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A Review on Soil Metal Contamination and its Environmental Implications

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ABSTRACT

The rapid increase in heavy metal accumulation within soil ecosystems has become a significant concern due to various anthropogenic activities such as industrial processes, agricultural practices, and urbanization. These activities have led to elevated levels of heavy metals like lead, cadmium, mercury, and arsenic in the soil, which, when surpassing permissible limits, pose severe toxicological risks to both human health and plant life. Once heavy metals are introduced into the soil, they can be readily absorbed by plants, subsequently entering the food chain and affecting the metabolic activities of humans and animals consuming these contaminated plants. Although trace amounts of heavy metals are naturally present in the soil, their concentration beyond safe thresholds can lead to deleterious effects, including disruption of enzymatic functions, damage to cellular structures, and interference with essential biological processes. Studies have highlighted that children living in urban and industrial areas are particularly vulnerable to heavy metal exposure, which can result in cognitive impairments, developmental delays, and various other health issues. Furthermore, long-term exposure to these metals can lead to chronic diseases such as cancer, kidney dysfunction, and cardiovascular disorders. Given the escalating threat posed by soil metal contamination, it is imperative to implement stringent management practices aimed at maintaining soil chemistry within safe limits. These practices may include the remediation of contaminated sites, the adoption of sustainable agricultural methods, regular monitoring of soil quality, and the use of phytoremediation techniques to mitigate the impact of heavy metals. Ensuring the safe production of food requires a comprehensive understanding of soil dynamics and the integration of innovative strategies to prevent and control heavy metal pollution. Consequently, addressing this environmental challenge is crucial for safeguarding public health, preserving ecological balance, and promoting sustainable development.

INTRODUCTION

Pollution means the addition of harmful things to the environment. These harmful chemical agents destroy the ecosystem and affect living and non-living creatures. The addition of these chemicals alters the composition of soil.

Soil pollution is not confined to a specific place. It is a global issue nowadays; sustainable development Goals and Millennium development goals by the United Nations are focused on the restoration of soil, focused nowadays on mitigating the heavy metals from soil. The heavy metals present in the soil are damaging the soil's natural environment. Around the world, the focus has been on the detection and removal of heavy metal contamination to ensure food security and zero hunger.

HEAVY METALS PRESENT IN SOIL

The presence of heavy metals in soil can have significant effects on various industries, such as agriculture and archaeology. Deshmukh et al. (2019) emphasized the importance of heavy metal levels in soil for determining irrigation requirements, crop selection, and fertilizer usage to achieve maximum yield. In a separate study, Qiu et al. (2019) examined the impact of heavy metals on buried cultural artifacts in soil, highlighting the importance of analyzing the spatial distribution and form of heavy metals to understand their effects on historical objects. Additionally, Zhang et al. (2020) discussed the challenges of soil contaminated with both heavy metals and pesticides, emphasizing the necessity for effective remediation strategies and assessment methods. In a recent study by Petruzzelli et al. (2020), they delved into the availability and accessibility of heavy metals in soil, underscoring the significance of examining these aspects to gauge potential risks to humans and the environment. Surprisingly, Besra & Mishra (2020) looked into the effectiveness of myco-remediation in soaking up heavy metals from polluted agricultural soil, proposing that mushrooms could serve as a valuable weapon in combating heavy metal contamination. Moreover, Longhi et al. (2022) debated the emergence of resistance to heavy metals in microorganisms that are exposed to soil, underlining the necessity of addressing the tolerance of bacteria towards heavy metals. Additionally, Deng et al. (2023) pinpointed the factors that govern the dispersion of heavy metals in agricultural soils. It is important to recognize that the quality of soil plays a key role in the levels of heavy metals present. Despite the findings that soil pH and organic matter do not have a significant impact, other soil characteristics are considered to be major factors in the distribution of heavy metals. The research available stresses the significance of recognizing and addressing the presence of heavy metals in soil within a variety of fields, including agriculture, environmental science, and archaeology. Several studies have investigated various aspects of heavy metal pollution in the soil, underlining the necessity for effective remediation plans and assessment techniques to reduce the potential dangers linked with heavy metal contamination.

The purpose of the study was to evaluate the factors affecting metal mobility in soil, identify potentially harmful elements for human health, assess metal accumulation in horticultural crops, and examine the toxicity of naturally occurring chromium in soils and water. The analysis showed high levels of heavy metals, such as chromium and nickel, in vegetables, indicating a transfer of metals from soil to plants. Soil environmental properties are complex, making remediation and treatment difficult and costly. A study by Mandal et al. (2020) discusses progress and future opportunities in biochar composites. Application and reflection in the soil environment are crucial. Sustainable materials such as biomaterials, biochar, and composites offer a practical solution for remediation. The focus is on soil remediation, specifically the removal of heavy metals using biochar-based composites. Moghal et al. (2020) conducted studies on immobilizing heavy metals and enhancing the geotechnical properties of cohesive soils using the EICP technique. They explored the swelling and permeability characteristics of two native Indian cohesive soils (Black and Red). Experiments were conducted to study the sorption and desorption of heavy metals (Cd, Ni, and Pb) on these soils to understand their response.

