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ASSESSMENT OF SOIL CONTAMINATION DUE TO HEAVY METALS: A CASE STUDY OF OKHLA INDUSTRIAL AREA, NEW DELHI

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Introduction:

The accumulation of heavy metals in soils is associated with both biological and geochemical cycles. Anthropogenic activities, including transportation, waste disposal, large-scale manufacturing, and social and agricultural practises, have a detrimental impact on the environment and the global ecosystem. These functions have detrimental impacts on human health and the well-being of all living species. The contamination of the environment with harmful metals has experienced a dramatic surge since the commencement of the industrial revolution. Although heavy metals are naturally present in soil, the majority of heavy metal contamination comes from nearby sources like road traffic, waste incineration, combustion of fossil fuels, and industry (especially nonferrous industries, power plants, iron and steel industries, and chemical industries). Agriculture also uses contaminated water for irrigation, sewage sludge, and fertilizer, especially phosphates and contaminated manure, as well as pesticides containing heavy metals. Metals can be found in the natural environment due to the long-distance transportation of atmospheric contaminants. Heavy metals are often present in soil and vegetation in small amounts, known as trace levels. Living organisms require these metals as micro-elements. Nevertheless, elevated concentrations of these heavy metals exert a deleterious impact on organisms due to their poisonous nature.

Impact of Heavy Metal: The presence of heavy metals in soil has a negative impact on the entire ecosystem when these poisonous substances move into groundwater or are absorbed by plants and animals. This can pose a significant hazard to ecosystems owing to the movement and buildup of these metals. Groundwater is a valuable resource for developmental activities (Alam & Singh, 2023), Anthropogenic activities contributed to the growth of Heavy metal pollution of groundwater in many geologic terrains (Alam & Singh, 2022). Contaminated soils used for agricultural production might provide a possible toxicity risk to crop plants, animals, and human beings due to the presence of heavy metals. The extensive agricultural and other human activities have led to the contamination of the biosphere with heavy metals, which presents significant challenges for the safe use of agricultural land (Wong et al., 2002).

Consuming vegetables is a significant route via which heavy metals can cause poisoning in humans. Vegetables cultivated in soils polluted with heavy metals exhibit increased levels of heavy metal accumulation. The degree of accumulation varies according on the kind of vegetable; some are more likely than others to accumulate larger quantities of heavy metals. Heavy metals found in contaminated veggies have the potential to cause a number of chronic ailments when consumed. According to OdohRapheal Kolawole Sunday Adebayo (2011), heavy metals in vegetable crops originate from growth media such soil, air, and nutrient solutions, which are then absorbed by the roots or leaves.

The presence of heavy metals in plants hampers their development, enzymatic activity, biological functions, photosynthesis, and the accumulation of other essential nutrients. Additionally, it causes harm to the root system. The impact of heavy metal pollution on soil might be substantial. Their effect on microbial activity is one of the primary effects (Wyszkowska, 2002). Other harmful consequences of heavy metals include negative effects on soil porosity, water retention capacity, cation exchange capacity (CEC), mineral composition, and seed germination. These effects are most severe when heavy metals are discharged by industrial waste. Heavy metal concentrations in soil that are higher than usual are detrimental to all living things (Ayolagha and Nleremchi, 2000)

Heavy metals (mg kg^{-1})	Standards	
	Indian standards (Awasthi, 1998)	European union standards (EU, 2002)
Cr	–	150
Mn	–	–
Cu	135–270	140
Zn	300–600	300
Ni	75–150	75
Cd	3–6	3
Pb	250–500	300

Permissible limit Heavy Metals Standards in Agricultural Soil

The soil's cation exchange capacity (CEC) plays a crucial role in influencing both the concentration and availability of heavy metals in the soil. Since the Cation Exchange Capacity (CEC) is influenced by the amount and type of organic matter and clay, it may be concluded that the concentration of heavy metals in soils is affected by the organic matter content and clay content.

