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Review of the Hazard to Human Health Associated with Environmental Heavy Metal Contamination

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ABSTRACT

Heavy metals, such as lead, mercury, cadmium, and arsenic, pose a significant environmental concern due to their persistent nature and potential health repercussions. Exposure to these metals can accumulate in body tissues and reach hazardous concentrations. Heavy metal contamination, particularly in emerging countries, is exacerbated by industrial growth and petroleum fuel use in transportation. Vegetables, which contain heavy metals and trace minerals, can be contaminated, leading to weakened immune systems, psychosocial disabilities, and increased upper gastrointestinal cancer. Soil pollution from quarrying sites, sewage water, industrial

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effluent, and hazardous materials, including heavy metals, can significantly hinder organic pollutants' biodegradation. Concentrated farming methods, pesticides, and biosolids can increase heavy metal concentrations, while biosolids can infiltrate soil horizons and contaminate groundwater. These sources contribute to soil pollution. Heavy metals are found in natural sources like geological events, water movement, and human activities. Water contamination can result from leaching, settling in aquifers, or runoffs.

Key Words: Environment, Heavy Metal, Pollution

Introduction:

The environmental damage that toxic substances create is a growing concern between regional customers. The aquatic environment is constantly exposed to toxins, mostly due to expanding industrialization, technological advancement, population growth, resource exploitation, and runoff from household and agricultural wastes. Due to their persistent nature, heavy metals are among the most harmful classes of these pollutants. They are non-degradable, poisonous, and tend to accumulate in organisms and undergo food chain amplification. Due to their permanence in the environment and their potential for major health repercussions, heavy metals that negatively affect human metabolism, such as lead, mercury, cadmium, and arsenic, are concerning. Acute heavy metal poisonings can harm the central nervous system, the heart, the digestive system, lungs, kidneys, liver, G.I. systems, endocrine glands, and bones. It is impossible to stay away from hazardous metal exposure entirely. Even those who ingest certain metals without occupational exposure because they are exposed to them through food, drink, or the air. However, lifestyle decisions that lessen the likelihood of hazardous heavy metal absorption, like dietary adjustments encouraging the safe metabolism or eliminating ingested heavy metals, can lower the risk of metal toxicity. (Rajeev Kumar et al., 2014). Trace metals that are harmful to human health and have a density of at least five times that of water are known as heavy or hazardous metals. Heavy metals are ingested, absorbed via the skin, and inhaled after being released into the environment through the air, food, drink water, or other man-made chemicals and goods. A slow buildup of these toxins happens if heavy metals enter and accumulate in bodily tissues more quickly than the body's detoxification processes can remove them. Exposure to heavy metals is unnecessary to cause toxicity in the body because these metals can accumulate in body tissues over time and reach hazardous concentrations much above allowable limits. Suruchi et al.(2011). Human activities such as mining, transportation, industrial production, and agriculture release a significant quantity of heavy metals into the biosphere. According to Niagu (1979, 1996), Pendias and Pendias (1989), and Rai (2009),The primary contributors to metal contamination are fossil fuel combustion,the smelting of metal like ores, municipal wastes, fertilizers, pesticides, and sewage. When waste materials containing metal-rich sulfides from mining activity have been stored or abandoned, heavy metal contamination and acid mine drainage become serious hazards (Concas et al., 2006; Rai, 2008).

The environment, particularly in emerging countries where medium-sized cities are expanding, is severely affected by heavy metal contamination. This is mainly because of uncontrolled pollution levels caused by causes such as increased industrial growth

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and increased petroleum fuel use in transportation. Many factors can lead to heavy metal pollution, such as using contaminated water for irrigation, applying fertilizers and insecticides containing metals, industrial emissions, transporting, harvesting, storing, and selling. (Radwan and Salama, 2006; Tuzen and Soylak, 2007; Duran et al., 2007). The earth naturally contains heavy metals. Human activity causes them to concentrate, and they can enter plant, animal, and human tissues through ingestion, food, and manual handling. They can also disrupt biological structures. According to the WHO, cadmium, lead, mercury, and arsenic are among the top ten substances that pose a serious risk to public health (Brathwaite & Rabone, 1985). Airborne deposition, trash disposal, fertilizer application, pesticide use, industry, and nuclear waste are a few of their sources.

