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A Study of Contaminated Soil in Urban Area of Aligarh and Reduction of Heavy Metals Using Phytoremediation Method

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ABSTRACT

Contamination of soil in the urban areas has been a major environmental problem among the fast industrializing cities in India. In the Aligarh urban area which has a high density of industrial activities, metal-based workshops, automotive emissions and unchecked disposal of wastes, heavy metals including lead (Pb), cadmium (Cd), chromium (Cr), nickel (Ni), and zinc (Zn) have been found to be accumulated significantly. Such pollutants are very dangerous to human health, the stability of the ecology and the productiveness of the soil as they are not biodegradable and are persistent. This paper examines the levels of the metal-pollution of 110 soil samples representing different industrial, road, waste-dump, and residential areas in Aligarh, and quantifies these metals using Atomic Absorption Spectrophotometry (AAS). The study also assesses the efficacy of phytoremediation by growing 3 species of hyperaccumulator plants Brassica juncea, Helianthus annuus, and Vetiveria zizanioides in 60 days in polluted soil. The findings suggest that the majority of samples are of moderate to high contamination with chromium, lead, and nickel indicating a high level of contamination. The phytoremediation experiments showed that the levels of metals were reduced significantly, which proved the ability of the plant-based remediation as an efficient, cost-effective and sustainable approach to restore the soil. The researchers recommend the use of phytoremediation as a long-term remedy in alleviating heavy-metal pollution in urban settings and should be incorporated in the city ecology planning in Aligarh.

Introduction

The growth of urbanization, industrial growth and random dumping of waste materials have also played a major role in the pollution of the soil in the Indian cities. The case of extreme metal concentration in surface soil can be best illustrated in Aligarh, the city with lock industries, electroplating units, small scale metal workshop, vehicular density, and waste dumping sites. The lead (Pb), cadmium (Cd), chromium (Cr), nickel (Ni), and zinc (Zn) are heavy metals that remain in the environment, cannot be biodegraded and lead to health risks to human beings, quality of ground water and balance of the ecosystem. Conventional methods of remediation- like soil washing, excavation or chemical regimens are expensive, disruptive and usually environmentally degrading. Phytoremediation has been proposed as an effective, environment-friendly, and inexpensive alternative. It also involves green plants in extracting, stabilizing or degrading contaminants. Brassica juncea, Helianthus annuus, Vetiveria zizanioides and Phragmites australis have been shown to be excellent in absorbing heavy metals in contaminated soils as hyperaccumulator species.

The study discusses the level of soil pollution in selected urban areas in Aligarh and compares the potential of phytoremediation process in reducing the level of heavy-metals. The article seeks to add scientific knowledge to enhance sustainable soil restoration and city environmental planning.

Review of Literature

Ghasera, Rashid, and Gupta (2021) studied the prevalence and the spatial patterns of heavy metal in the soil, groundwater, and vegetables in various regions of Aligarh, Uttar Pradesh. Their work showed that urban and peri-urban areas of Aligarh were marked with the high levels of toxic metals, which could be explained mostly by industrial effluent, sewage and uncontrolled dumping of wastes. The authors also determined that heavy metals had found its way into the local food chain using contaminated irrigation water and soils and this was a major threat to the health of the residents. Their results revealed the necessity to adopt the effective remediation strategies within the environmental management system in Aligarh. Chauhan and Mathur (2020) examined the phytoremediation capacity of *Helianathus annuus L.* (sunflower) and established that it had a high capacity to accumulate and remedy heavy metals in industrially polluted soils. They found in their experiments that sunflower plants could absorb large proportions of lead, cadmium and nickel by the root and shoot systems. The experiment proved that the plant could be an effective hyperaccumulator species and justified the more generalizability of phytoremediation in an industrially contaminated habitat. Badar *et al*. (2024) carried out a GIS-based measure of vulnerability of groundwater to heavy-metal pollution in the urban centres of Aligarh. Their study was based on pollution indices and spatial mapping devices and revealed areas that were at risk of contamination as well as showed a close correlation between industrial clusters, waste disposal activities and the worsening of groundwater quality. Their results highlighted that the heavy-metal pollution did not exist in the surface soil but appeared in the subsurface water system as well and, thus, worsened the environmental and public-health issues in the city. Kanwar *et al*. (2020) provided an all-inclusive overview of the phytoremediation technologies as applied in the process of eliminating toxic metals in the soil and water. The mechanisms of phytoextraction, phytostabilization, rhizofiltration, phytovolatilization were described by the authors and the ability of the different hyperaccumulator plants to reduce contaminants was evaluated. Their review indicated the benefits of phytoremediation which include cost effectiveness, environmental friendliness and the ability to be used in large scale but also revealed some of its drawbacks which include low remediation rate and limited to specific plant species. The research offered great scientific evidence in the choice of phytoremediation as a sustainable remedial alternative to deal with heavy-metal pollution.

