J. Sci. Innov. Nat. Earth: Vol. 5, Issue 1, 2025, Page 38-40 ISSN (Online) 2583-2093 OPEN ACCESS

Journal of Science Innovations and Nature of Earth

Journal homepage : https://jsiane.com/index.php/files/index

International, Double-Blind, Quarterly, Peer-Reviewed, Refereed Journal, Edited and Open Access Research Journal

Heavy Metal Concentration in Contaminated Water Caused By a Release of Industrial Pollutants and City Waste

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DOI: https://doi.org/10.59436/jsiane.331.2583-2093

Abstract

This study investigates the effects of urban trash and industrial pollutants on the concentrations of heavy metals in contaminated water sources. It makes the point that led, cadmium, mercury, and chromium (Cd, Cr, Cu, Hg, Pb, and Zn) concentrations in aquatic ecosystems are substantially increased by industrial operations and ill-designed waste management systems. This study determines the sources of these metals and measures their quantities in different water samples using sophisticated physicochemical methods of investigation. It also assesses the possible effects of these heavy metals on ecosystems and human health, highlighting the grave dangers that their presence poses to the environment and public health. This emphasizes how urgently improved waste management and pollution control are needed in order to lessen the negative effects of heavy metal contamination. Effective management techniques will be essential to lowering these hazards and safeguarding the public's health and the environment.

Keywords*:* Heavy Metal, (Cd, Cr, Cu, Hg, Pb, Zn), Concentration, Contaminated Water, Industrial Pollutants, City Waste.

Received 08.01.2025 **Revised 09.02.2025** **Accepted 01.03.2025**

Introduction

Water contamination from industrial pollutants and municipal waste is a severe environmental issue that has become worse over the past several decades due to accelerated industrialisation and urbanisation. Industrial sites, such as mines, manufacturing facilities, and chemical refineries, discharge a variety of hazardous substances, including heavy metals, into nearby water bodies. These contaminants either enter by runoff from waste storage facilities or directly discharge untreated industrial effluents into rivers, lakes, and groundwater systems. Similar to this, improper handling of sewage, stormwater, and municipal waste—all of which commonly include chemicals, heavy metals, and other dangerous substances—contributes significantly to contaminated water in urban areas. Building materials, automobile exhaust, and household items are a few of the municipal trash sources that release pollutants into the water. These contaminants accumulate in the water, severely deteriorating its quality and making it unsuitable for recreational, agricultural, or human use.

Figure1: Heavy Metals in The Environment

Heavy metals, such as lead, mercury, cadmium, arsenic, and chromium, pose a particularly serious risk to human health and the environment due to their persistence and ability to bioaccumulate.

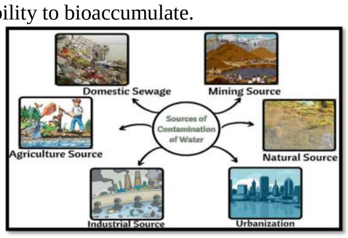

Figure 2: Contamination of Water through Different Sources

Heavy metals, in contrast to organic contaminants, tend to concentrate in sediment and aquatic species before making their way up the food chain. These metals can cause renal failure, increased cancer risk, brain damage, and other health problems when consumed by humans. Because heavy metals have an adverse effect on aquatic organisms' ability to develop, reproduce, and survive, their presence in water bodies also disturbs aquatic ecosystems. For example, fish mortality, changes in microbial activity, and a decline in biodiversity can result from elevated levels of metals like mercury and cadmium. The extensive pollution of water by urban and industrial waste highlights the pressing need for stronger environmental laws, better waste management techniques, and efficient water treatment technology to lessen the negative impacts of heavy metals.

Objectives of the study

•To determine which kinds of heavy metals are in the tainted water.
•To determine the levels of heavy metals in the impacted water sources.
•To identify the main sources of contamination with heavy metals.
•To assess the dangers that the contamination poses to the environment and public health.