The plant canopy collects air pollution deposition, which builds up in or on the leaves. Given that the accumulation is primarily determined by the quantity of pollutants deposited, exposure duration and the impact of meteorological conditions are critical considerations. As a result, many plant species are helpful for biomonitoring the deposition of contaminants in the atmosphere. Aerosols carrying heavy metals mostly deposit the elements on the leaf's surface. Nevertheless, since fine particulates can enter leaves through stomata and epidermal cells may fix particulates, there is no suitable way to remove all heavy metals from dust deposition entirely. Additional methods are required to demonstrate how airborne metals contribute to the contamination status of plants. Experimental studies utilizing tagged cadmium in the soil made it possible to distinguish between soil and airborne cadmium in several crops to remove all heavy metals from dust deposition entirely (Hovmand et al., 1983).

Vegetables are essential to a human diet because they include well-known heavy metals and trace minerals. If minor or trace elements originate from organic or plant sources, they are necessary for optimal health. On the other hand, they turn harmful if they originate from a metallic or inorganic source. The flow of nutrients, including trace elements, from soil to plant is essential to plant growth (Mohamed et al., 2003). Because they absorb heavy metals in their leaves, vegetables—especially leafy vegetables—acquire greater concentrations.

Food tainted with heavy metals can severely deplete the body of certain vital nutrients, which can further contribute to weakened immune systems, intrauterine growth retardation, deteriorated psychosocial abilities, malnutrition-related disabilities, and a high incidence of upper gastrointestinal cancer (Iyengar & Nair, 2000; Türkdogan et al., 2003; Arora et al., 2008).

CONTAMINATION OF SOIL WITH HEAVY METALS.

Sources of soil pollution include quarrying sites, sewage water used for irrigation, industrial effluent, and the deposition of hazardous material on the soil.

Natural processes of dissolving parent materials into the soil produce heavy metals, which are rarely hazardous and occur in rare amounts ($<1000 \text{ mg kg}^{-1}$) (Kabata-Pendias & Pendias, 2001; Pierzynski et al., 2000). The sources of metal-containing solids at polluted locations can range widely and include metal mine wastes, leaded gasoline and paints containing lead, fertilizer application, high metal wastes disposed of in landfills not properly protected, animal manures, biosolids (sewage sludge),