Methodology

The research used in the present study gives a scientific approach to investigate the level of heavy-metal pollution in the urban soils of Aligarh and analyze the efficacy of phytoremediation as a sustainable treatment technology. This chapter defines the research design, sampling methodology, the methods of collecting and processing the soil, the laboratory techniques used in the analysis of heavy-metal, experimental design of the phytoremediation. Descriptive analysis and controlled experimental trials make sure that the full evaluation of the contamination level and the possibility of choosing plant species to cleanse toxic metals is carried out adequately. The approach to the methodology was to ensure that scientific accuracy, reliability and consistency are upheld during the research process.

Research Design

The research design employed in this case is a combination of descriptive and experimental research design to estimate the situation of heavy-metal contamination in the urban soils of Aligarh and to determine the effectiveness of phytoremediation. The descriptive section records the amount and concentration of metals, including Pb, Cd, Cr, Ni, and Zn, in industrial, roadside, waste-dump, and residential zones with the help of laboratory analysis of gathered soil samples. The experimental part will be investigating the remediation capacity of Brassica juncea, Helianthus annuus and Vetiveria zizanioides by cultivating these species in a polluted soil and contrasting the levels of metals before and after treatment. The combination of these methods allows gaining a very clear picture of the contamination levels and shows an environmentally sustainable strategy of reducing the level of heavy-metals.

Sample Size-One hundred and ten soil samples were taken in the sampled urban locations. The stratified random sampling method has been used to provide a proportional segmentation of the industrial, roadside, waste-dump, and residential areas. The sample was sufficient to follow spatial differences of contamination levels within the area of the study.

Data Analysis-The research consisted of determining the frequency and percentage distributions of heavy-metal contamination levels throughout the 110 soil samples that were collected. This was due to the fact that the research did not include any questionnaires or surveys in its methodology. In order to present a clear picture of the contamination patterns in the region that was the subject of the investigation, the data were separated into three categories: low, moderate, and high contamination levels depending on the heavy metal.

Result and Discussion

There were 110 soil samples obtained from the urban districts of Aligarh, and Table 1 depicts the distribution of lead (Pb) contamination among those samples. The levels of contamination are classified as low (no more than 50 mg/kg), moderate (51–150 mg/kg), and high (more than 150 mg/kg), along with the frequencies and percentages that correspond to each of these categories. The following table offers a summary of the extent to which lead pollution is widespread and severe within the area under investigation.

Table 1: Lead (Pb) Contamination Levels

Pb Level (mg/kg)	Frequency (n=110)	Percentage (%)
Low (0–50)	28	25.45%
Moderate (51–150)	46	41.81%
High (>150)	36	32.72%

As observed in the table 1, the highest percentage of samples is under the moderate contamination with 41.81% as the percentage. The number of high contamination (32.72) shows that there are high contamination of Pb in some places, in particular, around the industrial and roadside sites. A low percentage of 25.45 of samples indicates low contamination. This is a distribution that indicates that lead pollution is a significant environmental issue in the urban areas of Aligarh. Table 2 provides a summary of cadmium (Cd) content of 110 soil samples in three categories, which are low (0-1 mg/kg), moderate (1-3mg/kg) and high (4-5mg/kg). The table has frequency counts and percentages indicating the distribution of Cd contamination throughout the area of the study.

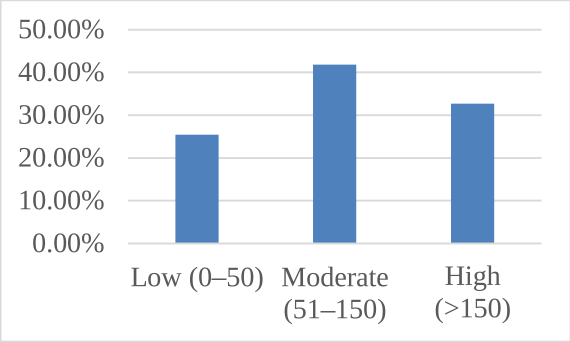

Figure 1: Graphical Representation of the Percentage of Lead (Pb) Contamination Levels

As can be seen, most heavy metals have moderate categories of contamination. Lead and chromium are relatively highly contaminated with severe contamination, which is an industrial impact. Cadmium has less contamination at the high levels, but moderate contamination is widespread. The same can be seen in Nickel with over fifty percent of the samples being below the moderate contamination range. As a whole the numbers indicate that there is great heavy-metal pollution thus the remediation process should include phytoremediation.

