil electro kinetic process is a modern and low-cost method for removing heavy metals from the soil [65]. The electrokinetic soil solution operates on the concept of establishing an ideal strength ground gradient on both sides of an electrolytic tank containing saturated soil polluted ions and small electrical particles, as well as water, which is transferred between the anodes [32].The anions, like the cations, continue to the anode and the cations to the negative. The pH of the anodes is maintained with buffer solutions. Metals may be separated using electroplating, precipitation/co-precipitation on anodes, ion-binding structures, or surfactant debris pumping. It works particularly well in well-drained soils with low groundwater flow rates [32].

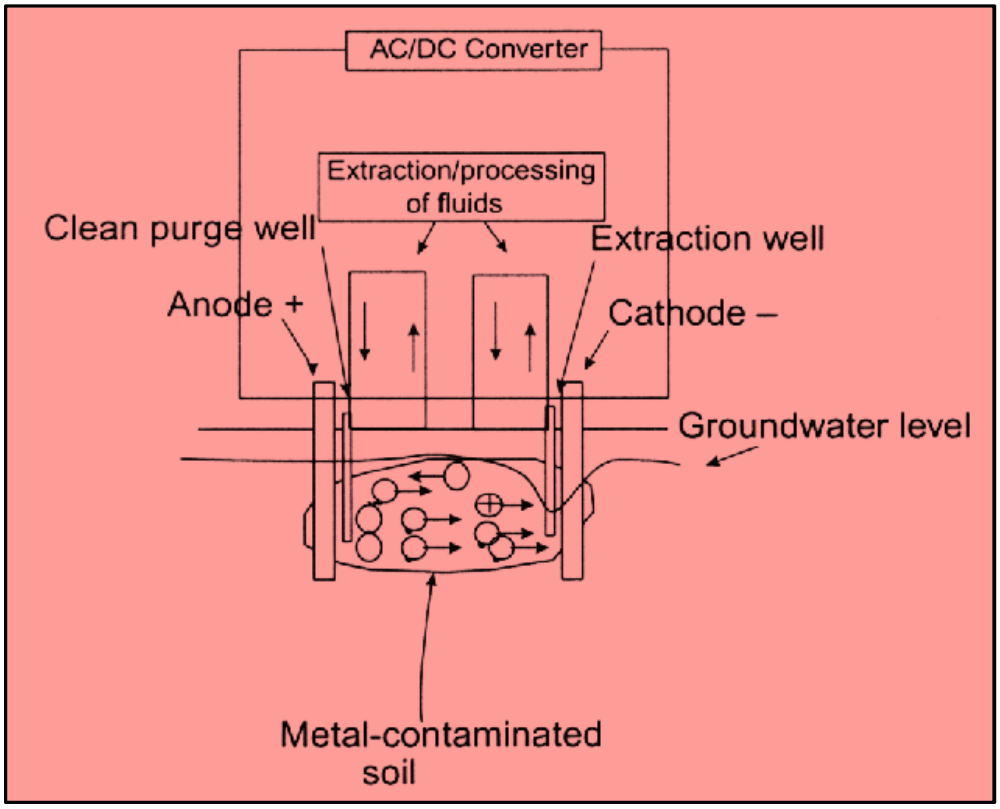

Fig. 5 Electro kinetic process for soil remediation [39].

BIOLOGICAL METHODS

Phytoremediation

It's a Greek term made up of two words: Phyto, which means "without floras," and Remedium, which means "without precision or eradication of evil." Many vegetable factors influence its development, including soil chemicals, bacteriological or herud exudates, and the host's biological capacity to absorb, accumulate, burn, transport, and dissolve iron. The term phytoremediation refers to a number of processes and systems that can disable, eliminate, or eliminate metals in different ways. Phyto-stabilization, phyto-accumulation, and phyto-volatilization are some of the terms used to describe phytoremediation.