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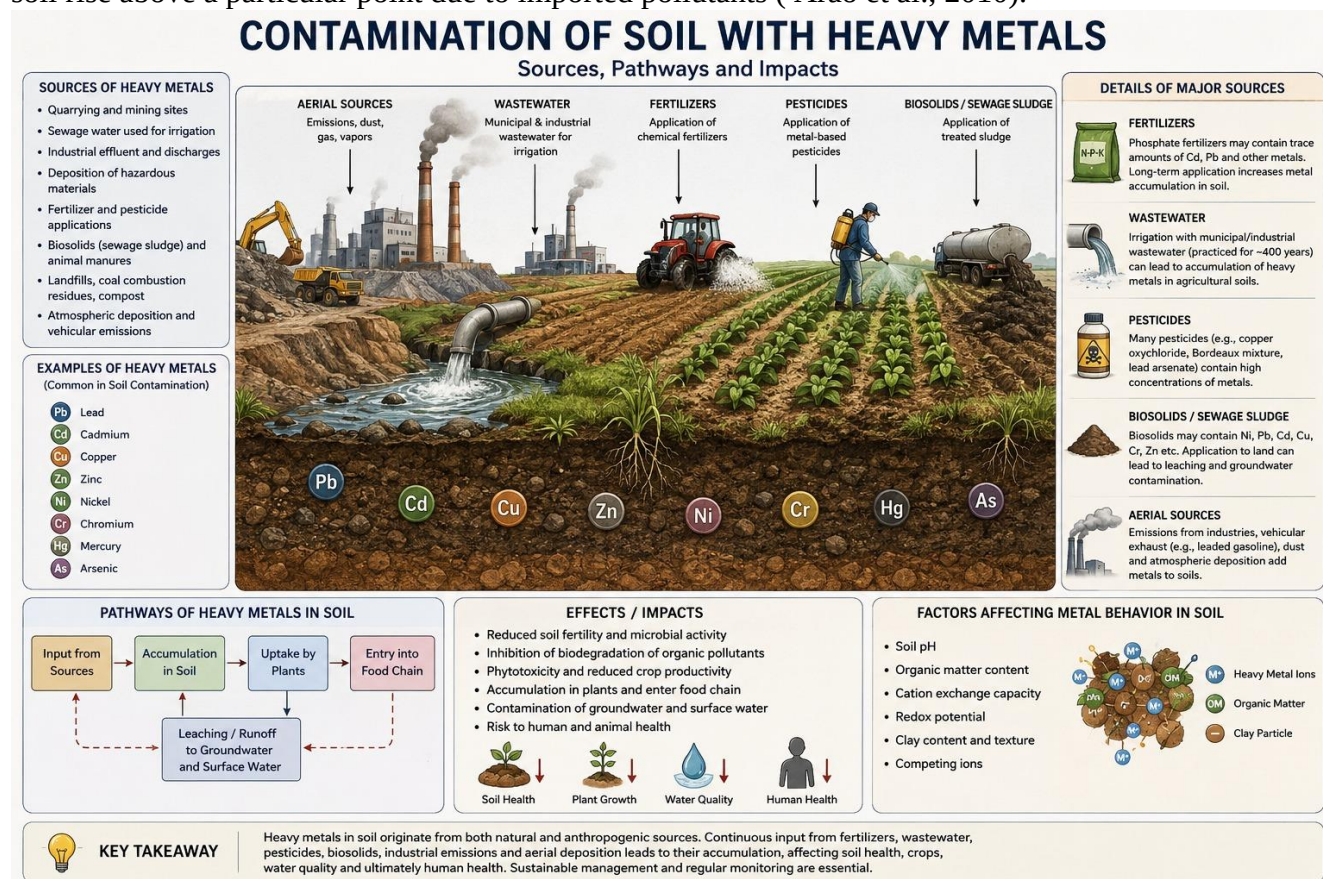
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leftovers from coal combustion, compost, petrochemicals, pesticides, and atmospheric deposition (Khan et al., 2008; Zhang et al., 2010; Basta et al., 2005). These heavy metals may impact metal transport by altering soil matrices. Mining, manufacturing, and synthetic items (such as pesticides, paints, batteries, industrial waste, and household or industrial sludge application to the ground) can all lead to heavy metal pollution of urban and agricultural soils. Contaminated soils can be found in or near mining waste piles and tailings, industrial locations where chemicals may have been spilled on the ground, fields where wastewater or municipal sludge has previously been applied, and so on. Hazardous metals in the soil can significantly hamper organic pollutants' ability to biodegrade (Maslin & Maier, 2000). There have been cases of soil pollution and polluted agricultural products in Japan when heavy metal levels in the soil rise above a particular point due to imported pollutants (Arao et al., 2010).



In concentrated farming methods, massive amounts of fertilizers are routinely applied to the soil to provide the right quantity of N, K, and P for crop growth. The complexes that provide these elements contain rare concentrations of heavy metal contaminants (such as lead and cadmium), which may significantly increase in quantity in the soil during ongoing fertilizer application (Jones & Jarvis, 1981). Lead and cadmium are two examples of metals without known physiological effects. Unintentionally adding Cd and other potentially hazardous elements to the soil, such as F, Pb, and Hg, results from some phosphatic fertilizer applications (Raven et al., 1998).

Metal concentrations in several well-known pesticides that were once frequently used

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in agriculture were high. In the U.K., nearly 10% of the approved pesticides are fungicides based on complexes containing Cu, Hg, Pb, Mn, or Zn. This includes well-known examples such as copper oxychloride and Bordeaux combination, which contain copper sulphate, as highlighted (Jones & Jarvis, 1981).

Sewage sludge and other biosolids are organic solid products created during wastewater treatment and can be recycled usefully (USEPA, 1994). The heavy metals Ni, Pb, Cd, Cu, Cr, and Zn are most frequently found in biosolids; the levels of these metals are determined by nature, the intensity of industrial activities, and the type of activity used in the biosolids treatment process (Mattigod & Page, 1983). Metals added to soils by applying biosolids may, in certain circumstances, infiltrate downhill through the soil horizons and contaminate groundwater (McLaren et al., 2005). Current studies on certain New Zealand soils treated with biosolids have led to higher drainage percolate concentrations of Ni, Cd, and Zn (Keller et al., 2002; McLaren et al., 2004).

Fertilizers.

In concentrated farming, large amounts of fertilizers are regularly applied to the soil to supply the right N, K, and P for crop growth. The complexes that provide these elements contain rare concentrations of heavy metal contaminants (such as lead and cadmium), which may significantly increase in quantity in the soil during ongoing fertilizer application (Jones & Jarvis, 1981). Lead and cadmium are two examples of metals without known physiological effects. Unintentionally adding Cd and other potentially hazardous elements to the soil, such as F, Pb, and Hg, results from some phosphatic fertilizer applications (Raven et al., 1998).