Threshold values (mg/kg dry weight)		
	Metal in plant	Metal in soil
Lead (Pb)	50	100-400
Zinc (Zn)	100-400	20-300
Nickel (Ni)	1-5	1-100
Copper (Cu)	20	50-100
Cadmium (Cd)	0.01-1	1-3
Manganese (Mn)	60	60
Chromium (Cr)	0.5-2	150
Arsenic (As)	3-10	40
Iron (Fe)	500-1500	1000

Doorstep toxic of Heavy Metals in Plant and Soil ,
Source: Tahar K. et al (2011)

Literature Review:

Aydinalp (2003) assessed the concentrations of heavy metals in the soils of the Bursa plain to estimate the extent of contamination. The study further determined the different types of heavy metals found in soils by employing a fractionation approach that relies on successive extraction.

Krishna and Govil (2007) has out research on heavy metal-induced soil contamination in a Surat, Gujarat, Western India industrial area. In Surat, Gujarat, India, soil pollution was the subject of the study. High concentrations of metallic elements including barium (Ba), copper (Cu), chromium (Cr), cobalt (Co), nickel (Ni), strontium (Sr), vanadium (V), and zinc (Zn) were evaluated by the researchers for their magnitude and dispersion.

The study conducted by Dasaram et al. (2010) examined the soil pollution, determine the spatial distribution and evaluate the extent of contamination using various indicators such as the index of geo-accumulation, enrichment factor, contamination factor, and degree of contamination.

Chen et al. (2015) investigated the geographical distribution of heavy metals in soil samples in a city in northeast China that lacks resources, and evaluated the associated risk. The study revealed that the levels of urban heavy metals, including Cd, Cr, Cu, Ni, Pb, and Zn, in soil samples taken at depths of 0-20 cm were measured at 6.17 mg/kg for As, 0.19 mg/kg for Cd, 51.08 mg/kg for Cr, 23.27 mg/kg for Cu, 31.15 mg/kg for Ni, 22.17 mg/kg for Pb, and 54.21 mg/kg for Zn. Human activities such as mining, industrial production, and agriculture have led to a rise in the concentration of heavy metals.

This information is based on metal distribution maps that were constructed using the inverse distance weighted interpolation procedure. The objective of these activities was to bring about changes in life and promote sustainable development.

The study done by Islam et al. (2015) investigated the levels of seven prevalent heavy metals in several vegetable species consumed in Bangladesh, as well as the potential harm they pose to human health. The investigation revealed that the levels of Ni, Cu, As, Cd, and Pb in the soil at certain locations above the acceptable soil quality threshold, indicating a significant environmental hazard.

Zhaoyong., et al. (2019) performed a health risk assessment of 10 heavy metals present in the urban dust in Chinese cities. Their findings revealed that among the three pathways of exposure, the most prevalent route of exposure was by hand-to-mouth consumption, as indicated by the highest Hazard Quotient (HQ).

According to Chakraborty et al. (2021), mining, industry, urbanization, and agricultural practices are only a few examples of the economic activities and development projects that release dangerous heavy metals into the soil, endangering both human health and the ecology.

Soil scientists conducted thorough investigations on the geographical distribution, pollution levels, and sources of heavy metal contamination in soil. Wang et al. discovered substantial soil contamination at the Dexing Copper Mine in Jiangxi, China, where the soil had an average copper (Cu) concentration that was 10 times greater than the typical values. The heightened concentration of copper was principally caused by the discharge of wastewater, deposition of dust, and accumulation of tailing piles from nearby copper mines, facilitated by sedimentation, rainfall, and water runoff. In a similar vein, Wen and his colleagues documented increased levels of lead (Pb) and cadmium (Cd) contamination in the top layer of soil in close proximity to the Jinding Pb-Zn mine in China. They attributed this pollution to the activities of surface mining and zinc smelting operations.

OBJECTIVES:

1. To analyze the Physical properties of soil in Industrial area of Delhi-NCR zone.
2. 2. The objective is to assess the occurrence of hazardous heavy metals (copper, zinc, lead, cadmium, mercury, chromium, and magnesium) in the soil of the industrial area.
3. To find out the Preventive measures for Soil Contamination.