The study by Tun et al. (2020) aimed to analyze the levels of toxic heavy metals in the soil of small-scale gold mining sites in Myanmar. The findings revealed elevated concentrations of heavy metals in the soil at these mining locations. The daily intake of metals was found to be below 1, indicating that they were within safe limits for consumption. However, Ahmad et al. (2021) reported higher enrichment concentrations of metals, suggesting that metals were also present in soil and fodder samples near roadsides. Natural zeolite, while containing high impurities, has a limited capacity to stabilize heavy metals in soil due to its single mechanism of heavy metal stabilization. The capacity of soil to stabilize heavy metals is limited. In their study, Ma et al. (2022) aimed to investigate zeolite modification technologies, understand how polymetallic contaminated soil is stabilized, and assess the effectiveness of MZEO for stabilization. Hyperaccumulators release transporters that help move heavy metals from soil to different parts of plants. Yaashikaa et al. (2022) explore the harmful effects of heavy metals on the environment and various phytoremediation methods for transporting and collecting heavy metals from polluted soil. Currently, research on heavy metals in city soil lacks spatial correlation analyses for different heavy metals. Current research on soil heavy metals in cities lacks spatial correlation analysis between different heavy metals and a relative assessment of ecological and health risks. Li et al. (2019) provide technical support for preventing and controlling urban heavy metal pollution. Meanwhile, Atta et al. (2023) study the accumulation of heavy metals in soils, vegetables, and crop plants irrigated with wastewater. They conduct a health risk assessment of heavy metals in Dera Ghazi Khan, Punjab, Pakistan. An investigation is carried out to determine metal concentrations in wastewater, soil, and various plant species. The average values of heavy metals in soil samples fall within the WHO/FAO safe limit, although levels of Cr and Pb stand out were the most frequent (100%) among the metals. The mustard (*Brassica juncea* L.) plant is a well-known and widely accepted hyper-accumulator of heavy metals.

IMPORTANCE OF SOIL QUALITY

The quality of the soil is extremely important for maintaining both agricultural productivity and environmental health. Good quality soil can improve crop yields and make them more resistant to changes in the climate, resulting in higher overall crop production. To assess soil quality, various factors such as pH levels, organic carbon content, nitrogen levels, phosphorus and potassium levels, and micronutrient levels need to be analyzed. Research has demonstrated that soil quality is affected differently by various types of land use, with agriculture generally producing better quality soil than plantation land. Methods like principal component analysis and assessing common soil parameters can help in the evaluation of soil quality and in determining how to manage and improve it. Soil quality is extremely important for a variety of ecosystems, including agricultural, forest, and disrupted ecosystems like reclaimed mine soils. Studies have indicated that adding organic matter to mine soils may not always lead to long-term improvements in soil quality. In agricultural systems, soil organic carbon (SOC) is known to be vital for maintaining soil health, preserving soil and water quality, and influencing nutrient, water, and biological processes. Developing soil quality indicators is crucial for assessing soil degradation and restoration, as seen in forest soils in southeastern Spain. According to Zornoza et al. (2007), the nitrogen content and bioavailability of litter are key factors in shaping microbial communities in soil ecosystems. In a study conducted in Southern Italy, Muscolo et al. (2014) emphasized the importance of identifying biochemical markers as early signs of changes in soil quality. Additionally, research has shown the significance of the connection between soil organic matter fractions and microbial metabolic diversity in forest ecosystems (Esperschütz et al. 2012). According to research by Tian et al. (2015), the relationship between the quality of litter, soil characteristics, and microbial communities plays a significant role in the priming effect, ultimately impacting the breakdown of organic matter in the soil, as discussed by Fanin et al. (2020). To assess soil quality in controlled experimental environments known as mesocosms, it is necessary to examine a range of chemical, biological, and combined indicators to gauge levels of mineral buildup, potential ecological threats, activity of soil organisms, fertility, and the overall health of the soil. According to a study by Napoletano et al. (2021), cover crops have been proven to enhance soil quality and protect the environment. They do this by reducing nutrient loss, improving soil moisture levels, and increasing organic matter in the soil. Another study by Ogilvie et al. (2021) highlights the significance of interactions between plant roots and soil in cover crop systems.

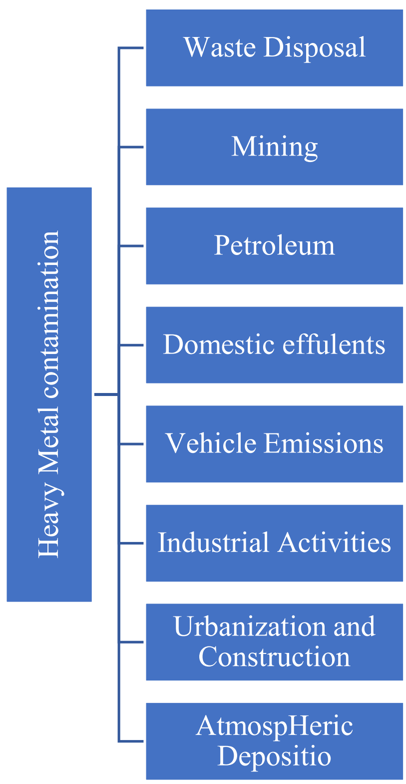

Fig. 1: The sources of heavy metal accumulation in soil matter.