Wastewater.

Supplying wastewater from municipal and industrial land sources and related pollutants to soil has been around for 400 years and is commonplace in various regions of the world (Reed et al., 1995). Around the world, it is estimated that 20 million (20 million) hectares (ha) of arable land are irrigated using wastewater. According to research conducted in several Asian and African cities, 50% of the vegetables consumed in metropolitan areas come from agriculture that uses wastewater for irrigation (Bjuhr, 2007). Farmers are typically more interested in increasing their output and earnings than welfare or environmental threats. Even while wastewater discharges contain relatively little metal, prolonged irrigation of such land can eventually result in a buildup of heavy metals in the soil.

Pesticides.

Lead arsenate was sprayed in fruit orchards for several years to control some parasite pests. Compounds containing arsenic were commonly used in Australia and New Zealand to control insects in banana trees and reduce ticks on animals. Wood has been well-preserved with preparations of copper, chromium, and arsenic (CCA), and there are currently many neglected sites where soil concentrations of these elements significantly exceed background concentrations. Problems could arise from this kind of contamination, particularly if the areas are developed for uses other than agriculture. In connection with fertilizers, these substances' administration has been more confined

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and limited to particular locations or crops (McLaughlin et al., 2000). Many well-known pesticides once widely used in agriculture had high metal concentrations. The trend continues, with approximately 10% of compounds approved for use as fungicides in the U.K. still being based on complexes containing Cu, Hg, Pb, Mn, or Zn. This includes used fungicidal copper-containing insecticides like copper oxychloride and Bordeaux combination, which contains copper sulfate (Jones & Jarvis, 1981).

Aerial sources.

These are sources of metals released into the atmosphere by vents or chimneys, gas or vapor streams, and transient emissions such as dust from garbage piles and storage facilities. Metals originating from airborne sources are often released into the gas stream as particles. Certain metals, such as Pb, As, and Cd, can also volatilize due to high temperatures. Until a decreasing air is maintained, these metals will transform into oxides and become smaller particles (Smith et al., 1995). Chimney emissions can be removed from the gas tributary by natural air movement over a large region while still dry or wet from precipitation operations. The floating release of lead from burning gasoline containing tetraethyl lead is another major form of soil contamination; this increases the amount of lead in soils in metropolitan areas and those near major roads. It is also possible to apply zinc and cadmium to the soils adjacent to highways; tires and lubrication fluids are two sources (USEPA, 1996).

CONTAMINATION OF WATER WITH HEAVY METALS.

In the natural world, geological events such as volcanic eruptions and rock weathering can result in elevated concentrations of trace metals. Leaking into lakes, rivers, and the ocean results from water movement (Bagul et al., 2015). Anthropogenic Sources: Smelting massive amounts of metal ores in open fires and mining discharge small amounts of heavy metals into the air. Metals were taken out of natural resources during the Industrial Revolution and processed in industries, which released heavy metals into the atmosphere. Likewise, the release of garbage into the environment—both household and commercial—leads to the presence of heavy metal traces. Farming and from vehicle exhausts. The list below illustrates how heavy metals enter the environment due to human activity. (i) Processing or smelting metal ores. (ii) Mining. (iii) Burning fossil fuels, including coal, petroleum, and oil, used to make kerosene. (iv) Getting rid of garbage from agriculture. (v) Eliminating waste from industry. (vi) Getting rid of household trash. (vii) Exhaust system discharge. (viii) Applying insecticides that include heavy metal compounds (salts) (Armah, 2014). Water contamination results from heavy metals from mining and industrial sources leaching into subterranean water, traveling along water pathways and eventually settling in an aquifer, or being washed away by runoffs into surface water (Duruibe et al., 2007). For instance, industrial wastewater and port activities were the sources of heavy metal contamination (As, Cd, Hg, Pb, Cr, and Zn) in Port Klang, Malaysia. Water was collected from 21 stations at three-month intervals, and the contamination factor (Cf) and contamination degree (Cd) were calculated to estimate the level of contamination in the sampling areas. This underscores the urgent need for environmental action (Sany et al., 2013). Illegal e-waste

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recycling activities have contaminated soil and pond water in China (Wu et al., 2015). In various Great Cairo Cities in Egypt, the presence of heavy metals, including Pb, Cd, Cu, Mo, Ni, and Cr, in the drinking water has been connected to the prevalence of specific disorders such as liver cirrhosis, chronic anemia, hair loss, and renal failure (Salem et al., 2000).

