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Assessment of Heavy Metal Contamination in Surface Water and Groundwater: Impacts, Mitigation and Remediation Strategies in Isnapur and Rudraram, Pashamailaram Industrial Area, Hyderabad

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ABSTRACT
This study evaluates heavy metal contamination in the most impacted locations within the Pashamailaram Industrial Area, Patancheruvu, Hyderabad, Telangana. Isnapur surface water and ground water and Rudraramsurface water and ground water were identified as the most polluted sites, exhibiting elevated concentrations of chromium (Cr), lead (Pb), iron (Fe), and arsenic (As) beyond permissible limits. The primary pollution sources include industrial discharges and improper waste disposal. The study recommends targeted mitigation measures to address contamination and protect local communities from health risks.

Keywords: heavy metal contamination, Pashamailaram Industrial Area, ground water

1. INTRODUCTION

The contamination of water resources by heavy metals has become a critical environmental and public health issue, particularly in industrial regions. Heavy metals, such as chromium, lead, arsenic, and iron, are persistent in the environment and pose significant risks to both human health and aquatic ecosystems (Singh *et al.*, 2018). Industrial activities, including metal processing, electroplating, and chemical manufacturing, contribute to the accumulation of these toxic metals in water bodies and groundwater systems (Gupta *et al.*, 2017).

The Pashamailaram Industrial Area in Hyderabad has experienced rapid industrial expansion, leading to increased heavy metal contamination in surface water and groundwater. Previous studies have reported that industrial effluents discharged into nearby water bodies often contain high levels of toxic metals, which can bioaccumulate in aquatic organisms and enter the food chain (Sharma & Dubey, 2019). The presence of heavy metals beyond permissible limits in drinking water sources can lead to serious health complications, including neurological disorders, kidney damage, and increased cancer risks (WHO, 2017).

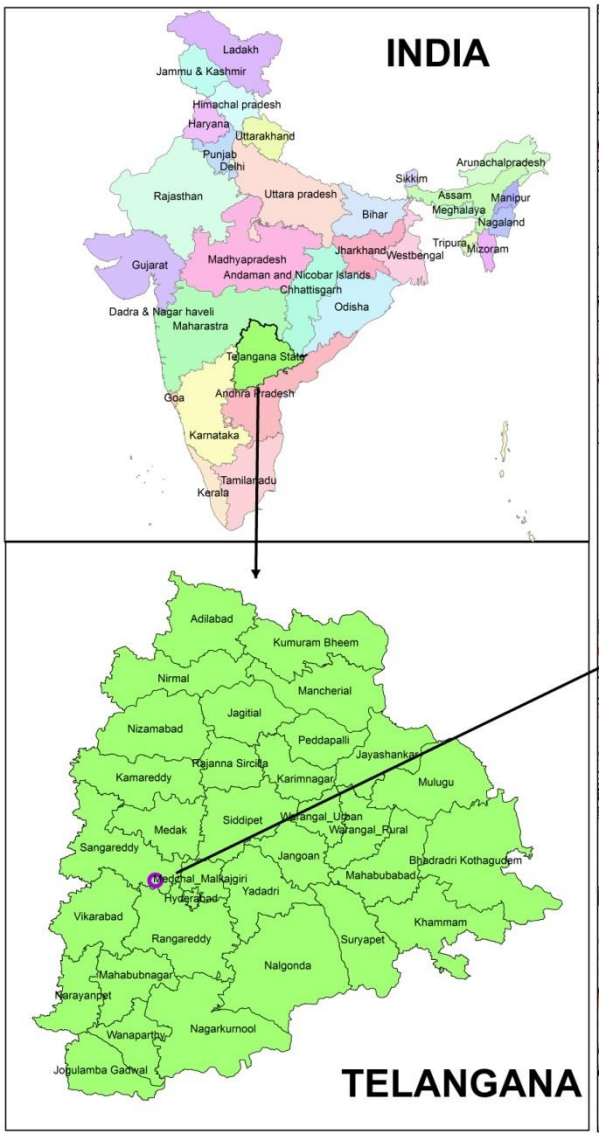
This study focuses on two highly contaminated locations, Isnapur and Rudraram surface water and

ground water, where metal concentrations exceed national and international safety standards (BIS IS: 10500, 2012). The study aims to assess the extent of heavy metal contamination, analyze seasonal variations, and propose effective mitigation and remediation strategies to reduce pollution and protect public health.