SOURCES OF SOIL CONTAMINATION

Soil contamination with heavy metals has many sources: industrial effluents, sewage untreated water, mining activities, anthropogenic activities, agronomic practices, domestic effluents,

Soil metal contamination can come from a variety of sources and can have lasting effects on soil microbial properties (Fig. 1). A study conducted by Chander et al. (2001) in Lower Saxony, Germany, looked at soils contaminated with sewage sludge, sediment, and debris from mining and factory operations. They observed that the ratio of biomass C to soil C decreased in the order of sludge > sediment > debris contamination, corresponding to the increasing presence of heavy metals. In China, Wang et al. (2003) investigated soil contamination and the uptake of heavy metals by plants in polluted areas, underscoring the impact of heavy metal contamination on plant health. Möller et al. (2004) studied the issue of urban soil pollution in Damascus, Syria. They highlighted the dangers of heavy metal build-up in humans and livestock from directly consuming soil or breathing in dust. Krishna et al. (2008) looked at soil contamination in the Manali Industrial Area in Chennai, Southern India. Sollitto et al. (2010) investigated heavy metal pollution in the Zagreb Region in Northwest Croatia using advanced geostatistics methods. Chandrasekaran et al. (2014) analyzed the levels of heavy metals in the soils of Yelagiri Hills, Tamilnadu, India, investigating both human-made and natural sources. Meanwhile, Zhao et al. (2014) studied soil contamination in China and ways to address it, and Hou et al. (2020) looked at metal pollution in agricultural soils and how bioremediation can promote food safety and sustainability. Additionally, Qin et al. (2020) conducted a detailed examination of heavy metal pollution in Chinese agricultural soils, exploring sources like pesticides, fertilizers, vehicle emissions, coal combustion, sewage irrigation, and mining.

Soil pollution is the addition of harmful agents into the soil; these alter the composition of the soil, which changes the reaction of soil towards something like a change in the pH at low pH. Some elements become toxic, and some element's activity is disturbed due to the change in the pH. Elements show maximum activity at a specific pH. Plant growth is affected by the pH of the soil. The nutrient cycle of the soil is disturbed by the addition of foreign elements. Every element has its side effects when it exceeds its limit. At a certain pH, the leachability of contaminants increases. The World Health Organization has given the range of soil pH between 6 and 7.5.

With time the world is going toward rapid urbanization and advanced agricultural practices. With this advancement in techniques, more and more chemicals are being used that are posing harmful effects on the soil environment. When excess amounts of fertilizers are used, concentrations of heavy metals and other toxic metals are increasing with negative effects on flora and fauna. The ecosystem is destroyed due to such activities. The metals are required in trace amounts to operate in the best manner, but due to the addition of external factors, they are increasing day by day, which is leading to the lethal stage. Heavy metals are present in the earth's biosphere. These metals are lead, mercury, arsenic, and copper; these metals are present in the natural soil in trace quantities. The main source of these elements in the soil is the weathering of materials over time and the accumulation of these heavy metals in the soil. With time, these metals accumulate in the soil, and day by day, the quantity of these metals is increasing, due to which crops and humans are being affected.

IMPACTS ON PLANT GROWTH AND AGRICULTURAL PRODUCTIVITY

The phototoxic effects related to heavy metals are also observed in different studies. According to Nachana'a Timothy et al. (2019), heavy metal accumulation has causing direct effect on plants, and it may change the activity cycle of plants by changing the enzyme activity, affecting plant growth, and directly changing the soil quality. Rojczyk-Gołebiewska et al. (2013) studied the Krebs cycle activity and its effects on the plant concluded that some metals like iron and, manganese, and zinc could affect the activity of the Krebs cycle by inhibiting or promoting some specific enzymes of the cycle. Therefore, it directly affects the energy production of plant cells. The medicinal plants consumed with heavy metal accumulation had even more adverse effects.

Finck (1980) studied the accumulation of zinc and copper-like metals in the soil due to the use of town waste for the fertilization of the soil. Deficiency of heavy metal indeed causes damage to the plant, but it is also not beneficial for the plants to accumulate the heavy metals more than the standard. As far as the agro system is concerned, the fertilizers used increase the productivity of the fruits, but once the heavy metal concentration is increased, its management is difficult. A controlled environment is important for plant growth and human safety.

In animals, bioaccumulation is also causing serious health issues. When the animals eat grass or consume polluted water, heavy metals accumulate in their tissues. When humans consume these animals in the form of meat, these metals enter the human body and affect different organs of the body. For example, in humans, the quantity of Pb lead, even in trace amounts, can retard the growth.

ANTHROPOGENIC ACTIVITIES

Anthropogenic activities are responsible for this heavy metals' accumulation (Tilwankar et al. 2018). Some heavy metals play an important part in the physiological activities of humans as well as plants. The geography of the environment also participates in heavy metal deposition. Some areas are enriched with minerals and metals. It is beneficial until it is at the permissible level of heavy metals Environment protection agencies are fully focused on controlling the heavy metal balance in soil. The environment due to rapid industrialization, the accumulation is increasing robustly (Ali et al. 2015, Karim et al. 2015) reported that due to the growing population, the demand for food is also increasing, as well as more land is required for housing. The cultivating land is reducing day-by-day urbanization. With the growing need for food and less agriculture, such activities are used to enhance the quantity of crops, but unfortunately, the quality of the soil and crop yields are decreasing. The addition of fertilizers, pesticides, sewage water irrigation, and municipal waste disposal GIS is used for getting the source of pollutants. (Buck et al. 1995) found that the excess use of fertilizers causes the deposition of heavy metal accumulation; the study was for cadmium and zinc. It was observed that this accumulation was because of ion exchange, and it also reduces the pH of the soil.