Literature Review

Mishra *et al*. (2019) who highlight the serious effects it has on the ecosystem and public health. Because they are not biodegradable, heavy metals build up in ecosystems and cause long-term environmental harm. The most common pollutants, according to the authors, are metals including arsenic, lead, mercury, cadmium, and chromium. further emphasise how important environmental biotechnology is to creating long-term solutions for this expanding issue. Scientists may be able to clean up polluted surroundings without adding more dangerous chemicals by employing bio-based technology. The study's conclusion urges tighter laws and increased public education on the risks associated with heavy metal pollution, both of which are essential for preserving the environment and human health. Kapoor and Singh (2021). According to their findings, there are several ways that heavy metals might infiltrate aquatic systems. These include natural geological processes, agricultural practices, urban runoff, and industrial discharges. Toxic metals including lead, cadmium, mercury, and nickel are frequently found in high amounts in industrial effluent from the mining, electroplating, and manufacturing sectors. The authors suggest a number of tactics to lessen the pollution caused by heavy metals, including boosting sustainable farming methods, upgrading wastewater treatment facilities, and improving e-waste management. In order to remove heavy metals from water sources, Kapoor and Singh stress the necessity for a multifaceted strategy that involves tighter environmental regulations, more public awareness campaigns, and the creation of environmentally friendly technology. Williams (2019), who emphasises the threats to human health and the environment as well as the metal's ubiquitous occurrence. The author goes into great depth about heavy metals, including arsenic, cadmium, lead, mercury, and chromium, emphasising how persistent they are in the environment and how easily they may build up in living things. Williams also highlights the increasing issue of agricultural contamination, which occurs when pesticides and fertilisers high in metals are overused and introduce dangerous materials into soils and water systems. It advises that in order to reduce their environmental impact, enterprises should adopt cleaner production processes and regulatory frameworks should be improved, especially with regard to the disposal of agricultural and industrial waste. Singh *et al*. (2022) research focusses on how heavy metals may be harmful to living things, especially aquatic environments. The authors talk about how heavy metals may have a significant impact on human health, biodiversity, and water quality once they are incorporated into the water. Long-term contamination can result from the binding of metals such as lead, cadmium, and mercury to sediments in rivers and lakes, even after the removal of the initial source of pollution. The grave effects of unmanaged heavy metal contamination on the environment and public health are demonstrated by these case studies. Singh *et al*. suggest stricter environmental monitoring, the use of heavy metal-specific water treatment technology, and the creation of regulations limiting harmful material emissions from industry as solutions to these problems. They emphasise how crucial it is for nations to work together to address this global issue since heavy metal pollution frequently crosses national boundaries and affects several ecosystems. Ahmad *et al.* (2021). In order to provide a thorough risk assessment for human exposure, the study uses sophisticated analytical techniques to quantify the quantities of hazardous metals including lead, cadmium, and arsenic in numerous environmental samples. According to Ahmad *et al*., there is rising worry over heavy metal pollution of soil and water, especially in regions with high industrial and agricultural production. According to Ahmad *et al.*, pinpointing contamination hotspots and stopping more pollution need routine monitoring of the quality of the soil and water. To lessen the hazards related to heavy metal pollution, they support the creation of early warning systems and the use of public health initiatives. In order to remove heavy metals from polluted ecosystems, the study's conclusion calls for more funding for research and development of remediation technologies, such as the use of nanoparticles and other cutting-edge materials.

Research Methodology

Study Area- The research focusses on Aligarh, Uttar Pradesh, India, which is well-known for its inadequate waste management and industrial operations (lock manufacturing, electroplating, and tanneries). Rivers, canals, groundwater sources, and industrial discharge points impacted by both urban garbage and industrial pollutants are important sites for sampling.

Sampling Procedures- Over the course of six months, monthly water samples will be taken from urban and industrial drainage locations. Rivers, canals, and groundwater close to residential and commercial areas will all be sample locations. The pH, temperature, and conductivity of the samples will be measured in-situ while they are kept in sterile bottles. To assure accuracy, each location will have three replicas.

Data Analysis- Software for statistical processing will be used to process the data, compute descriptive statistics, and compare the outcomes with BIS and WHO guidelines. While GIS maps the locations of pollution hotspots and their geographical distribution across Aligarh, multivariate analysis (PCA) will determine the causes of contamination.

