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Assessment of Heavy Metal Contamination in Agricultural Soil Around Industrial Zones of Kanpur

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Abstract

The rapid industrialization of Kanpur, one of India's major industrial hub has led to significant environmental concerns, particularly regarding soil contamination in adjacent agricultural zones. This study assesses the concentration and distribution of heavy metals such as lead (Pb), cadmium (Cd), chromium (Cr), nickel (Ni), zinc (Zn), copper (Cu), and arsenic (As)—in agricultural soils located around the industrial periphery of Kanpur. Soil samples were collected from multiple sites in proximity to leather tanning, textile, and chemical industries, and analyzed using Atomic Absorption Spectroscopy (AAS). The study underscores the urgent need for environmental monitoring, implementation of stringent industrial waste management practices and remediation strategies to safeguard soil health and agricultural productivity in the region. Heavy metals in most samples, with concentrations of Pb, Cr, and Cd significantly exceeding the permissible limits set by the World Health Organization (WHO). The continuous discharge of untreated or partially treated industrial effluents has led to the accumulation of toxic metals in agricultural soils, which poses serious threats to soil health, crop productivity and food safety. This study emphasizes the urgent need for regular environmental monitoring, adoption of cleaner production technologies by industries, and implementation of sustainable soil remediation techniques.

Key Words-Heavy metals, Agricultural soil, Industrial areas, World Health Organization (WHO)

INTRODUCTION

Soil is one of the most vital natural resources that supports terrestrial life, serving as the primary medium for plant growth and an essential component in nutrient cycling, water filtration, and food production. However, the quality and functionality of soil are increasingly being threatened by anthropogenic activities, particularly those related to urbanization and industrialization. Among the various pollutants released into the environment, heavy metals represent a particularly concerning group due to their non-biodegradable nature, potential toxicity, and long-term persistence in the environment (Nagajyoti *et.al*. 2010).

Heavy metals such as lead (Pb), cadmium (Cd), chromium (Cr), copper (Cu), nickel (Ni), zinc (Zn), and arsenic (As) are introduced into the soil through multiple pathways, including atmospheric deposition, irrigation with contaminated water, application of fertilizers and pesticides, and most notably, through the direct discharge of industrial effluents (Alloway, 2013). Some organic pollutants, heavy metals do not degrade over time, they accumulate in the upper soil layers, where they can interfere with soil microbial communities, alter physicochemical properties, and reduce the productivity and safety of agricultural outputs (Yadav *et.al*. 2020).

Kanpur, Uttar Pradesh is known as the "Manchester of the East," Kanpur hosts a dense cluster of industries including leather tanneries, electroplating units, textiles, fertilizers, pesticides, and dyes (Singh *et.al*. 2022). These industries, especially those concentrated in areas like Jajmau, Panki, Dada Nagar, and Kalpi Road, are well-documented for generating large quantities of solid and liquid waste. While these sectors contribute significantly to the local economy, their environmental management practices are often outdated or poorly enforced. Many industrial units discharge partially treated or untreated effluents directly into natural water bodies such as the Ganga River, or into open fields and drains, leading to environmental degradation (Kumar *et.al.* 2021).

Agricultural lands situated in proximity to these industrial zones are highly susceptible to contamination. Farmers often rely on irrigation from wastewater channels or nearby contaminated water sources due to limited freshwater availability. Over time, continuous use of such water and atmospheric deposition of heavy metal particulates contribute to the gradual accumulation of toxic metals in agricultural soils. This contamination poses serious threats not only to soil fertility and crop yield but also to human health through the food chain, as crops grown in contaminated soils may uptake and store these metals in edible tissues (Gupta *et.al.* 2019). Industrial regions of India have reported significant accumulations of Pb, Cd, and Cr in the topsoil and vegetation, especially in peri-urban agricultural zones (Sharma *et.al.* 2017). In Kanpur, preliminary assessments have indicated elevated concentrations of Cr and Cd, attributed mainly to effluents from leather and electroplating industries (Yadav *et.al.* 2020). The persistent accumulation of heavy metals in agricultural soils surrounding the industrial zones of Kanpur. This contamination could significantly impair agricultural productivity, endanger public health through contaminated food chains, and degrade regional ecological integrity. Future prospects for managing and mitigating heavy metal contamination in this region should encompass integrated scientific, technological, and policy-driven strategies.