Electronic waste

It is legally required for manufacturers of electronic devices to include information about how to dispose of their products in the user handbook. E-waste is the recognized primary source of heavy metals, dangerous chemicals, and diseases linked to carcinogens that affect the skin, respiratory, digestive, immune, endocrine, and nervous systems, including cancer. E-waste management and disposal can help prevent these diseases. Electrical and electronic equipment (EEE) use is growing exponentially to close the digital gap. When ICT wastes are not disposed of scientifically, the consequences for human health and the environment are concerning (Mahipal et al., 2016).

Given that it generates substantial amounts of metal-rich wastewater, it is inherently more likely to pollute than the food processing sector. However, this does not suggest that those operating in this sector will not also pollute; the electroplating sector stands to gain economically from reducing metal discharges, as these are inversely correlated with resource efficiency. Metal discharges can be decreased, for example, by decreasing drag-out from plating baths and reducing losses. Another industry that can produce Metal-rich wastewater and airborne lead pollution, both of which have the potential to end up deposited in surface water resources (as well as on land). There is a higher danger of pollution in industries that use heavy metals as essential raw materials (Rekha et al., 2014).

Oil Fertilizers Industry

Refining zinc (and sometimes lead) naturally produces cadmium as a byproduct because these metals are present in the raw ore. Nonetheless, recycling cadmium is relatively easy once it is gathered. Cadmium is primarily used in nickel/cadmium batteries, rechargeable or secondary power sources with high output, extended lifespans, little maintenance requirements, and high electrical and physical stress resistance. Cadmium is a versatile element, finding its use in various applications. The coating is preferentially corroded if damaged. Cadmium coatings offer good corrosion resistance, especially in high-stress situations like marine and aerospace applications requiring high safety or reliability. Additionally, cadmium is used in alloys, electrical compounds, pigments, and PVC stabilization, showcasing its adaptability and usefulness in various industries. Additionally, cadmium is an impurity in several items, such as phosphate detergents, refined petroleum-based goods, and fertilizers (Mustapha, 2014).

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Exposure of Humans to Food, Water, and Air

When mined ores are deposited on the ground surface for manual dressing, heavy metal contamination of surface and subsurface water sources causes significant soil pollution and increases pollution.

Surface dumping causes a lot of AMD by exposing the metals to air and rain. These metals are absorbed by plants and then build up in their tissues when agricultural soils become contaminated (Trueby, 2003). When humans consume polluted plants and animals, they are exposed to heavy metals, which have been shown to cause different biochemical illnesses. In conclusion, every living thing in an ecosystem is contaminated in different ways depending on where in the food chain they are located (Peplow, 1999). These metals are also accumulated in the tissues and milk of animals that graze on such contaminated plants and drink from contaminated waters, as well as marine life breeding in heavy metal-polluted seas (Trueby, 1992; Peplow, 1999).

EFFECTS OF CONTAMINATION WITH HEAVY METAL

The following illnesses have been linked to heavy metal exposure, including lead, cadmium, copper, molybdenum, nickel, and chromium: renal failure, cirrhosis of the liver, hair loss, and chronic anemia in Egyptians (Salem et al., 2000); effects on bones, cadmium fractures, lead neurological consequences, and arsenic-related skin cancer (Jarup, 2003). According to reports, animals are more susceptible to tumors and mutations caused by heavy metals (Degraeve, 1981). They are capable of causing genetic damage to an animal's germ cells, whether female or male. (Hayes, 1984; Wagner, 1993; Groten and Vanbladeren, 1994). They are seen as developing poisons that impact human health through plant biomagnification (Groten & Vanbladeren, 1994).

According to reports, breathing in contaminated air, consuming contaminated water, coming into direct contact with soil, and consuming food made of plants grown in soil contaminated with metals are some of the ways that heavy metals are linked to human health (Dudka and Miller, 1999 and Bhagure and Mirgane, 2011). Extended periods of exposure to heavy metals, including cadmium, copper, lead, nickel, and zinc, can result in catastrophic health problems for humans. (Reilly, 1991). These heavy metals have protracted biotic half-lives and can accumulate in different bodily organs, leading to unpleasant side effects (Jarup, 2003; Sathawara et al., 2004; Ata et al., 2009).