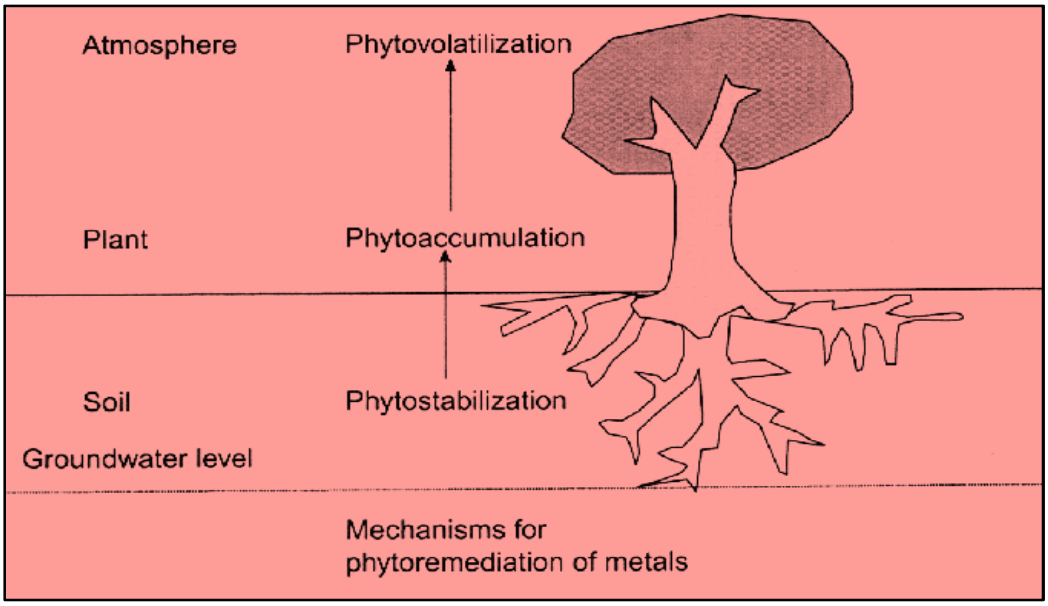

Fig. 7 Mechanisms for phytoremediation of metals [39].

Phyto-volatilization

Metals are created from the earth or transformed into a small number of poisonous odours that are released into the air during the flowering process [69]. Since the inside of the flowers is produced mechanically, which is normally regulated inside the plants by other enzymes or genes, the transformation of large metals is gaseous / volatilized. To improve the ability of plants to make energy, the phyto-volatilization process typically employs genetically modified plants [57].

Large-scale phyto-volatilization of groundwater solutions appears to be ineffective. Since no one has the power to stop the metal from being used in phyto-volatilization, the immeasurable structures are continuously purified and stuck in the air, and therefore become a temporary or natural hazard. Moreover, phyto-volatilization results in minor losses and no elimination of polluted herbal biomass, posing a problem of environmental negligence [48].

Phytoextraction- Contains the seed of herbs for heavy metal purification in the soil [22]. The ability of vegetarians to stimulate, transmit, and stabilize metals from the earth's surface to the surface of the flower beds is the basis for this sun-driven method. To plant biomass, heavy metals are separated from the earth [78].Herbal biomass is simple to recycle, dispose of, treat or oxidize, and soil-bind. Hyper accumulators are plants that can absorb metals from their firing organs and store them in the field or in parts of the plant that do not accumulate metals [19].

Plants that can be used for extraction should have the following characteristics:

- the ability to accumulate iron in the upper part of the soil,
- the acceptance of high iron content
- the ability to cultivate quickly with high biomass and large roots.