Methodology: In this research, data were collected on the concentrations of heavy metals in five different zones. Heavy metals are highly toxic and can have damaging effects on the environment and human health. This study is aimed to identify the levels of heavy metal pollution in these areas in order to mitigate the risks associated with exposure.

Study Area:

The Study Area covers Industrial area in South Delhi. Delhi is located at $28^0$37'N, $77^0$14'E/28.61^0N', 77.23^0E and lies in North India. It borders the Indian states of Haryana on the north, west and south. The National Capital Territory of Delhi covers an area of 1484km^2 of which 483km^2 is designated rural, and 700km^2 urban. It has a length of 51.9km and a width of 48.48km. As we can see there are so many different industrial areas in Delhi and NCR but we have chosen the industrial area in South Delhi i.e Okhla (Phase I, II, III) because it is not possible to study each and every industrial area as the entire area of Delhi is much larger.

- In this research, data were collected on the concentrations of heavy metals in five different zones.
- Zone no 1 was near Modi Mill, Okhla Phase-I
- Zone no 2 was B.Block, Okhla Phase-II
- Zone no 3 was Near Electricity house, Okhla phase-III
- Zone no 4 was In front of Luxor mark Excel, Okhla Head
- Zone no 5 was Sangam Vihar , Okhla Outer area

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Study area: Okhla Industrial Area (Phase I, Phase II, Phase III, Okhla Head, Okhla Outer area)

Sampling and Analysis:

Using a plastic scooping trowel, top soil from the surrounding region was combined with dirt from the industrial area to create a polythene bag containing 0 to 5 feet of soil sample depth. The sample was collected using an Auger, and GPS was utilized to record the sample's position.

Experimental Procedure:

- Weigh 0.5 g or suitable quantity of oven dried (105^{0}C) sample thoroughly ground and sieved through 0.2 mm sieve in a conical flask or Beaker.
- Add distilled water and acid mixture.
- Digest the sample at 200 ^{0}C on a hot plate till the volume is significantly reduced with a whitish residue.
- Filter the suspension through a Whatman No. Filter Paper 42. makeup to 100 ml in a volumetric flask and
- Measure concentration directly in the filtrate by an ICP-OES.

Analysis:

Concentration in ppm = $\frac{\text{(ppm in extract- Blank X A)}}{\text{Wt}}$

A = Total Volume of the Sample

Wt = Weight of air-dry Soil

The sample were analyzed and result was calculated.

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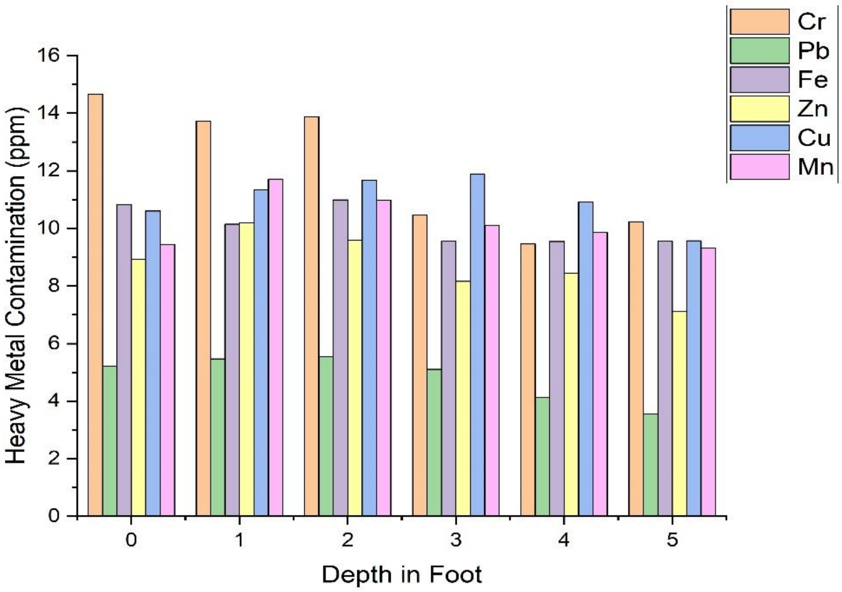
Result and Discussion:

An investigation of the entry of heavy metals into different soil profiles is crucial due to the significant impact these metals have on soil, water, and agricultural systems. Prolonged use of industrial wastewater and sewage wastewater for irrigation can lead to the accumulation of hazardous amounts of heavy metals in soils, hence impeding plant development and elevating metal concentrations in plants. When animals ingest such plants, they can become part of the food chain and could cause harm to both animals and humans. The current investigation was conducted to analyse the soils from different locations in order to identify the presence of heavy metal contaminants. An investigation was conducted to study the vertical mobility of Manganese (Mn), Chromium (Cr), Lead (Pb), Zinc (Zn), Iron (Fe), and Copper (Cu) in soil. The study focused solely on the vertical distribution of heavy metals in soil profiles at five distinct locations. It established several connections between the available and total amounts of heavy metals (namely Mn, Cr, Pb, Zn, Fe, and Cu) in the surface layer of these soils. The obtained data indicated diverse concentrations of heavy metals in the five zones. Zone 1 (Okhla Phase I) had the most elevated levels of heavy metals, above the permissible thresholds for lead, cadmium, and manganese concentrations. Zone 2 had marginally reduced concentrations of heavy metals, namely lead and manganese, which nonetheless beyond the suggested thresholds. Conversely, Zone 3 (Okhla Phase III) demonstrated comparatively lower levels of heavy metals. The heavy metal concentrations were lowest in Zone 4 (Okhla Head). The concentration of heavy metals in Zone 5 (Okhla outer region) was the lowest.

Table no.1: Shows Heavy Metal Contamination in Zone 1 (Okhla Phase I)

Depth in Foot	**Zone 1 Okhla industrial Area(Phase-I)**					
	Cr	Pb	Fe	Zn	Cu	Mn
0	14.656	5.211	10.814	8.914	10.605	9.434
1	13.718	5.467	10.145	10.193	11.345	11.717
2	13.879	5.543	10.994	9.586	11.68	10.981
3	10.466	5.107	9.549	8.159	11.894	10.111
4	9.456	4.121	9.545	8.431	10.918	9.848
5	10.234	3.546	9.565	7.106	9.575	9.311



Column plot shows Heavy Metal Contamination in Zone 1 (Okhla Phase I)

The heavy metal contamination in Zone No. 1 of Okhla Area, as shown in Table No. 1, is as follows: Cr (15.56 mg/kg), Pb (5.76 mg/kg), Fe (11.31 mg/kg), Zn (9.93 mg/kg), Cu (11.98 mg/kg), and Mn (11.17 mg/kg). These values are elevated in the same bore hole but at different depths within the area.

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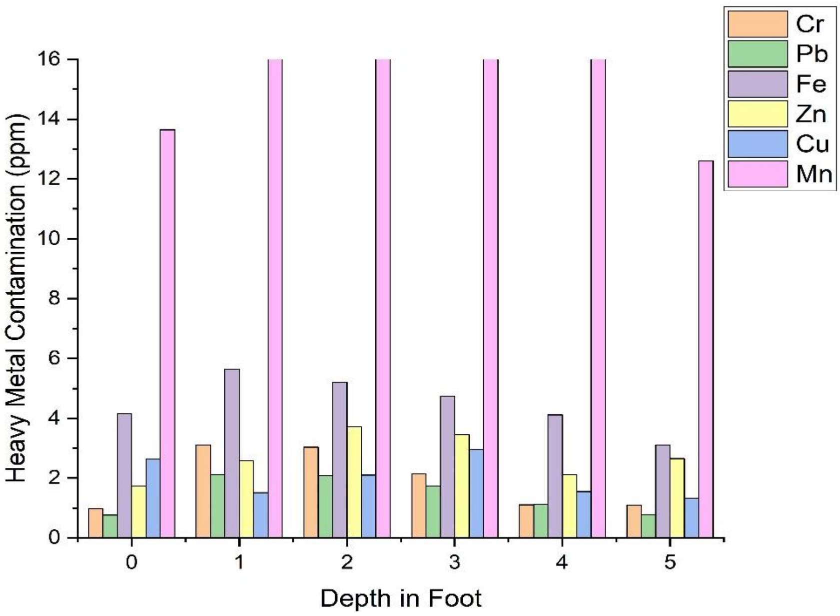
Table no. 2 Heavy Metal contamination in Zone 2 (Okhla Phase-II)