Further studies should explore in the bioavailability and translocation of metals in various crops. The effects of heavy metals on soil micro biota and it also affect the human beings by using food chain transfer models. Contamination losses the economic valuation of agriculture. The concentrations of several heavy metals exceeded the permissible limits set by national and international environmental standards, with Pb, Cr, and Cd posing the greatest risk.

MATERIALS AND METHODS

STUDY AREA

The study was conducted in and around the industrial zones of Kanpur, a major urban and industrial hub in Uttar Pradesh, India. The city is geographically located at 26.4499° N latitude and 80.3319° E longitude along the banks of the Ganga River. Industrial areas such as Jajmau (leather tanneries), Panki (thermal and chemical industries), Dada Nagar (electroplating and engineering units), and Fazalganj (textile and plastic processing industries). These areas are surrounded by agricultural lands that are often irrigated using water from local drains, rivers, and industrial wastewater.

SOIL SAMPLING

A total of 20 soil samples were collected from agricultural fields located within a 5–10 km radius of the industrial zones. Sampling was conducted during the Rabi season. Each soil sample was collected at a depth of 0–20 cm using a stainless-steel auger to avoid contamination. Samples were collected in pre-cleaned polyethylene bags. The samples were label, transported to the laboratory and air-dried at room temperature (Yadav *et.al*. 2024)

SAMPLE PREPARATION

Samples were crushed and sieved through a 2 mm mesh to remove moisture. For heavy metal analysis, 1 gram of soil from each sample was digested using a mixture of HNO_3 and $HClO_4$ (3:1 ratio) on a hot plate until a clear solution was obtained.

HEAVY METAL ANALYSIS

The concentrations of heavy metals, including Lead (Pb), Cadmium (Cd), Chromium (Cr), Copper (Cu), Zinc (Zn), Nickel (Ni), and Arsenic (As), were determined using Atomic Absorption Spectrophotometry (AAS) (Model: PerkinElmer Analyst 400). Calibration was performed using certified standard solutions and all measurements were conducted in triplicate to ensure accuracy. Blanks and certified reference materials (CRM) were included to maintain quality control (Yadav *et. al*. 2024)

STATISTICAL ANALYSIS

All data were statistically analyzed by IBM SPSS (version 26). Descriptive statistics (mean, standard deviation) and Pearson's correlation analysis were used to explore relationships between heavy metal concentrations and soil parameters. ANOVA was applied to compare metal concentrations between different locations and with control samples. Significance was assessed at $p < 0.05$.

RESULTS AND DISCUSSION

Lead (Pb)

Lead concentrations ranged from 86.45 to 135.78 mg/kg, with the highest level detected in Panki (135.78 mg/kg), far exceeding the typical background value of 20–40 mg/kg in uncontaminated soils. Elevated Pb levels in Panki and Dada Nagar may be attributed to emissions from thermal power plants, battery

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manufacturing, and vehicular exhaust deposition. Result of this study is mentioned below (Table 1).