Pesticides

Pesticides are also the cause of soil pollution. Although these are used for the plant's well-being, it has so many worse effects on the soil. Pesticides can damage the plant in different ways. A study reported that it can cause chlorosis, disturb the photosynthesis cycle, and plant leaf pigmentation. It can change the enzyme of the plant. The toxic elements present in pesticides when washed off with rain or while watering the fields, these elements get mixed with soil and constitute a soil component. These elements leech down over time and disturb the nature of the soil. In advanced agricultural practices, the farmers are using pesticides for pest control in excess amounts. These practices are safe for plants, but when it comes to soil, it is harmful to the soil environment. A study in 2007 (Komatsuzaki & Ohta 2007) was conducted on wheat that resulted from the dramatic increase in heavy metals that were due to excessive use of fertilizers and pesticides. Pesticides' toxic content leaches down and gets mixed with the underground water. That underground water is then used for different purposes.

By the passage of time, many studies have shown the heavy metal accumulation in the crop of wheat. Lead and cadmium are the most focused metals for the wheat crop as per their effects. Wang et al. (2011) studied the wheat of Northwest China and concluded that the roots of the wheat plant contain more Cadmium in the plant as compared to the shoot. Ma et al. (2019a) worked on the different zones of soil with higher and lower deposition of heavy metals from the atmosphere and further calculated the results of lead. Afterward, Ma et al. (2019b) worked on the mechanism of lead uptake due to the environmental deposition of heavy metal lead in the wheat crop; this study gave the understanding of the lead uptake from the soil to plant as it is directly related to food security and human health as well.

Petroleum

Petroleum effluents, called sludge of petroleum products, when mixed with the soil, contain many toxic metals as well as other polluting agents. The impact of heavy metal pollution from petroleum activities is a growing concern in various regions of the world. Rusai et al. (2020) conducted a study in Romania to assess the pollution levels of heavy metals and total petroleum hydrocarbons (TPH) in soil and vegetation near oil pipelines and oil wells. The results showed that the concentrations of heavy metals and TPH exceeded the limits, indicating the extent of pollution in the area. Mokarram et al. (2020) focused on the assessment of the water quality of river water in southern Iran, especially the Khor River, due to industrial wastewater. In this study, the water quality index and heavy metal assessment index were used to determine the pollution level at different stations along the river, highlighting the impact of heavy metal pollution on water quality. In a comprehensive review by Priyadarshanee & Das (2020), the potential of metal-resistant bacteria in the biosorption and removal of hazardous heavy metals in wastewater treatment was discussed. This review highlighted the different mechanisms by which bacterial biomass binds different metal ions and highlighted the importance of environmental parameters in the metal removal process. Zheng et al. (2020) conducted a human health risk assessment in the Pearl River Delta urban agglomeration in China, focusing on heavy metal contamination of soil and food crops. This study systematically evaluated the risks associated with heavy metals such as Cd, Cr, Pb, Hg, and As and provided insights into the spatial risk patterns of heavy metal contamination in soils and crops. Yan et al. (2020) discussed phytoremediation as a promising approach for revegetation of heavy metal-contaminated areas and highlighted the mechanisms by which plants absorb, transport, and detoxify heavy metals in contaminated soils. In a study by Li et al. (2020), the effects of co-contamination of heavy metals and TPH on soil bacterial communities were investigated. This study focused on the changes in microbiota in soil contaminated with heavy metals and TPH and revealed the responses of soil microorganisms to different types of pollution. Overall, the reviewed literature highlights the significant impact of heavy metal pollution from petroleum activities on soil, water, and vegetation in different regions. Research highlights the need for effective remediation strategies and risk assessments to reduce the negative impacts of heavy metal contamination on human health and the environment.

Mining Activities

Mining activities and the expansion of industrial areas are causes of pollution globally. Carbon emission, as well as the effluents of industries, when they enter into the natural water untreated, is destroying the marine ecosystem. Well, when it comes to other sources of water, the heavy metals present in the water leech down and become part of the groundwater table. This polluted groundwater Is then used for irrigating the fields. These heavy metals move into the different parts of the plant. The heavy metals present in the soil are now part of our food chain. Marine food also contains Heavy metal accumulation in their bodies. When these are consumed cause different damages to Human health (Meena 2021). Lead (Pb), Mercury (Hg), cadmium (Cd), nickel (Ni), and arsenic (As) are the most lethal ones. Heavy metals are present in the soil environment naturally, but a little change in its composition can cause serious health effects. The heavy metals do not affect alone. They combine with other elements, either organic or inorganic forms, forming chelates, microfibers, microplastics, and others. The specific forms are more toxic, like dimethyl mercury, which is more toxic in inorganic form.

Root vegetables are used worldwide for their health benefits, like carrots, radishes, parsley, and beetroots (Knez et al. 2022). These are now at risk of eating. These vegetables are consumed widely for their antioxidant properties. Heavy metal contamination is also observed, but microplastic addition is more dangerous. The fragments of fibers deposit into the plant from the soil directly. Entering into the plant system, this fiber travels into other parts of the plants, like fruits and leaves. The consumption of these plastic fibers poses serious health risks. The research was conducted BY (Chary et al. 2008) at Musi River. It was observed that (Zn) zinc chromium, copper and mercury, nickel, and lead were detected in leafy and non-leafy parts of plants. Cattle milk was also analyzed in the results the heavy metals concentration was increased in the urine and blood of individuals due to the consumption of these plants and vegetables as well the cattle milk. The heavy metal addition in soil not only destroys the plant it is also not favorable for soil. These heavy metals accumulate in the parts of plants' roots and shoots as well as in the fruits that we consume. The amount of heavy metals is tolerant to the body up to some extent; when it crosses the lethal dose, it becomes hazardous to human health. The amount of zinc, chromium, and lead was higher in leafy vegetables like spinach and roots.