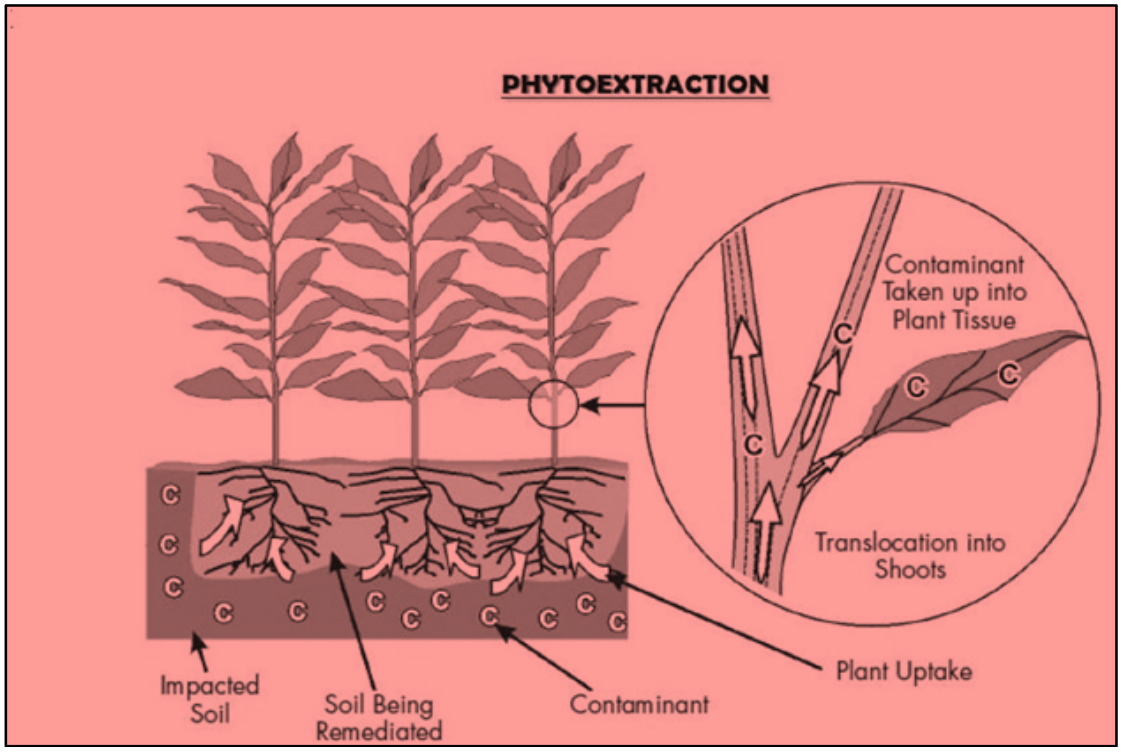

Fig. 8 Phytoextraction: remove heavy metals from soil[71]

Phyto-strengthening

Flowers can be used to reduce the supply and movement of iron in soil, which can be paid for with plant reinforcement [17]. Its aim is to keep heavy metals from accumulating on the surface of plants that have evolved beyond the rhizosphere's origin or rainfall [2]. Phyto-reinforcement is commonly used in soils where phytoextraction is difficult or impossible. It contributes to full environmental regeneration by increasing soil fertility. It has the potential to worsen the issue of highly contaminated soil [44]. Planting herbal remedies to absorb metal pollutants and adjust to local air conditions is helpful in this situation.

The highest concentrations of iron are collected by nonmetallic plants from the earth to the root, with only minor movement to the central section's [42]. Florida alters the transition of the rhizosphere, which has various physical and chemical properties, causing metals to cling to contaminated soil. The development of the iron roots is transmitted to the loam microorganisms, who are delighted with the increased growth and use of heavy metal in the loam [60].

CHEMICAL METHODS

Soil washing

The extraction method is determined by the metal and the soil. Washing the soil is an easy way to complete a task without making a long-term commitment. A variety of chemicals have been used to extract large particles from the earth [61]. This can be accomplished in reactors or by heap leaching. Inorganic acids with a pH below 2 such as sulfuric and hydrochloric acid, carbon-based acids such as acetic and citric acid, chelating agents such as ethylene diaminetetraacetic acid (EDTA) and nitrilotriacetate (NTA), and the various compounds mentioned above are examples of these agents. These extracts can easily prepare soil with 10-20% mud and carbon-based material[23].