2. STUDY AREA

The study was conducted in Isnapur and Rudraram surface water and ground water, which are located within the Pashamailaram Industrial Area, Hyderabad. These areas are characterized by extensive industrial operations, including metal processing, electroplating, and chemical manufacturing, contributing significantly to environmental pollution.

Map showing Isnapur and Rudraram locations of Surface water and Groundwater



3. OBJECTIVES

1. To assess the levels of heavy metal contamination in surface water and groundwater at Isnapur and Rudraram.
2. To determine the potential sources of contamination.
3. To evaluate the environmental and health impacts of heavy metal pollution.
4. To propose effective mitigation and remediation strategies for these sites.

4. METHODOLOGY

- **Sampling Procedures:** Water samples were collected from Isnapur and Rudraram surface water and groundwater during post-monsoon, pre-monsoon and monsoon seasons. Sampling locations were selected based on proximity to industrial discharge points and potential contamination sources.
- **Sample Collection and Preservation:** Surface water samples were collected using pre-cleaned polyethylene bottles, while groundwater samples were extracted from borewells and hand pumps

using sterile containers. Samples were immediately acidified with nitric acid (HNO3) to maintain metal stability and stored at 4°C for laboratory analysis.

- **Laboratory Analysis:** Collected samples were analyzed for heavy metals, including arsenic (As), chromium (Cr), lead (Pb), and iron (Fe), using Inductively Coupled Plasma Mass Spectrometry (ICP-MS) and Atomic Absorption Spectroscopy (AAS). Quality control was ensured through calibration with standard solutions and duplicate analysis.
- **Data Analysis:** Metal concentrations were compared with Bureau of Indian Standards (BIS IS: 10500) and World Health Organization (WHO) guidelines to evaluate contamination severity. Statistical methods, including mean, standard deviation, and correlation analysis, were applied to identify contamination trends and sources.
    - The metal concentrations in Surface water & Ground water for two sampling locations were analyzed across Post Monsoon, Pre Monsoon and Monsoon seasons. The data provides insights into the Surface & Ground water quality and potential contamination in the study area. The details of the sampling locations are given in Table 1 & Table 2 and results of the analysis are presented in Table & Table 4.

Table-1: Sampling locations of Surface water

S. No.	Sampling Location	Latitude	Longitude	Post Monsoon (November - February)	Pre Monsoon (March - June)	Monsoon (July – October)
1	Isnapur	17.550358	78.189455	08.11.2023	09.04.2024	12.08.2024
2	Rudraram	17.562885	78.167309	08.11.2023	09.04.2024	12.08.2024

Table-2: Sampling locations of Ground Water

S. No.	Sampling Location	Latitude	Longitude	Post Monsoon (November - February)	Pre Monsoon (March - June)	Monsoon (July – October)
1	Isnapur	17.540223	78.211008	08.10.2023	09.04.2024	12.08.2024
2	Rudraram	17.562885	78.167309	09.10.2023	10.04.2024	13.08.2024