Depth in Foot	Zone no-2 Okhla Industrial Area(Phase-II)					
	Cr	Pb	Fe	Zn	Cu	Mn
0	0.978	0.757	4.145	1.725	2.647	13.637
1	3.109	2.103	5.647	2.569	1.514	17.311
2	3.031	2.096	5.202	3.721	2.101	18.909
3	2.139	1.736	4.736	3.445	2.966	17.107
4	1.107	1.113	4.111	2.123	1.546	17.634
5	1.103	0.783	3.109	2.653	1.332	12.609



Column plot shows Heavy Metal Contamination in Zone 2 (Okhla Phase II)

Similarly, in Zone No. 2 of the Okhla Industrial area, the following values were found to be higher during the analysis of samples in table no.2: Cr 3.00 mg/kg, Pb 2.16 mg/kg, Fe 5.46 mg/kg, Zn 3.70 mg/kg, Cu 2.96 mg/kg, Mn 18.88 mg/kg. These values were observed to be higher in the same bore hole but at different depths.

Table No.3 Heavy Metal contamination in Zone 3 (Okhla Phase-III)

Depth in Foot	Zone 3 Okhla Industrial Area (Phase-III)					
	Cr	Pb	Fe	Zn	Cu	Mn
0	0.413	1.215	4.744	4.332	2.416	13.315
1	1.213	1.567	5.214	4.176	3.221	13.211

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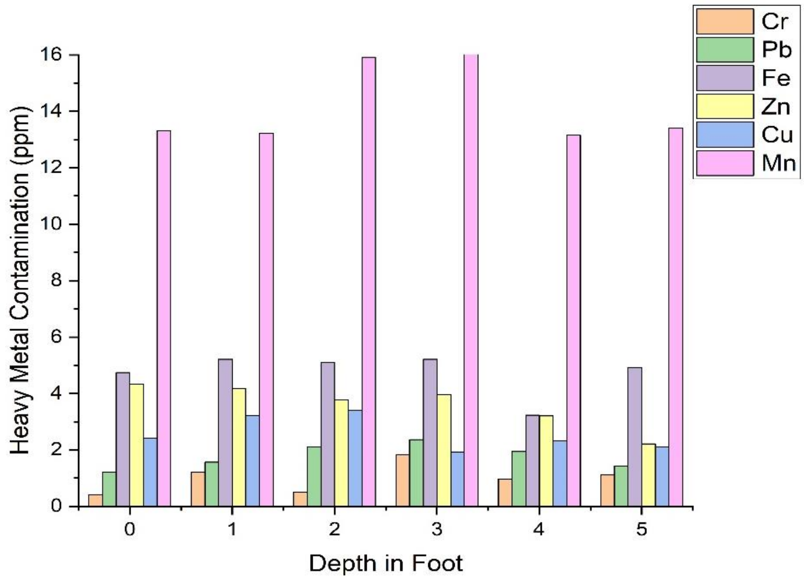
2	0.511	2.115	5.104	3.784	3.405	15.914
3	1.837	2.367	5.213	3.949	1.929	16.309
4	0.973	1.938	3.234	3.204	2.312	13.148
5	1.109	1.434	4.918	2.211	2.105	13.407



Column plot shows Heavy Metal Contamination in Zone 3 (Okhla Phase III)

The table displays the levels of heavy metal pollution at Zone No. 3. Specifically, in Table No. 3, the corresponding values for Cr, Pb, Fe, Zn, Cu, and Mn were found to be 1.87 mg/kg, 2.06 mg/kg, 5.14 mg/kg, 4.32 mg/kg, 3.11 mg/kg, and 15.9 mg/kg. These values were seen to be greater in the same bore hole but at different depths.