Cadmium (Cd)

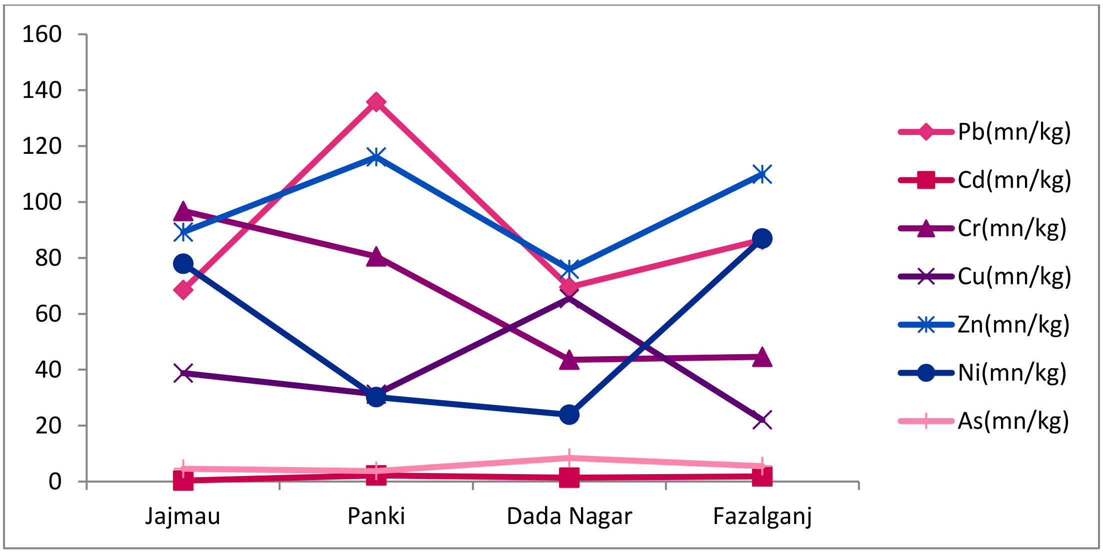
Cadmium levels varied from 2.18 to 1.43 mg/kg, with the maximum concentration observed at Dada nagar and Panki. While the presence of Cd in industrial areas such as Jajmau and Fazalganj were expected due to electroplating and dye industries, elevated levels in control sites could be linked to the use of phosphate fertilizers or irrigation water contamination. Result of this study is mentioned below (Table 1).

Chromium (Cr)

Cr concentrations ranged from 80.55 to 96.80 mg/kg, with Panki and Jajmau showing the highest levels due to the presence of leather tanneries, a major source of hexavalent chromium. Cr levels in these soils exceed the recommended safe limit of 64 mg/kg (WHO/FAO), indicating potential risk to soil health and food safety. Result of this study is mentioned below (Table 1).

Table1. Mean Concentration of Lead (Pb), cadminum(Cd), Chrominum (Cr), Copper (Cu), Zinc (Zn), nickel (Ni) and Arsenic (As) Values Of Various Land In Kanpur

S.No.	Study site	Pb(mn/kg)	Cd(mn/kg)	Cr(mn/kg)	Cu(mn/kg)	Zn(mn/kg)	Ni(mn/kg)	As(mn/kg)
1.	Jajmau	68.56	0.33	96.80	38.76	89.29	77.94	4.56
2.	Panki	135.78	2.18	80.55	31.28	116.07	30.23	3.75
3.	Dada Nagar	69.59	1.43	43.55	65.48	75.96	23.90	8.45
4.	Fazalganj	86.45	1.83	44.67	22.05	109.96	86.95	5.52



Copper (Cu)

Cu concentrations varied from 22.05 to 65.48 mg/kg, with the highest level at Dada Nagar, likely due to metal processing and alloy industries. All values were within the permissible limits (below 100 mg/kg), but elevated Cu can still impact microbial enzyme activity over time. Result of this study is mentioned above (Table 1).

Zinc (Zn)

Zn ranged from 56.04 to 116.07 mg/kg, with Panki showing the maximum. Zinc levels in several locations, were near or above background thresholds, possibly due to agricultural amendments and wastewater use. Although Zn is essential, excess levels may cause phytotoxicity. Result of this study is mentioned above (Table 1).

Nickel (Ni)

Ni levels were highest at Fazalganj (86.95 mg/kg) and Jajmau (77.94 mg/kg), both approaching or exceeding the safe limit of 75 mg/kg. Ni contamination in industrial sites may result from petroleum refining, electroplating, and alloy production. Result of this study is mentioned above (Table 1).