Result

Heavy Metal Concentrations- The results showed that Aligarh's several water basins were significantly contaminated with heavy metals. The concentrations of lead (Pb), cadmium (Cd), mercury (Hg), arsenic (As), and chromium (Cr) were highest near industrial discharge locations. Lead concentrations, for example, varied between 0.2 and 1.5 mg/L, with the highest readings above the WHO threshold of 0.01 mg/L. Notably, the amounts of mercury and cadmium exceeded allowable limits. The average concentrations of each element were shown using tables and graphs, allowing for a direct comparison with safe standards.

Table 1: Heavy Metal Concentrations in Water Basins of Aligarh

Heavy Metal	Range of Concentrations (mg/L)	Highest Reading (mg/L)	WHO Standard (mg/L)	Exceedance Factor	Remarks
Lead (Pb)	0.2 - 1.5	1.5	0.01	Up to 150 times	Significantly exceeds WHO limits
Cadmium (Cd)	0.05 - 0.08	0.08	0.003	Up to 27 times	Exceeds allowable limits
Mercury (Hg)	0.02 - 0.03	0.03	0.006	Up to 5 times	Exceeds safe limits
Arsenic (As)	0.01 - 0.02	0.02	0.01	2 times	Slightly exceeds safe limits
Chromium (Cr)	0.02 - 0.05	0.05	0.05	Within safe limits	Meets WHO standards

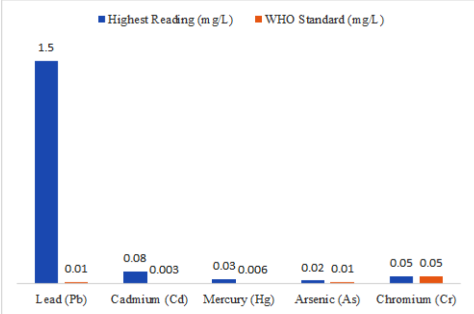

Figure 3: Heavy Metal Concentrations in Water Basins

Table 2: Sources and Health Effects of Heavy Metals

Heavy Metal	Sources	Health Effects
Essential Heavy Metals		
Zinc (Zn)	Oil refining, Plumbing, Brass manufacturing	Gastrointestinal disorders, Kidney & Liver abnormal functioning
Copper (Cu)	Copper polishing, Plating, Printing	Abdominal disorders, Metabolic activity abnormalities
Iron (Fe)	High intake of iron supplements & oral consumption	Vomiting, Diarrhea, Abdominal pain, Dehydration & lethargy
Cobalt (Co)	Hip alloy replacement case	Hematological, Cardiovascular, Hepatic, Endocrine issues
Non-Essential Heavy Metals		
Chromium (Cr)	Steel fabrication, Electroplating, Textile	Lung disorders (bronchitis, cancer), Renal and reproductive system issues
Lead (Pb)	Batteries, Coal combustion, Paint industry	Serious effects on mental health (Alzheimer's disease), Nervous system issues
Arsenic (As)	Atmospheric deposition, Mining, Pesticides	Dermal issues (cancer), Brain & Cardiac problems
Mercury (Hg)	Coal combustion, Fish, Mining, Paint industry, Paper industry, Volcanic eruption	Sclerosis, Blindness, Minamata disease, Deafness, Gastric problems, Renal disorders
Cadmium (Cd)	Plastic, Fertilizers, Pesticides	Osteo-related problems, Prostate cancer, Lung diseases, Renal issues

Spatial Distribution- Based on a spatial study, it was found that the concentration of heavy metal contamination was higher in regions adjacent to industrial zones, namely in water bodies near tanneries and electroplating units. Cadmium and mercury levels were higher at urban trash disposal locations. The geographical variation in contamination was depicted using maps created with GIS tools, which clearly showed hotspots in industrial regions and lower concentrations in residential zones.