Chronic exposure to food and water containing cadmium (Cd) leads to a buildup of Cd in the kidneys, which can induce kidney disorders (ATSDR, 1993). If nickel (Ni) levels in consumables are higher than permitted, it is confirmed to be fatal. (Pacyna and Niagu, 1988). Increased exposure to Cd may cause lung conditions such as alveolitis, bronchiolitis, and emphysema. Subchronic inhalation of cadmium may potentially have renal consequences (relating to the kidneys) (Young, 2005; Ogwuegbu & Muhanga, 2005).

Native Americans' lifestyles are disrupted by toxic heavy metals in lakes, reservoirs, and rivers since they depend on these bodies of water for their regular water supply (Rai et al., 2002). According to (Al-Busaidi et al., 2011), Fish lowers blood cholesterol and is one of the main sources of protein for humans. It also provides omega-3 fatty acids, which reduce the risk of stroke and heart-related illnesses. These are metals that fish

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can accumulate in addition to water through the food chain (Hadson, 1988).

Human hyperglycemia, depression, sinus congestion, exhaustion, infertility, and growth issues have all been related to nickel deficiencies. In contrast, excess consumption causes hypoglycemia, asthma, headaches, nausea, and other symptoms, as well as epidemiological symptoms, including lung and nasal cancer. Higher zinc concentrations may hamper growth and reproduction (Rattan et al., 2005).

HEAVY METAL CONTAMINATION IN THE ENVIRONMENT REGULATION.

Maintaining the integrity of ecosystems and protecting human health depends heavily on controlling environmental heavy metal contamination. Here are a few tactics that are frequently used:

Pollution Prevention:

The best action is implementing policies to stop heavy metal pollution before it starts. This entails employing alternative materials, cleaner production techniques, and best practices in the mining, manufacturing, and agriculture sectors.

Treatment Technologies:

Removing heavy metals from contaminated soil, water, and air using various treatment techniques. These include chemical processes like coagulation, filtration, and centrifugation; physical processes like filtration, sedimentation, and centrifugation; and biological processes like bioremediation and phytoremediation.

Rules & Guidelines:

Governments enforce stringent regulations and policies that are vital to the preservation of the environment. These regulations are designed to restrict the release of heavy metals into the environment. They establish guidelines for allowable concentrations of heavy metals in food, soil, water, and air and can levy fines for noncompliance.

Establishing monitoring programs:

systematically evaluating the concentrations of heavy metals in various environmental compartments is part of monitoring and surveillance. This permits prompt intervention actions and aids in the early detection of contamination.

Waste Management:

Establishing appropriate waste management procedures to prevent hazardous materials, including heavy metals, from being disposed of improperly. This covers recycling and appropriate disposal in approved treatment facilities or landfills.

Public Education and Awareness:

Educate the public, business community, and decision-makers about the dangers of heavy metal pollution and the value of implementing sustainable practices. Education

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can empower communities to take action and hold polluters accountable. Encouraging global cooperation and teamwork to tackle cross-border problems associated with heavy metal contamination is known as international cooperation. Global knowledge, technology, and resource sharing can improve the efficacy of control efforts.

Investing in research and development to enhance methods for heavy metal contamination detection, remediation, and management is known as research and innovation. Innovation is also required to find practical and long-lasting answers to difficult environmental problems.

Heavy metal-contaminated soil ecosystems require remediation to be protected and restored (Wuana & Okieimen, 2011). Understanding the origin of the pollution, the chemistry of heavy metals, their effects on the environment, and the threats they pose to human health are necessary for this. Phytoremediation, which uses plants to absorb metals from the environment, is another method for managing heavy metals (EPA, 1998). It is inexpensive and offers the advantages of a natural solution to environmental issues. Reductions in the amount of cadmium that plants take up can be accomplished by phytoextraction, soil dressing, chemical soil cleansing, managing irrigation in paddy fields, and using a variety of rootstocks (Arao et al., 2010).

Conclusion:

In summary, due to various cascading effects, environmental contamination with heavy metals threatens human health, ecosystems, and socioeconomic stability. The effects of heavy metal pollution are seen globally, causing harm to ecosystems and communities everywhere, from soil erosion and water pollution to ecological deterioration and economic hardship. It will need coordinated efforts to address this complex issue, from public awareness campaigns and community involvement to technology innovation and regulatory enforcement. By working together, societies can only combat the scourge of heavy metal contamination, protect ecosystems, and guarantee future generations' sustainability.

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