Table-3: Heavy Metal Concentrations at Isnapur and Rudraram Surface water

S. No.	Name of the metal (mg/L)	Test Method	RESULTS					
			Isnapur			Rudraram		
			Post Monsoon	Pre Monsoon	Monsoon	Post Monsoon	Pre Monsoon	Monsoon
1	Arsenic (As)	3120-B	BDL	BDL	BDL	BDL	BDL	BDL
2	Barium (Ba)	3120. B	0.52	0.65	0.48	0.55	0.67	0.52
3	Chromium (Cr)	3120-B	0.11	0.16	0.15	0.14	0.16	0.12
4	Cobalt (Co)	3120-B	BDL	BDL	BDL	BDL	BDL	BDL
5	Copper (Cu)	3120-B	0.1	0.15	0.08	0.09	0.19	0.14
6	Manganese	3120-B	0.62	0.54	0.58	0.14	0.18	0.12

	(Mn)							
7	Iron (Fe)	3120-B	1.02	1.25	0.96	3.96	4.05	2.85
8	Nickel (Ni)	3120-B	0.04	0.06	0.05	0.06	0.08	0.07
9	Lead (Pb)	3120-B	0.06	0.07	0.06	0.05	0.07	0.05
10	Zinc (Zn)	3120. B	0.05	0.07	0.05	0.11	0.18	0.09

Table-4: Heavy Metal Concentrations at Isnapur and Rudraram Ground water

S. No.	Name of the metal (mg/L)	Test Method	IS: 10500 Requirement (Acceptable Limit)	IS: 10500 Permissible Limit in absence of alternate source	RESULTS					
					Isnapur			Rudraram		
					Post Monsoon	Pre Monsoon	Monsoon	Post Monsoon	Pre Monsoon	Monsoon
1	Arsenic (As)	3120-B	0.01	0.05	0.04	0.09	0.04	0.03	0.06	0.04
2	Barium (Ba)	3120. B	0.7	No relaxation	0.24	0.33	0.13	0.08	0.1	BDL
3	Chromium (Cr)	3120-B	0.05	No relaxation	0.06	0.07	BDL	0.05	0.08	BDL
4	Cobalt (Co)	3120-B	--	--	BDL	BDL	BDL	BDL	BDL	BDL
5	Copper (Cu)	3120-B	0.05	1.5	0.07	0.11	0.08	0.04	0.09	BDL
6	Manganese (Mn)	3120-B	0.1	0.3	0.14	0.24	0.12	0.09	0.15	0.06
7	Iron (Fe)	3120-B	1.0	No relaxation	0.45	0.52	0.48	0.52	0.60	0.48
8	Nickel (Ni)	3120-B	0.02	No relaxation	BDL	BDL	BDL	BDL	BDL	BDL
9	Lead (Pb)	3120-B	0.01	No relaxation	0.03	0.08	BDL	0.04	BDL	BDL

10	Zinc (Zn)	3120. B	5	15	0.1	0.15	0.14	0.14	0.26	0.12

5. RESULTS AND DISCUSSION

The results indicate significant heavy metal contamination in both surface water and groundwater samples collected from Isnapur and Rudraram. Chromium and lead were detected at concentrations exceeding permissible limits in both surface and groundwater, posing serious health and environmental risks. Iron contamination was particularly severe in Rudraram, with levels reaching 4.05 mg/L in surface water and 1.75 mg/L in groundwater, far surpassing the acceptable limit of 1.00 mg/L. Arsenic levels in Isnapur groundwater samples exceeded safety thresholds, highlighting the urgent need for remediation measures.

Surface water contamination exhibited seasonal variations, with the highest metal concentrations observed during the monsoon season. Increased runoff from industrial areas contributed to the spread of pollutants into nearby water bodies. Post-monsoon samples revealed residual contamination due to sediment accumulation, while pre-monsoon groundwater samples showed elevated metal levels due to reduced dilution and continued industrial discharge.

Groundwater samples from Isnapur (GW-1) and Rudraram (GW-2) were found to be highly contaminated with lead, arsenic, and chromium. The presence of arsenic in Isnapur at levels reaching 0.09 mg/L, significantly above the permissible limit of 0.05 mg/L, raises concerns about long-term exposure risks. Lead concentrations in both sites were dangerously high, with levels of 0.08 mg/L in Isnapur and 0.04 mg/L in Rudraram, well beyond the acceptable limit of 0.01 mg/L. These findings indicate a pressing need for industrial waste regulation and groundwater protection strategies.