In medicinal plants, the accumulation of heavy metals is even more alarming. Now, the world is moving again to herbal medicines. The plants have been used for medicinal purposes since the world came into being. Plants are used to treat almost every disease. Studies were conducted at Pretoria to check the amount of heavy metal deposition in the plants that were used to treat cancer. Samples of different places were collected and analyzed. Inductive coupled plasma (ICP-MS) Spectroscopy was used to analyze the quantity of heavy metals. The results showed that all the metals were within the permissible level. As the amount of heavy metal is continuously increasing, prolonged use will create critical issues. In a study conducted to check the heavy metal concentration in vegetables, two vegetables, cabbage and carrots, were selected. Their concentrations were measured, and in the results, all the metals were in high concentration except nickel.

ENVIRONMENTAL IMPACTS

Effects on Soil Microorganisms

Microorganisms are crucial for maintaining the balance in soil ecosystems through nutrient cycling and decomposition processes. However, prolonged exposure to heavy metals can negatively impact these microorganisms. This can result in reduced diversity, activity, and biomass of microbial populations, as well as changes in their composition. Moreover, heavy metals can disrupt important microbial functions like nitrogen fixation and carbon mineralization, causing imbalances in nutrient levels and soil fertility by Sharma et al. (2020). As a consequence, plant productivity may decrease, and overall ecosystem health could be compromised. It is essential to assess the impact of heavy metal accumulation on soil microorganisms.

The addition of heavy metals is increasing day by day due to anthropogenic activities. We are ingesting these heavy metals by different means. Food security is the

Table 1: The amount of metals that are permissible according to WHO and FAO.

Element	The permissible amount of heavy metals(mg/kg)
Cd	0.2
Pb	0.3
Ni	67.9
Fe	425.5
Cu	73.3
Zn	99.4

most concerning agenda. According to Islam et al. (2007), heavy metals are accumulating in the soil, destroying the soil's natural environment; due to anthropogenic activities, bioaccumulation is alarming in the food chain, and human activities like the use of detergents, mining, effluents of industries, vehicle exhaust are the main causes of heavy metal deposition in the soil. The plants uptake the heavy metals from the soil and transport them into the leaves or fruits. Consumption of these vegetables and fruits is causing serious health issues in human life. Belhaj et al. (2016) studied the effect of sewage-irrigated sunflower plants and then compared it to the untread plants and saw a great difference in the heavy metal concentration of chromium, copper, zinc, and nickel. Hu et al. (2018) studied the soil of Southeast China for the study of identification of heavy metals and finding its sources. Heavy metal concentration was noticed after the application of fertilizers to the soil. Moreover, Rai et al. (2019) in the study stated that cadmium and lead present in the soil accumulate in the soil of rice fields. It was also observed that an increase in pH caused the immobilization of heavy metals.

Contamination of Surface Water and Groundwater

Ghosh et al. (2012) in a study revealed that for a long-term application of sewage, untreated water used for agriculture causes heavy metals to transfer into the crops and vegetables further, this study shows that effluents of heavy metals are most important to remove from the water before using it as an agricultural watering. Additionally, Alghobar et al. (2017) reported the heavy metal accumulation in tomatoes irrigated with sewage water in a city of India named Mysore. Xue et al. (2019) studied the heavy metals present in the crops of wheat and maize. This study was conducted in comparison to groundwater and sewage water irrigation. This study gave a special focus on mitigating untreated water of sewage.

In food soil stabilization the accumulation of heavy metals is disturbing the metabolic system of humans as well as directly affecting the mortality rate. Ingestion of heavy metals is causing serious health effects. Soil pollution with heavy metals in China is worse (Yang et al. 2018). This study is a comparison of areas of China from industry and agriculture. Cadmium, lead, and arsenic were more serious in Southeast China more severe than in Northwest China. Children are more affected than adults and old people. As a result, toxic heavy metals transfer into the plant tissues; this accumulation of metals in the plant can have adverse effects on plants as well as humans who eat them. This study showed the effect of heavy metals on the growth of maize plants. The heavy metals cadmium and chromium were observed. Cd was the most toxic. Atomic absorption spectroscopy (AAS) was used for the analysis of samples. It was observed that the affected plants had stunted growth. In another experiment, two heavy metals were added and combined to check the activities that resulted in more adverse. The two metals together were also observed to check the impact. It