Table 2 shows cadmium (Cd) levels of contamination in 110 soil samples collected in different urban areas in Aligarh. The Cd concentrations will be classified in three groups namely low (0-1mg/kg), moderate (1-3mg/kg), and high (>3mg/kg). The table gives the frequency of samples and the corresponding percentage of each category, which gives a quantitative description of the presence of cadmium in the area of study.

Table 2: Cadmium (Cd) Contamination Levels

Cd Level (mg/kg)	Frequency (n=110)	Percentage (%)
Low (0–1)	40	36.36%
Moderate (1–3)	52	47.27%
High (>3)	18	16.36%

The table 2 indicates that the moderate contamination category has the best frequency of 47.27% of the soil samples. These are an indication that almost 50 % of the locations sampled have observable cadmium concentrations. The category with low contamination that is 36.36 indicates that over one-third of the samples are between acceptable and slightly higher levels. The percentage of samples falling within the high contamination range is only 16.36% and it indicates that dire cadmium pollution is not as extensive as it was. Generally, the data indicates that the level of Cd contamination in Aligarh is mainly moderate, which is probably caused by the ongoing industrial emissions, waste disposal, and vehicle activity.

The percentage distribution of the levels of cadmium contamination is visually represented in Figure 2 depending on the data presented in Table 2. There are three categories with percentages of low, moderate and high (36.36%, 47.27% and 16.36%). The figure gives a clear pictorial comparison on the prevalence of each level of contamination level and therefore Cd distribution across the study area can easily be interpreted.

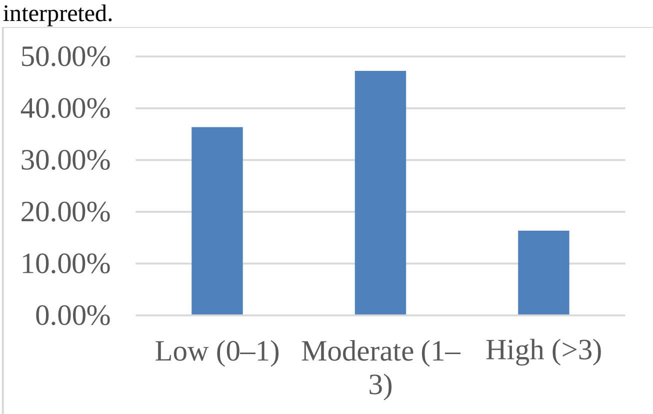

Figure 2: Graphical Representation of the Percentage of Cadmium (Cd)

Contamination Levels

As the figure 2 shows, moderate Cd contamination is the most widespread category, as the larger part or bar in the graph shows. This means a wide spread of cadmium in the urban soils. The low contamination is the next category which indicates that a considerable percentage of areas have lower levels of cadmium. The largest category in the figure is the high contamination, which emphasizes the fact that the excessive pollution of Cd is not large but still, there are particular hotspots. In general, the graph validates progressive *yet al*arming accumulation of cadmium in the environment, which makes it necessary to regularly monitor and remediate the environment (phytoremediation).

Table 3 will contain a distribution of the content chromium (Cr) contamination in 110 soil samples gathered in different localities in Aligarh. The levels of contamination are determined into three categories such as low (0-75mg/kg), moderate (76-150mg/kg) and high (>150mg/kg). Every category contains the amount of samples (frequency), as well as the percentage corresponding to it, which provides an in-depth description of the chromium dispersion in the study area.

Table 3: Chromium (Cr) Contamination Levels

Cr Level (mg/kg)	Frequency (n=110)	Percentage (%)
Low (0–75)	22	20.00%
Moderate (76–150)	50	45.45%
High (>150)	38	34.54%

This table 3 shows that the most frequent category is moderate contamination as 45.45 % of the soil samples are in the 76150 mg/kg range. This implies that the pollution of chromium is rampant in the urban setting. The category of high contamination which is 34.54 of the samples shows that a good part of the study area is very contaminated with Cr- probably because of the industrial activities, metal workshops and the disposal of waste materials. The number of samples that are in the low contamination category is only 20 percent which demonstrates that the areas that are not contaminated or not much affected are limited. On the whole, the allocation indicates that chromium pollution is a significant threat to the environment in Aligarh.