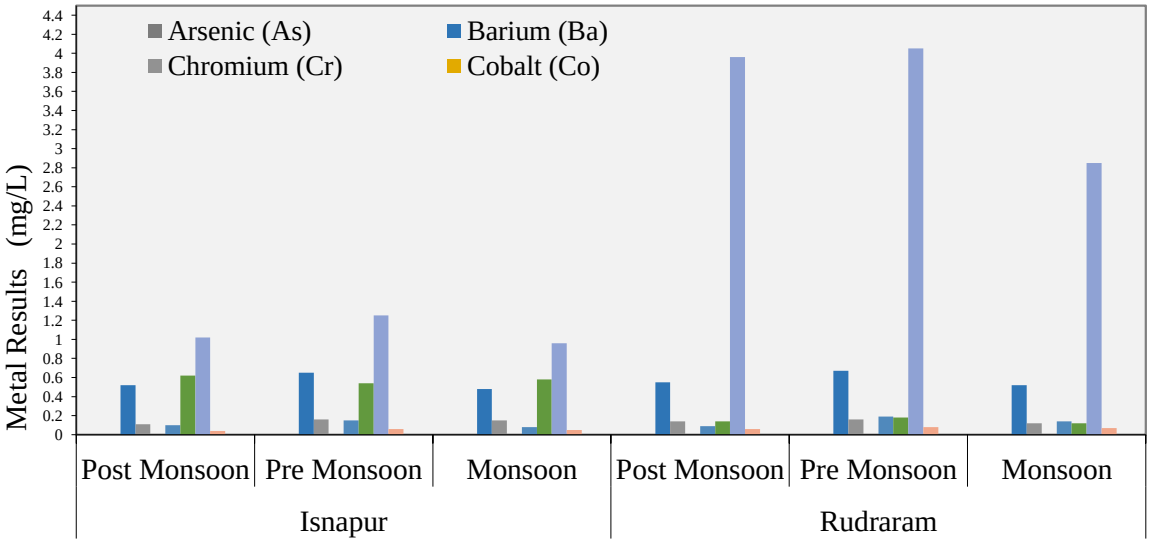


Figure: Metal Concentrations in Surface Water at Isnapur & Rudraram Area

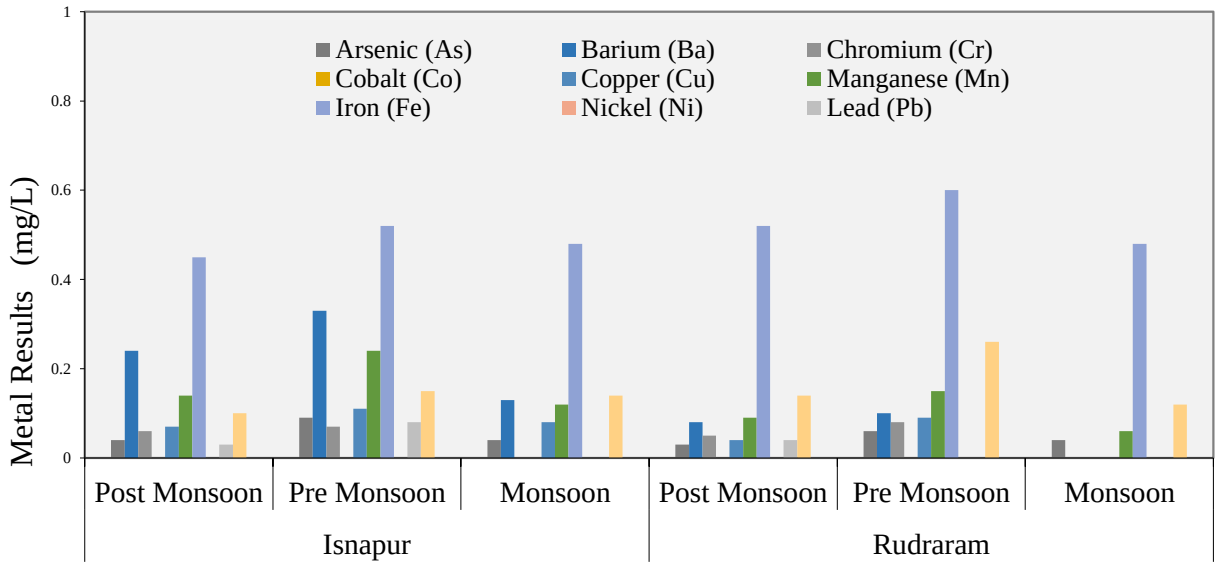


Figure: Metal Concentrations in Groundwater at Isnapur & Rudraram Area

6. ENVIRONMENTAL AND HEALTH IMPACTS

- Heavy metal contamination in Isnapur and Rudraram poses significant environmental and health risks. Elevated chromium and lead levels contribute to water toxicity, affecting aquatic ecosystems and biodiversity. The presence of iron at high concentrations results in poor water quality, making it unsuitable for domestic and agricultural use.
- Health effects associated with long-term exposure to these metals include kidney damage, neurological disorders, and increased cancer risk due to arsenic contamination. Lead exposure, particularly in children, leads to cognitive impairment and developmental delays. Chromium toxicity is linked to respiratory issues and skin diseases. Continuous exposure to contaminated water sources endangers both human and ecological health, necessitating immediate intervention.

7. MITIGATION AND REMEDIATION MEASURES

To address the contamination at Isnapur and Rudraram, a multi-faceted approach incorporating various remediation techniques is necessary:

- **Industrial Wastewater Treatment:** Implementing advanced effluent treatment plants (ETPs) at industrial facilities to ensure that wastewater is treated before discharge.
- **Regular Monitoring:** Establishing continuous water quality monitoring programs to track contamination trends and enforce regulatory compliance.
- **Phytoremediation:** Introducing metal-accumulating plants such as vetiver grass and water hyacinths in contaminated sites to absorb and immobilize heavy metals.
- **Community Awareness Programs:** Educating local communities about water contamination risks and promoting safe drinking water practices.