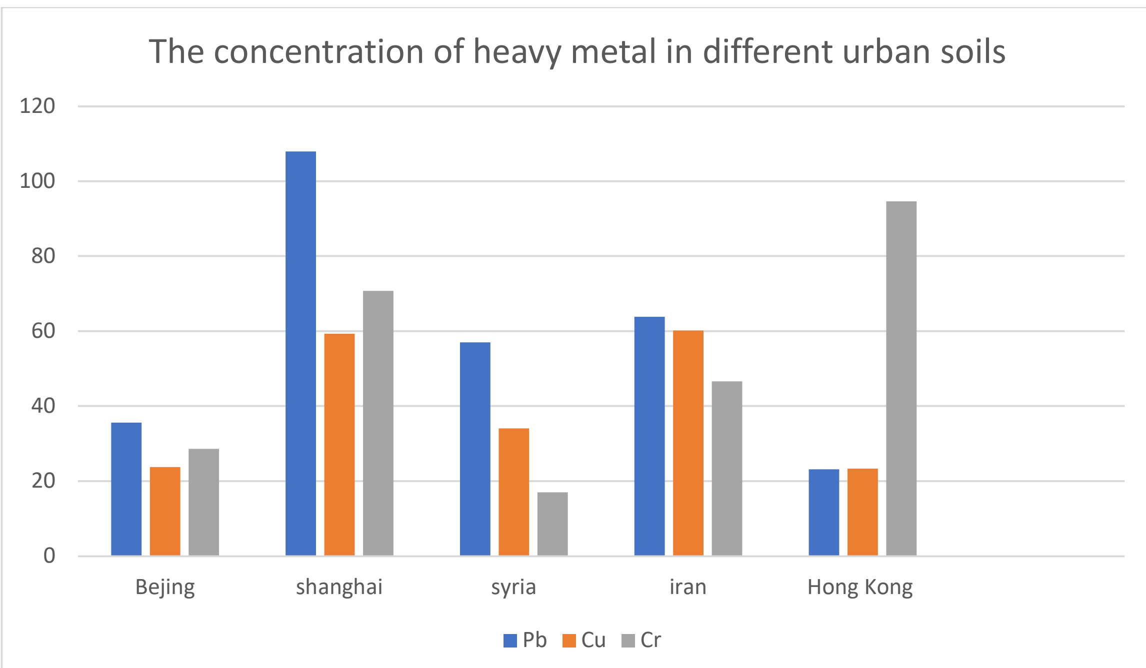

Fig. 2: The concentration of heavy metals in different urban soils.

gave even worse results. The effect observed was that seed protein also decreased.

In another study, the effect of heavy metal accumulation was observed in animal milk. The grazing cattle of river swans consume the vegetation, and the milk produced from that animal is consumed by the population living there (Perveen et al. 2017). Two data sets were analyzed for the heavy metal accumulation from the Swan River. Data A was an upstream area of the Swan River. Data B was downstream of the river swan. Samples of milk were collected from different areas around the Swan River. For the analysis of heavy metal accumulation atomic absorption Spectroscopy was used. After the quantification of data sets it showed that the concentration of heavy metals in the milk is greater in data set B. Zinc metal had the highest concentration, and the lowest was Ni and Pb. In another study (Muhammad et al. 2019), two areas of Baluchistan were selected to check the contamination of heavy metals. This study was conducted to compare Zhou and Lorelei for heavy metal contamination. For checking the contamination Atomic Absorption Spectroscopy was used. The results showed that the concentration of iron was greatest, and Cd was least concentrated in the Zhob area. Fig. 2 shows the concentration of heavy metals in different soils. According to Afzal et al. (2014), the study was conducted to determine the heavy metal accumulation in the soil as well as groundwater. It is reported that the heavy metals iron, nickel, chromium, cadmium, manganese, and zinc were analyzed, and all of them were high, but chromium was the most concentrated, 0.82-2.25 $mg.L^{-1}$

Heavy metal accumulation is not only confined to soil. Its main source is water that irrigates the fields; the water coming to irrigate the fields is mixed with the effluents of industries that contain loads of heavy metals in the water. This polluted water does not only contain heavy metals but also other more dangerous elements but, in this study, we are focused only on the heavy metals and their effects on plants and human health. Most of the areas are irrigating the fields with the sewage water merged with polluted water from industries. The farmers are not aware of this matter and how this will affect the health of people who consume this unhealthy food. Cereals are the most consuming foods like maize and wheat is most cultivated. A study revealed the amount of lead in wheat; this lead was out of the permissible level of metal (Table 1). The water we drink is also not fit to drink; the air we breathe in also contains the particles that are coming from the vehicle exhaust, the heavy metals are also present in the air. Heavy metals are essential for plants and animals in a permissible amount. Guo et al. (2018) were conducted to check the lead, Arsenic, and Mercury in the wheat; in the results, Cadmium was more in the wheat as compared to lead, and the concentration of metals was most in the roots as compared to the stem and leaf.

After that, according to Asif et al. (2020) study conducted at a well-known industrial area, Hattar, it was observed that all the effluents were directly drained into the waters. It was seen that due to the shortage of water for agriculture, this water is used. This untreated water that is drained into the natural waters from the industries contains an excess of heavy metals. A study reported that two million tons of water is disposed of into natural waters per day. It is destroying the marine aquatic system.

Resources of soil pollution are very diverse. The ecosystem is disturbed by the heavy metal accumulation in the soil due to anthropogenic activities. Sewage-irrigated food that contains heavy metals enters the food chain directly or indirectly. Directly, it enters the body through breathing activity and dermal touch; indirect ways are eating contaminated food and drinking contaminated water. Another study for resource checking was conducted in Kasur, Punjab, Pakistan; the common source of the heavy metal was the leather industry of Kasur, Pakistan (Malik et al. 2010). The study was conducted in Islamabad, Pakistan for the determination of heavy metal accumulation in the soil. The samples were analyzed to check the movement of heavy metals from soil, stem, and roots. The grass species showed the highest concentration of Zn.