The visual representation of distribution of percentage of the chromium contamination levels per the data in Table 3 is depicted in Figure 3. The three groups, namely low, moderate, and high, have been shown in the figure with their percentages (20.00%, 45.45%, and 34.54%). The graphical presentation enables the instant comparative insight of the range and magnitude of Cr contamination through the sampled locations.

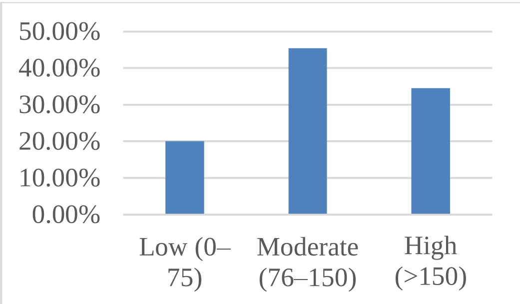

Figure 3: Graphical Representation of the Percentage of Chromium (Cr) Contamination Levels

It is clear that the moderate levels of chromium contamination are the most visualized in the figure 3 as it highlights the fact that almost half of the sampled sites have high levels of Cr. High contamination category also constitutes a significant percentage of the graph, which further supports the observation that the pollution of chromium in a number of areas in Aligarh is serious. The low contamination segment is the least, which means that there are rather limited areas which are clean or hardly contaminated. All in all, the figure indicates that chromium is among the most dangerous heavy-metal contaminants of the urban soils of Aligarh, and thus, the remediation intervention is urgently required.

The data in Table 4 shows the distribution of the level of nickel (Ni) contamination in 110 soil samples at urban sites in Aligarh. These contamination rates are classified as low (030mg/kg), moderate (3175mg/kg), and high (>75mg/kg). In each category, the samples within the given range are provided as well as the percentages of the samples. This table gives a clear explanation of the level of Ni pollution within the study area.

Table 4: Nickel (Ni) Contamination Levels

Ni Level (mg/kg)	Frequency (n=110)	Percentage (%)
Low (0–30)	30	27.27%
Moderate (31–75)	57	51.81%
High (>75)	23	20.90%

It is visible in the table 4 that moderate nickel contamination is the most common type of sample, representing 51.81% of the soil samples. This means that over fifty percent of the sampled sites have moderate concentrations of Ni, which are probably caused by the automobile emissions, metal fabrication units, and industrial effluents. Low contamination category represents 27.27 percent of the samples indicating that there is a section in the study area that is only slightly contaminated. Conversely, 20.90% of the samples exhibit high contamination indicating certain hotspots whereby the pollution of nickel occurs. The total distribution shows that the contamination of nickel is moderate in Aligarh, and the areas should be remedied with particular care.

Figure 4 gives a graphical presentation of percentage distribution of level of Ni contamination according to the data in Table 4. The percentage proportion of samples under low, moderate and high contamination profile, which represent 27.27, 51.81 and 20.90 percent, respectively, are represented in the figure graphically. The visualization helps to perceive the prevailing category of contamination in a simple and quick way and determines the relative variations of the three levels.

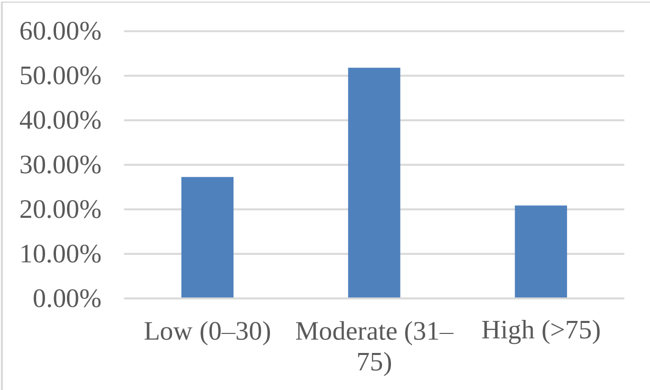

Figure 4: Graphical Representation of the Percentage of Nickel (Ni) Contamination Levels

The figure 4 indicates quite clearly that the average level of contamination is the biggest part of the table, pointing to the fact that the pollution with nickel occurs in most of the places that are being sampled. The low contamination section seems smaller showing that there are less sites where the Ni build-up is less pronounced. The high contamination percentage is relatively low in comparison with the moderate one, but it remains a large percentage, which indicates that there are some regions where the problem of nickel contamination is rather serious. In general, the number elucidates nickel as an excellent urban soil pollutant in Aligarh and leads to the idea that specific remediation measures, including phyto-remediation, are required to decrease both the Ni concentration in further hotspots.