Arsenic (As)

As concentrations ranged from 3.78 to 8.47 mg/kg, with the highest detected in Panki and Dada Nagar. While levels were below the critical limit of 10 mg/kg (WHO), arsenic accumulation over time poses long-term risks to food safety and human health. Result of this study is mentioned above (Table 1).

DISCUSSION

The present study indicates that agricultural soils in close proximity to industrial areas in Kanpur—namely Jajmau, Panki, Dada Nagar, and Fazalganj—are significantly contaminated with heavy metals such as Pb, Cd, Cr, Cu, Zn, Ni, and As. These concentrations, especially of Pb and Cr, surpass the permissible limits set by FAO/WHO (2007) and the Indian Standards IS 10500 (2012) for agricultural soils. The findings are consistent with previous reports from similar industrial regions, where untreated or poorly treated industrial effluents and atmospheric deposition contribute to persistent soil pollution (Rattan *et.al*. 2005; Singh *et.al.* 2021). Leather processing units in Jajmau are a major contributor to elevated Cr levels due to the widespread use of chromium salts in tanning (Kumar & Chopra, 2012). Panki and Dada Nagar, dominated by metalwork, thermal power plants, and electroplating industries, show higher levels of Pb, Cd, and Cu, pointing to emissions and improper disposal of industrial waste as the primary sources. This aligns with studies indicating that urban-industrial soils in India often show heavy metal accumulation from similar anthropogenic inputs (Rajaram *et.al*. 2008; Tiwari *et. al.* 2020). Heavy metals like Cd and Pb, even at low concentrations, are non-essential and toxic to both plants and soil microbes. They interfere with nutrient uptake, enzyme activity, and microbial diversity (Giller *et.al.* 2009; Awasthi *et.al.* 2023). The elevated Zn and Ni levels detected, although essential at trace levels, can become phytotoxic when concentrations exceed critical thresholds, leading to reduced crop productivity and microbial dysfunction (Alloway, 2013).

The presence of arsenic (As) and cadmium (Cd) is particularly concerning due to their carcinogenic and bioaccumulative properties. Long-term consumption of crops grown in contaminated soils poses serious health risks including kidney dysfunction, developmental defects, and cancer (USEPA, 2014; Sharma & Agrawal, 2006). Bhuiyan *et.al*. (2010) and Kisku *et.al*. (2015) have shown similar risks in peri-urban agricultural zones exposed to industrial discharges. The results also show a spatial trend in contamination—concentrations decrease with increasing distance from industrial hubs—suggesting localized pollutant dispersion patterns (Yadav *et.al*. 2022). When compared with other industrial zones in India such as Delhi, Ludhiana, and Varanasi, Kanpur shows similar or higher levels of heavy metal burden in agricultural soils (Singh & Singh, 2014; Meena *et.al.* 2020).

CONCLUSION

The significantly higher metal concentrations in industrial sites confirm the impact of industrial discharges and poor environmental regulation on agricultural land quality. These findings underscore the urgent need for soil remediation, regulatory interventions, and alternative irrigation strategies to prevent heavy metal accumulation in food crops. The level of heavy metal contamination in agricultural soils surrounding the industrial zone of Kanpur. The analysis revealed concentrations of metals such as lead (Pb), cadmium (Cd), chromium (Cr), nickel (Ni), and zinc (Zn), which often exceeded permissible limits set by international and national environmental agencies. These findings suggest that prolonged industrial activity, improper waste disposal and lack of effective pollution control measures have substantially contributed to the degradation of soil quality in the region. The accumulation of these heavy metals poses serious threats to agricultural productivity, food safety, and the health of local populations. Metals such as Cd and Pb, in particular, are known to bioaccumulate in crops and enter the food chain, raising concerns over long-term ecological and human health impacts.

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