Table no.4 Heavy Metals Contamination in Zone 4 (Okhla Head)

Depth in Foot	Zone no 4 Okhla Industrial Area (Okhla Head)					
	Cr	Pb	Fe	Zn	Cu	Mn
0	14.078	3.029	5.101	5.115	10.641	16.702
1	13.145	4.006	4.893	7.45	11.486	16.171
2	13.014	2.891	4.706	6.561	10.401	18.081
3	12.005	2.917	3.055	8.009	10.006	11.183
4	12.781	2.002	1.181	6.593	9.019	11.019
5	12.712	1.806	1.004	7.672	9.518	9.197

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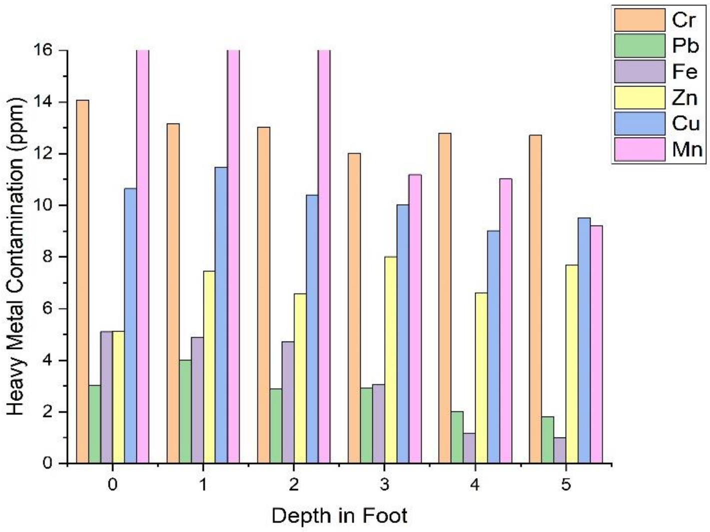
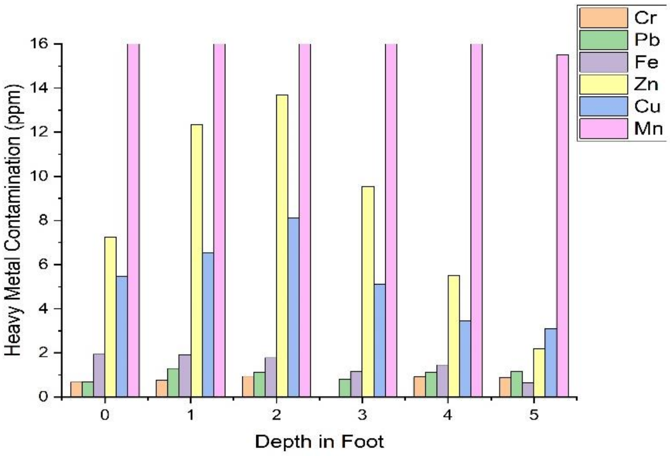


Column plot shows Heavy Metal Contamination in Zone 4 (Okhla head)

The heavy metal contamination levels in Zone No. 4 of Okhla Industrial Area (Okhla Head) are as follows: Chromium (Cr) was found to be 14.07 mg/kg, Lead (Pb) was found to be 4.00 mg/kg, Iron (Fe) was found to be 5.10 mg/kg, Zinc (Zn) was found to be 8.00 mg/kg, Copper (Cu) was found to be 11.48 mg/kg, and Manganese (Mn) was found to be 18.08 mg/kg. These values were observed to be higher in the same bore hole but at different depths.