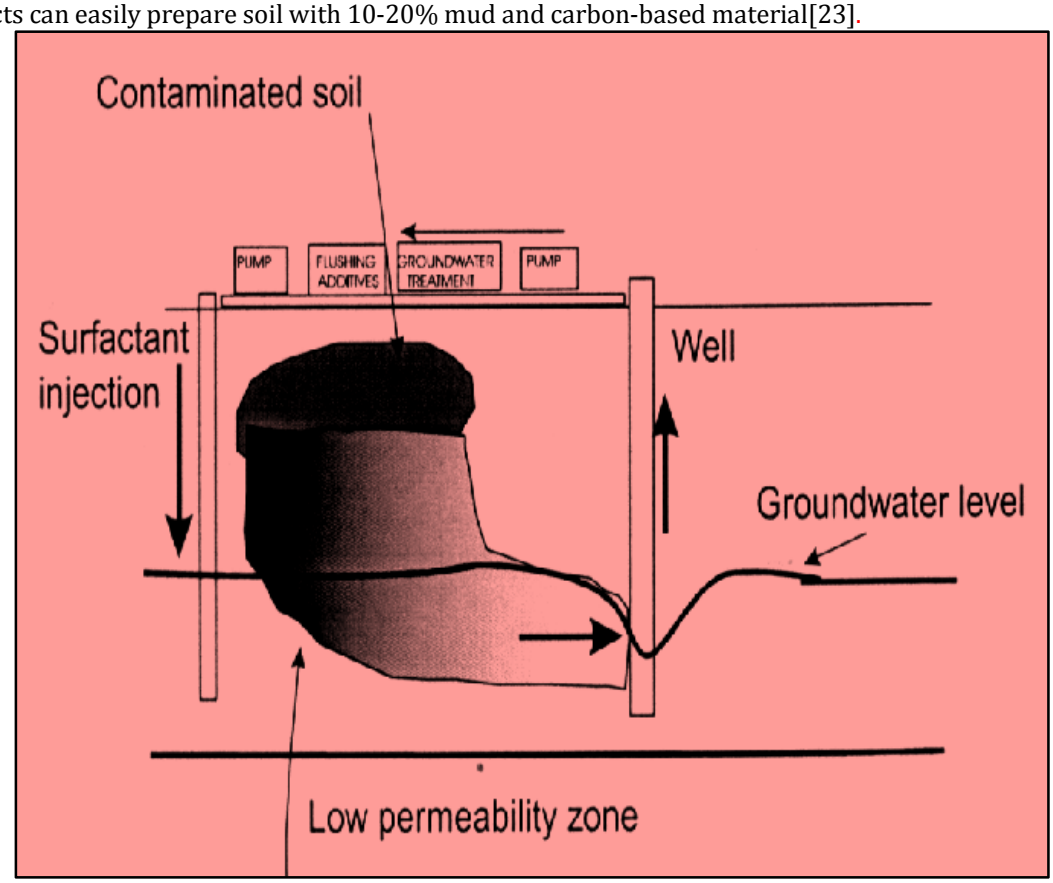

Fig. 9 Soil washing process using injection of water or solution containing chemicals including acids, chelating agent or surfactant [39].

Weight loss

When we travel from one location to another with limited exposure to heavy metal, we can experience exhaustion and excessive tiredness. Turbulence, precipitation, and adsorption reactions cannot transport critical metals to the earth [50]. Organic and non-organic matter in the soil is commonly used to make essential metals for soil mitigation [37]. Animal manure and bio-solids are two common biotic modifications used to treat iron deficiency. These days, low-iron compost items are used to control iron in the soil [16]. Farm manure has been shown to be effective in promoting Fe, Cr, Ni, Mn, and Pb on the ground, and diammonium phosphate has been shown to be effective in strengthening Cu, Cd, and -Zn on the ground[3]Organic goods increase the soil's natural content.

Because of their ease of use and low cost, biomaterials have been widely used in recent years to disable essential minerals in the soil. Biomaterials are a form of material that is made up of bio-char and has gotten a lot of coverage as a way to keep valuable minerals out of the soil [59].

Bio-char is made up of carbon-rich materials such as coal ash, animal waste, biomass, plant residues, and bio-solids [67]. Large metals do not function in the soil as a result of changes in soil properties, especially pH growth [49].

FUTURE DEVELOPMENTS IN THE REFINING OF HEAVY METALS

The costs and effects of technology, as well as the difficulty of the mission, have rendered soil cleaning a difficult task [18]. The biotic solution of large quantities of contaminants shows substantial benefits in

terms of environmental protection, field use, public sentiment, and related costs as compared to the physiological processes of chemical reactions [64]. Although there are many practical and technological drawbacks to using the biological field scale, this limit can be minimized with proper field management and improvement [51]. Biological approaches encourage a more systematic application in contaminated industrial or urban areas in order to reduce soil mineral content and improve soil fertility [67]. In small contaminated sites where highly polluted soil has been excavated, biotic methods are used. The use of transgenic technology, as well as field scale experiments, to increase biological performance and efficiency. Because of its efficacy and success in the field, some researchers developing plant hyper-accumulators in the future would be a smart decision [41]. Plant varieties suitable for phytoremediation must be able to generate high-quality biomass, be adaptable to different climates, have a long and branched root system, be able to mix, suck, move, and sew metals in the upper sections of the earth, be easy to harvest, and be genetically modified [56]. The combination of innovative soil, plants, and microbes, as well as transgenic technology, will pave the way for future growth [20].

CONCLUSION

Essential metals are abundant in the troposphere, which is characterized by increased growth, city expansion, and capital exploitation, determined atmospheric conditions and selection for human nutrition. To avoid further environmental degradation and part thereof, steps have been taken on a national and international level to address the major pollution issue. In order to effectively fix polluted areas, a variety of remedial procedures are employed. Successful and different repair processes have been contrasted which is widely used to cleanup dirty fibers; physical treatments can fully extract critical metals from polluted environments, but they are more costly and naturally destructive. In a small area of soil, this approach is often used. The best, least costly, and most cost-effective are biological methods which are time-consuming methods that extends to a low to medium soil levels. The chemical methods are simple, easy to remember, generally accepted, and cost-effective.

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