EFFECTS ON HUMAN HEALTH

The presence of heavy metals in soil is a serious concern for human health as they can potentially enter the human food chain (Kasraei 1996). The rapid growth of industries, cities, and farming has resulted in an increase in heavy metal pollution in soil, sparking worries about how the metals are spread, their levels in different areas, and their impact on human health (Krishna et al. 2004). Research has found that heavy metal contamination in soil not only harms human health but also has negative effects on agriculture (Jing et al. 2007). Using natural materials like olive husk and cow manure has been studied as a way to decrease the availability of heavy metals in polluted soil. Emphasizing the importance of sustainable farming practices, a study by Clemente et al. (2007) highlighted the need for implementing methods that promote environmental health. Other research conducted by Chopra et al. (2009) has delved into strategies for managing heavy metal pollution in agricultural land to prevent harm to human well-being. Findings from various studies have shown that heightened levels of heavy metals in soil, particularly lead and chromium, can potentially endanger the health of individuals living in industrial and residential areas. Concerns have been raised specifically regarding the health of children. In a study by Olawoyin et al. (2012), the risks of heavy metal exposure in such regions were underscored. Furthermore, assessments on heavy metal accumulation in crops grown in soil irrigated with treated wastewater have further magnified the urgency of examining the potential health hazards associated with heavy metal exposure. According to a study by Qureshi et al. (2016), the issue of heavy metal contamination in soil, particularly in northern Telangana, India, is a significant concern. Recent research, like the one conducted by Adimalla et al. (2018), has focused on assessing the distribution, contamination levels, and potential health risks associated with heavy metals in surface soils in this region. Additionally, studies have explored phytoremediation mechanisms as a potential way to remove heavy metals from contaminated soil, underscoring the importance of understanding how heavy metals impact human health. Overall, the literature emphasizes the importance of continuous research and the development of effective management strategies to address the impact of heavy metals in soil on human health.

Reports that heavy metals enter into the human body by directly drinking polluted water or indirectly through the food chain, but HM are a source of oxidative source for cells (Lawal et al. 2021). This study showed human health effects. The consumption of metals above the permissible level is causing lung cancer, cerebral palsy, mental retardation, and even gastrointestinal issues. Some of the metals cause genetic disorders, and the DNA by Adduct Formation was observed in this study. The cattle that stray eat from the dumping sites and consume the polluted things that contain heavy metals, too. Eating the meat of these cattle can add HM to the human metabolism (Su et al. 2014). Heavy metals are reported to be the most polluting soil in terms of heavy metals. Mulching is also a source of pollution.

Disruption of Soil Structure and Nutrient Cycling

The addition of heavy metals is disrupting the nutrient cycle. The enzymes of the system are disturbed by the activity of heavy metals. Cd is a heavy metal that affects metabolism in a way that a person becomes calcium deficient. Cd is announced as the 6th most toxic heavy metal.

If we talk about lead (Pd), it can cause damage to the digestive tract. Nickel is the heavy metal that is most lethal. It can even cause tumors in the human body. Waseem et al. (2014) stated that lead intake is causing the high level of lead in the blood. It is reported that it is a reason for hypertension in the population. Constables of Karachi city are more affected than in Islamabad, as in Islamabad, there is less exhaust from vehicles. The school children of Lahore had effects of Cd, which directly led to the disease of osteotoxic. The metal deposition on soil has direct effects on human health. Metal particles are entering into the human body through the respiratory system through dust particles. It causes breathing disorders as it directly enters the lungs. Heavy metals are entering into the body with dermal contact. It is posing serious allergies and skin irritations.

Analytical Methods for Detection and Monitoring

The removal of heavy metals from the soil is a major environmental issue that requires effective analytical methods. Researchers have proposed various techniques for this purpose. Goltz et al. (1994) discussed using soil vapor extraction (SVE) to eliminate volatile organic compounds from the vadose zone. Buck et al. (1995) recommended physical extraction methods like magnetic separation or aqueous biphasic processes to remove challenging phases such as uranium metaphosphate from soils. Carabias-Martínez et al. (2005) emphasized the use of pressurized liquid extraction (PLE) to extract environmental pollutants from soil samples. In addition, analytical methods like near-infrared reflectance spectroscopy (NIRS) have been studied for predicting different soil properties. In a study by Chang et al. (2001), it was mentioned that soil roughness can affect soil organic carbon assessment when using field spectrometry. Similarly, Denis et al. (2014) also highlighted this impact. Another study by Russell et al. (2016) introduced a fast fluorescence-based technique for screening hydrocarbon contaminants in soil and water samples. These methods are aimed at providing efficient and reliable ways to analyze and eliminate contaminants from soil. Overall, the review of the literature indicates that a combination of analytical methods like SVE, PLE, NIRS, and fluorescence screening can be used effectively to remove heavy metals and other pollutants from soil. More research and innovation in this field are crucial to addressing environmental concerns related to soil pollution.