Table no. 5 Heavy Metals Contamination in Zone 5 (Okhla Outer area)

Depth in Foot	**Zone no.5 Okhla Industrial Area (Okhla Outer area)**					
	Cr	Pb	Fe	Zn	Cu	Mn
0	0.665	0.684	1.931	7.245	5.456	27.654
1	0.764	1.293	1.912	12.345	6.549	29.145
2	0.942	1.108	1.778	13.677	8.109	25.167
3	0.011	0.814	1.165	9.546	5.116	25.119
4	0.906	1.108	1.453	5.515	3.443	21.757
5	0.896	1.167	0.657	2.193	3.104	15.516



Column plot shows Heavy Metal Contamination in Zone 5 (Okhla Outer area)

Similarly, in Zone No. 5 Okhla Industrial area, the results obtained from the examination of samples in table no. 5 were as follows: Cr 0.93 mg/kg, Pb 1.32 mg/kg, Fe 1.91 mg/kg, Zn 13.76 mg/kg, Cu 8.00 mg/kg, Mn 29.05 mg/kg. These levels were found to be greater in the same bore hole.

As we can see that our result shows that in different parts of south delhi from where the samples were taken is moderately or highly contaminated soil due to various reasons, but most of the times we can say that now industrialization and moving towards modernizations are the main cause of exposure to heavy metals in the environment. Now it is very important to take some remediation or measures to control that exposure.

Remediation of Heavy Metals in Contaminated Soils: The presence of heavy metal in soil has a high tendency to concentrate in plants and thereafter be transferred via the food chain, posing a significant risk to human health (Mohamed and Ahamadou, 2010). The primary goal of any soil remediation strategy is to provide a conclusive resolution that ensures the safeguarding of both human health and the environment (Khan et al., 2008). Remediation is often governed by various regulatory mandates and can also be guided by evaluations of hazards to human health and the environment in cases where there are no legally mandated standards or when the standards are just advisory (Martin and Ruby, 2004). The physical and chemical characteristics of heavy metal contaminants in soil play a crucial role in determining the most suitable technique for remediation of soils polluted with heavy metals.

To determine the nature, quantity, and dispersion of heavy metals in the soil, it is necessary to conduct a thorough analysis of the soil pollution. After the site has been analysed, it is necessary to establish the target concentration of each metal in the soil (Chen et al., 1999).

These strategies are frequently employed in conjunction with one another to provide a more cost-effective and efficient cleanup of a polluted site.

(i). Physical Remediation: The primary methods of physical remediation are soil renewal and thermal desorption. The former method involves the use of uncontaminated soil to replace the contaminated soil, either completely or partially. The objective is to reduce the concentration of pollutants and enhance the soil's ability to recover its environmental condition (Qian and Liu, 2000).

Soil Excavation: The technique includes replacing the polluted soil with fresh dirt. This approach is appropriate for the remediation of minor pollution. The excavation and physical extraction of soil is often regarded as the most ancient way of remediating polluted soil. It continues to be utilised on several sites, including residential areas that have been polluted with high levels of heavy metals.

Soil spading: The technique entails excavating the contaminated soil to a significant depth, hence facilitating the dispersion of pollutants into deeper areas for the purpose of dilution and natural deterioration (Zhang et al., 2014).

New soil Importing: The process is introducing a substantial quantity of uncontaminated soil into the polluted soil, either by layering it on the surface or by thoroughly blending it, in order to diminish the concentration of pollutants. Soil replacement may efficiently separate the soil and ecosystem, hence reducing the impact of contaminants on the environment. This invention is expensive and only appropriate for soil in a confined region (Zhou et al., 2004).

Soil Isolation: Soil isolation refers to the process of separating soil polluted with heavy metals from soil that is not contaminated. However, in order to fully remediate the soil, further engineering measures are still required.

(ii). Thermal Desorption: The procedure entails the use of steam, microwaves, and infrared radiation to heat the polluted soil, causing the pollutants, such as mercury (Hg) and arsenic (As), to evaporate (Li et al., 2010).

Vitrification Remediation: Applying high temperature to the polluted site can reduce the mobility of heavy metals in the soil, resulting in the creation of a transparent substance (Mallampati et al., 2015).

Electrokinetic Remediation: Soil electrokinetic remediation is a modern and economical physical technique used to remediate heavy metals. The process of soil electrokinetic remediation relies on the establishment of an electric field gradient of appropriate intensity on both sides of the electrolytic tank

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that holds the saturated contaminated soil. The process of electrophoresis, electric seepage, or electro migration is employed to separate heavy metals found in the soil, resulting in a reduction of pollution (Yao et al., 2012).