Conclusion

As a result of industrial emissions, vehicular pollution, and improper waste disposal practices, the urban soils of Aligarh are significantly contaminated with heavy metals such as lead, cadmium, chromium, nickel, and zinc. The majority of the samples exhibit moderate to high contamination levels, which pose serious risks to human health, agricultural productivity, and ecological balance. The findings of this study demonstrate that the urban soils of Aligarh are significantly contaminated. The experiment on phytoremediation revealed that Brassica juncea, Helianthus annuus, and Vetiveria zizanioides are effective hyperaccumulator species that are able to reduce heavy-metal concentrations through natural, environmentally friendly mechanisms. This substantiates the use of phytoremediation as a viable and sustainable remediation strategy for the restoration of urban soil. As a result of these findings, the research suggests that phytoremediation should be implemented on a large scale in Aligarh. Additionally, the study suggests that stronger regulatory measures, improved waste management, expanded green cover, and continuous environmental monitoring should be implemented in order to reduce soil contamination and improve the long-term environmental health and sustainability of urban areas.

References

Ahemad, M. (2015). Phosphate-solubilizing bacteria-assisted phytoremediation of metalliferous soils: a review. 3 Biotech, 5(2), 111-121.

Ali, S. A., & Ahmad, A. T. E. E. Q. U. E. (2019). Analysis of chemical and heavy metal concentrations of leachates and impact on groundwater quality near Dhapa dumping ground, Kolkata. Asian Profile, 47(1), 19-37.

Ashfaque, F., & Inam, A. (2019). Interactive effect of potassium and flyash: a soil conditioner on metal accumulation, physiological and biochemical traits of mustard (Brassica juncea L.). Environmental Science and Pollution Research, 26(8), 7847-7862.

Badar, M. S., Ali, S., Daniyal, Akram, M. W., Faheem, K., Khan, S. U., & Farooqi, I. H. (2024). GIS-based assessment of groundwater vulnerability to heavy metal contamination via water quality pollution indices in urban Aligarh, India. Water Practice & Technology, 19(2), 419-434.

Banday, U. Z., Nazir, A., Fatima, M., Swaleh, S. B., Al-Asadi, M., & Usmani, N. (2023). Heavy metal–induced genotoxic, physiological, and biochemical responses in Schizothorax esocinus (Heckel 1838) inhabiting the Dal Lake, India, and phytoremediation by indwelling plants. Environmental Science and Pollution Research, 30(24), 65688-65701.

Chauhan, P., & Mathur, J. (2020). Phytoremediation efficiency of Helianthus annuus L. for reclamation of heavy metals-contaminated industrial soil. Environmental Science and Pollution Research, 27(24), 29954-29966.

Ditta, A., Mehmood, S., Imtiaz, M., & Tu, M. S. (Eds.). (2024). Bio-organic Amendments for Heavy Metal Remediation: Water, Soil and Plant Approaches and Technologies. Elsevier.

Emenike, E. C., Iwuozor, K. O., & Anidiobi, S. U. (2022). Heavy metal pollution in aquaculture: sources, impacts and mitigation techniques. Biological Trace Element Research, 200(10), 4476-4492.

Ghasera, K. M., Rashid, S. A., & Gupta, K. (2021). Heavy metals abundance and distribution in soil, groundwater and vegetables in parts of Aligarh, Uttar Pradesh, India. Current Science, 121(8), 1056-1063.

Gorelova, S. V., Kolbas, A. P., Muratova, A. Y., Frontasyeva, M. V., Zinicovscaia, I., & Okina, O. I. (2023). Prospects for the use of sorghum bicolor for phytoremediation of soils contaminated with heavy metals in temperate climates. In Phytoremediation: Management of Environmental Contaminants, Volume 7 (pp. 263-301). Cham: Springer International Publishing.