- **Stricter Policy Enforcement:** Imposing stringent industrial discharge norms, along with penalties for non-compliance, to prevent further pollution.
- **Groundwater Recharge Techniques:** Encouraging artificial recharge methods, such as rainwater harvesting and aquifer recharge wells, to reduce metal concentrations in groundwater.
- **Bioremediation:** Utilizing bacteria and fungi capable of breaking down or immobilizing heavy

metals in polluted sites.

- **Chemical Stabilization:** Employing lime and phosphate compounds to reduce heavy metal mobility in contaminated soils and water sources.
- **Sediment Dredging:** Removing contaminated sediments from affected water bodies to limit metal re-suspension and prevent further dispersion.
- **Establishment of Green Buffer Zones:** Creating vegetative buffers around industrial areas to filter pollutants before they reach water bodies.
- **Advanced Filtration Systems:** Installing reverse osmosis (RO) and activated carbon filters at water treatment plants to remove heavy metal contaminants.
- **Legislative Action:** Strengthening environmental regulations and ensuring industries comply with pollution control standards through regular inspections.

8. CONCLUSION

Isnapur and Rudraram surface & ground water are the most severely contaminated sites in the Pashamailaram Industrial Area. The presence of Chromium, Lead, Iron, and Arsenic in excess of permissible limits presents serious health risks. Immediate intervention through industrial wastewater treatment, phytoremediation, and bioremediation is necessary to restore water quality and safeguard public health. The implementation of strict environmental regulations, continuous monitoring, and community involvement will play a crucial role in mitigating further contamination and ensuring sustainable water resource management.

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