(iii). Chemical Remediation: Chemical remediation is the process of using chemicals to remove or stabilise contaminants present in soil that is polluted. Various chemical remediation procedures exist, such as chemical leaching (also known as soil washing), immobilisation techniques, and stabilisation methods (Tampouris et al., 2001).

Soil Washing: The process of soil leaching involves the use of particular reagents to cleanse heavy metal polluted soil by eliminating the heavy metal complex and soluble irons that are absorbed onto the solid phase particles. Through the use of this technique, the soil is effectively purified by isolating the heavy metals, which are then reclaimed from the extraction solution.

Immobilization Techniques: Chemical fixation involves the introduction of reagents or materials into polluted soil to create substances that are insoluble or have limited mobility and low toxicity. This process effectively reduces the movement of heavy metals into water, plants, and other environmental areas (Zhou et al., 2004).

Solidification/Stabilizing: Heavy metals can be immobilised and remediated to mitigate their potential negative impact on human health and the environment. This procedure is occasionally referred to as stabilisation.

(iv). Biological Remediation: Bioremediation is a technology that harnesses the power of micro-organisms to naturally break down contaminants. This can be done by either utilising the micro-organisms' inherent ability to degrade substances (intrinsic bioremediation), or by boosting their capacity through the introduction of additional microbes, nutrients, electron donors, and/or electron acceptors (enhanced bioremediation) (EPA, 2001).

Phyto-remediation: Phytoremediation is the utilisation of plants and their associated microbes to remediate specific pollutants found in soil, sludge, sediments, wastewater, and groundwater, either partially or fully. It has the capability to eliminate radionuclides, organic contaminants, and heavy metals (Ali et al., 2013).

Phyto-extraction: Phyto-remediation begins with phyto-extraction, which involves the absorption of pollutants from soil or water by plant roots and their subsequent movement and storage in the plant's biomass, namely the shoots (Sekara et al., 2005).

Phyto-stabilization: The procedure entails diminishing the movement and accessibility of metals in the environment, hence impeding their movement into groundwater or the food chain (Erakhrumen, 2007). Plants are employed to mitigate wind and water erosion, which disperses substances containing high levels of heavy metals.

Phytofiltration: The subsequent significant step in phytoremediation is phytofiltration, which encompasses rhizofiltration (utilisation of plant roots), blastofiltration (utilisation of seedlings), or caulofiltration (utilisation of excised plant shoots) (Migula, et al., 2004). Metals are absorbed or adsorbed in this process, thereby reducing their mobility in subsurface water (EPA, 2001). Plant roots directly extract heavy metals from water. The plants are cultivated hydroponically, either in water or in water-saturated materials like sand, utilising aquatic species or hydroponic techniques.

Conclusion: Soils can be polluted by the buildup of heavy metals and metalloids due to emissions from various sources. Scientific evidence has demonstrated that heavy metals are detrimental to both human and environmental well-being.

It is evident from the outcome that various areas of Okhla are contaminated with heavy metals to varying degrees. Consequently, it is crucial to consider the presence of harmful heavy metals in contaminated soils while choosing suitable remedial measures.

Soil remediation is essential for reducing the dangers associated with heavy metal contamination, making the land suitable for agriculture, improving food security, and addressing land tenure issues.

Governments should actively encourage the synchronisation of data collecting, research, law, and regulations. They should also take into account the utilisation of indicators and give valuable data that aids in establishing standards and guideline values. These measures are intended to safeguard human and environmental health against the harmful effects of heavy metal pollutants. Accurate assessment of exposure is crucial for safeguarding vulnerable populations and those at high risk. In addition, governments should educate individuals and raise their awareness on the detrimental effects of heavy metals on both human health and the environment.

In summary, this study emphasises the importance of ongoing surveillance of heavy metal contamination in places affected by pollutants to avert additional damage to both human well-being and the ecosystem. We propose the implementation of strategies to mitigate heavy metal contamination, including the enforcement of more stringent laws on the disposal of industrial waste and the enhancement of public education regarding the hazards associated with heavy metal exposure.

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