Temporal Variation- The six-month research period saw variations in the amounts of heavy metals. Because of restricted water flow and pollutant deposition during the dry season, pollution levels were often greater; but, during the rainy season, concentrations were likely lower because of rainfall dilution. Temporal graphs showed notable variations that peaked in the months before to the monsoon, especially in lead and cadmium levels.

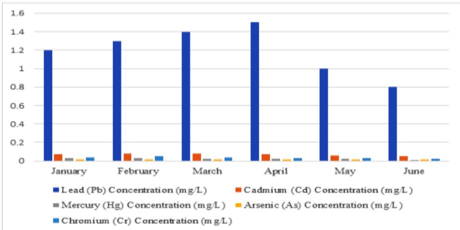

Figure 4: Temporal Variation in Heavy Metal Concentrations

Discussion

Interpretation of Results-Lead and chromium contents in particular are increased and are closely associated with industrial discharge from electroplating and metal processing units. Cadmium and mercury levels in locations with significant urban trash flow were alarming. The findings imply that inappropriate urban waste disposal and industrial activity are the main causes of the pollution, which has a considerable negative impact on the quality of the water in Aligarh's main water bodies.

Comparison with Standards- Most of the reported heavy metal concentrations were higher above permissible levels when compared to WHO and BIS standards. For example, lead concentrations were up to 150 times higher than allowed limits, while suggested criteria for mercury and cadmium were also exceeded. The seriousness of the local water pollution is highlighted by the limits' consistent exceeding.

Table 3: Comparison of Heavy Metal Concentrations with WHO and BIS Standards

Heavy Metal	Measured Concentration	WHO Standard	BIS Standard	Exceedance Factor	Remarks
Lead (Pb)	Up to 1.5 mg/L	0.01 mg/L	0.05 mg/L	Up to 150 times	Significantly exceeds safe limits
Cadmium (Cd)	0.08 mg/L	0.003 mg/L	0.01 mg/L	Up to 27 times	Exceeds recommended thresholds
Mercury (Hg)	0.03 mg/L	0.006 mg/L	0.006 mg/L	Up to 5 times	Exceeds safe limits
Arsenic (As)	0.02 mg/L	0.01 mg/L	0.05 mg/L	2 times	Slightly exceeds safe limits
Chromium (Cr)	0.05 mg/L	0.05 mg/L	0.1 mg/L	Within safe limits	Meets WHO and BIS standards

Implications for Public Health- Significant dangers to public health are posed by the high concentrations of heavy metals, particularly to populations who depend on polluted water for drinking, farming, or bathing. Extended exposure to high lead concentrations has been associated with neurological harm, while mercury and cadmium have been related to liver and kidney damage as well as an increased risk of cancer. If the pollution is not treated, the local community may suffer grave long-term health effects.

Table 4: Exposure, Symptoms, Causes, and Diagnosis of Heavy Metals Poisoning

Exposure Type	Symptoms	Causes and Risk Factors	Diagnosis
Short Term	- Confusion - Numbness - Nausea - Vomiting - Coma	- Industrial Exposure - Pollution - Foods - Medicines - Contaminated Cookware - Lead Paints - Insecticides	- Blood Tests - Kidney Tests - Urine Test - Liver Test - EKG
Long Term	- Headache - Weakness - Tiredness - Muscle Pain - Joint Pain - Constipation	- Industrial Exposure - Pollution - Foods - Medicines - Contaminated Cookware - Lead Paints - Insecticides	- Blood Tests - Kidney Tests - Urine Test - Liver Test - EKG

Conclusion

According to this study, there is a serious heavy metal pollution in Aligarh's water bodies. The main causes of the higher levels of lead, cadmium, mercury, arsenic, and chromium are industrial discharges and poor urban waste management. The results showed concentrations that, especially in the vicinity of industrial zones and poorly managed waste regions, substantially exceed environmental safety limits. Improving waste management procedures, enforcing stronger industrial laws, and implementing cutting-edge waste treatment technology are all necessary to solve this problem. In order to successfully manage heavy metal pollution in water sources, future study should concentrate on long-term monitoring to comprehend seasonal and yearly oscillations in contamination, investigate relationships between heavy metals and other contaminants, and assess remediation solutions.

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