Hamsa, N. (2018). Silicon Mediated Amelioration of Heavy Metal Contaminated Soils of Peri Urban Bengaluru (Doctoral dissertation, University of Agricultural Sciences, GKVK.).

Hernández Guiance, S. N., Coria, I. D., Faggi, A., & Basílico, G. (2023). Phytoremediation of Soils Polluted by Heavy Metals and Metalloids: Recent Case Studies in Latin America. In Phytoremediation: Management of Environmental Contaminants, Volume 7 (pp. 317-332). Cham: Springer International Publishing.

Hussain, K., Haris, M., Qamar, H., Hussain, T., Ahmad, G., Ansari, M. S., & Khan, A. A. (2021). Bioremediation of waste gases and polluted soils. In Microbial Rejuvenation of Polluted Environment: Volume 2 (pp. 111-137). Singapore: Springer Singapore.

Kanwar, V. S., Sharma, A., Srivastav, A. L., & Rani, L. (2020). Phytoremediation of toxic metals present in soil and water environment: a critical review. Environmental Science and Pollution Research, 27(36), 44835-44860.

Mahamood, M., Khan, F. R., Zahir, F., Javed, M., & Alhewairini, S. S. (2023). Bagarius bagarius, and Eichhornia crassipes are suitable bioindicators of heavy metal pollution, toxicity, and risk assessment. Scientific Reports, 13(1), 1824.

Maharana, M., Manna, M., Sardar, M., & Sen, S. (2020). Heavy metal removal by low-cost adsorbents. In Green adsorbents to remove metals, dyes and boron from polluted water (pp. 245-272). Cham: Springer International Publishing.

Malik, A., Alam, I., Faridi, M. R., & Ayub, S. (2019). Corporate social irresponsibility towards the planet: a study of heavy metals contamination in groundwater due to industrial wastewater. Social Responsibility Journal, 16(6), 793-807.

Muzammal, S., Akram, A., Shakoor, M. B., Ahmad, S. R., Farid, M., & Shakoor, M. H. (2023). Biochar-assisted phytoremediation for heavy metals-contaminated soils. In New Frontiers in Plant-Environment Interactions: Innovative Technologies and Developments (pp. 359-384). Cham: Springer Nature Switzerland.

Oladipo, B., Akintunde, A. M., Ajala, S. O., Olatunji, S. O., Falowo, O. A., & Betiku, E. (2020). Phytoextraction of Heavy Metals from Complex Industrial Waste Disposal Sites. In Methods for Bioremediation of Water and Wastewater Pollution (pp. 341-371). Cham: Springer International Publishing.

Parihar, J. K., Parihar, P. K., Pakade, Y. B., & Katnoria, J. K. (2021). Bioaccumulation potential of indigenous plants for heavy metal phytoremediation in rural areas of Shaheed Bhagat Singh Nagar, Punjab (India). Environmental Science and Pollution Research, 28(2), 2426-2442.

Saif, S., Khan, M. S., Zaidi, A., Rizvi, A., & Shahid, M. (2017). Metal toxicity to certain vegetables and bioremediation of metal-polluted soils. In Microbial Strategies for Vegetable Production (pp. 167-196). Cham: Springer International Publishing.

Sailesh, A. R., Riyazuddin, S., Kumar, K. S., Chakraborthy, A., & Namuduri, S. (2023). Application of Electroremediation Coupled with Phytoremediation Techniques for the Removal of Trace Metals in Sewage Sludge. In Phytoremediation: Management of Environmental Contaminants, Volume 7 (pp. 129-144). Cham: Springer International Publishing.

Singh, A., & Prasad, S. M. (2015). Remediation of heavy metal contaminated ecosystem: an overview on technology advancement. International Journal of Environmental Science and Technology, 12(1), 353-366.

Tabinda, A. B., Tahir, A., Dogar, M., Yasar, A., Rasheed, R., & Mahnoor. (2023). Role of microorganisms in the remediation of toxic metals from contaminated soil. In Phytoremediation: Management of Environmental Contaminants, Volume 7 (pp. 231-259). Cham: Springer International Publishing.

Zeb, A., Liu, W., & Zhang, Y. (2022). Effects of nanoparticles on alleviating phytotoxicity of soil heavy metals: potential for enhancing phytoremediation. In Sustainable Agriculture Reviews 53: Nanoparticles: A New Tool to Enhance Stress Tolerance (pp. 327-344). Cham: Springer International Publishing.