Getting rid of heavy metals from the soil is a major issue for the environment, and it requires special techniques to do it properly. Qu et al. (2019) looked at how soil minerals, organic matter, and heavy metals interact, underscoring the need to understand how reactions at interfaces can help immobilize them. Chang et al. (2019) introduced a new method called circulation-enhanced electrokinetic (CEEK) using EDTA to remove lead from polluted soil, showing how keeping the pH neutral can help get rid of heavy metals. In a study conducted by Li et al. (2019), investigated a newly discovered bacterium that can both absorb and oxidize Mn (II) to remove heavy metals from the soil. This research points to the promising potential of using microbial-based methods for soil remediation. Another study by Gnanasundar et al. (2020) delved into the use of electrokinetic and phytoremediation to address inorganic contaminants in the soil. They emphasized the effectiveness of processes like electro-osmosis, electro-migration, and electrophoresis in removing these pollutants. Lastly, a study by Wang et al. (2024) introduced an electro-spun nanofiber membrane treated with amines as a barrier material for remediating Cr (VI) contaminated soil. Their findings showcased the membrane's impressive adsorption capabilities and ability to be reused. In a recent study, Yang et al. (2022) introduced a new method for removing Cd and Cu from agricultural soil using a combination of organic acid solubilization and eluent drainage. This technique is both eco-friendly and effective for soil remediation. Additionally, Bhat et al. (2022) highlighted the potential of phytoremediation in removing heavy metals from soil. They specifically focused on using hyper-accumulator plant species that can tolerate high concentrations of heavy metal contaminants. Inobeme et al. (2023) talked about new developments in tools for measuring heavy metals, emphasizing the need for different methods to get precise results. The research indicates that a mix of advanced analytical tools, like microbial methods, electrokinetics, phytoremediation, and new materials, is crucial for effectively getting rid of heavy metals from soil.

Remediating techniques are also used like ion exchange, ultrafiltration, some membrane processes, and photocatalysis (Abarca 2020). These techniques were introduced, but nowadays, these are used by merging, giving better results. Soil restoration is most focused on researchers nowadays. Different techniques are used to remove heavy metals. It is believed that heavy metals can never be eradicated, but they can be reduced to some extent by using different techniques. Advanced techniques are applied nowadays. For example, soil stabilizers are used to fix the soil. Different kinds of siderophore metal complexes are used to remove metals from soil. This is an advanced technique combined with chelating agents (Hadia-e-Fatima 2018). Several strategies have been used for the remediation of heavy metals from soil. Path evaluation has been used to assess the adsorption of Cd, Cu, Ni, Pb, and Zn with the aid of using soil primarily based totally on elements which include soil pH, CEC, natural carbon content, and clay content. Electrodialytic remediation combines electrodialysis with the electromigration of ions in polluted soil to take away heavy metals (Hu et al. 2018). Phytoextraction, the usage of vegetation like *Brassica napus* and *Raphanus sativus*, has proven capacity for extracting heavy metals from infected soil (Mortvedt 1995). In situ, immobilization of metals has been highlighted as a promising answer for soil remediation that specializes in manipulating the bioavailability of heavy

Country	Cd	Hg	Pb
Austria	-15%	-36%	-51%
Belgium	-52%	-59%	-81%
Bulgaria	-75%	-59%	-65%
Croatia	-35%	-39%	-61%
Cyprus	-62%	-70%	-20%
Czechia	-27%	-38%	-62%
Denmark	-3%	-66%	-29%
Estonia	-11%	19%	-47%
Finland	-41%	-41%	-40%
France	-57%	-65%	-48%
Germany	11%	-52%	-33%
Greece	-83%	-69%	-84%
Hungary	1%	-42%	3%
Ireland	-30%	-31%	-32%
Italy	-49%	-50%	-36%
Latvia	-48%	9%	-98%
Lithuania	-1%	-10%	10%
Luxembourg	-33%	-62%	-36%
Malta	-92%	-81%	-16%
Netherlands	-77%	-54%	-84%
Poland	13%	-17%	0%
Portugal	-27%	-30%	-25%
Romania	-15%	-51%	-36%

Decrease as the comparison in 2005.

Increase as a comparison in 2005!

Fig. 3: Reduction percentage of heavy metals in comparison of 2021 with 2005.

metals through the usage of soil amendments (Derakhshan Nejad et al. 2018). Phytoremediation, which entails the usage of vegetation to ease up heavy metallic infected soil, has been identified as an environmentally sustainable technique

(Ashraf et al. 2019). Different remediation strategies, which include in situ immobilization, phytoremediation, and organic strategies, have been reviewed for eliminating heavy metals from soil (Dhaliwal et al. 2019). The multidisciplinary technique of phytoremediation entails soil chemistry, plant physiology, and plant-microbiology interactions to ease up heavy metallic infected soil (Shah et al. 2020). Fig.3 shows the reduction of heavy metals in 2021 as compared to 2005. Overall, that research displays diverse, powerful techniques for remediating heavy metals from soil.

CONCLUSIONS

The heavy metals present in the soil are causing serious health effects on humans directly or indirectly. These heavy metals present in soil enter the plant and then persist, entering the food chain. Every metal has different effects. Different studies showed that due to urbanization, industrialization, the addition of fertilizers, and new agricultural practices, environmental effects are the cause of the addition of heavy metals in the soil day by day. Different analytical techniques like SVE, PLE, and NIRS, are being used to determine the heavy metals. However, there is a dire need to focus on maintaining the soil chemistry for the safe production of crops and vegetables. We need to raise awareness among farmers for safe agricultural practices, and public awareness is also necessary for proper waste disposal.

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