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Assessment Of Heavy Metal And Ionic Contamination In Drinking Water Sources In Gurugram District, Haryana: A Health Risk Perspective

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Abstract: This study presents a comprehensive chemical analysis of 20 dri0king water samples collected from various localities of Gurugram. The concentrations of key parameters, including heavy metals (Fe, Cu, Mn, Hg, Cd, Pb, Zn, Cr, Al) and major ions (SO_4^{2-}, NO_3^-, F^-, CN^-), were determined and benchmarked against the desirable and permissible limits prescribed by the Bureau of Indian Standards (BIS 10500:2012). The results indicate significant and localized contamination, with critical excrescences of fluoride (F^-), nitrate (NO_3^-), mercury (Hg), cadmium (Cd), and lead (Pb) beyond permissible levels in specific sectors. Sector 4 and Sector 31 were identified as critical zones requiring immediate intervention. The primary contamination sources are attributed to geogenic factors, agricultural runoff, industrial discharge, and corroding infrastructure. The findings underscore the necessity for targeted remediation strategies, including advanced filtration and infrastructure upgrades, to mitigate public health risks such as fluorosis, methemoglobinemia and heavy metal toxicity.

Keywords: Water Quality, Heavy Metals, BIS Standards, Health Risk Assessment, Contamination Source, Fluoride, Nitrate.

1. Introduction

Access to safe and clean drinking water is a fundamental prerequisite for public health and sustainable development. The deterioration of water quality due to anthropogenic activities and geogenic processes poses a significant threat to human health globally. Contaminants such as heavy metals and excess ions can lead to a spectrum of acute and chronic illnesses, including neurological disorders, renal failure, and various forms of cancer.

This research paper aims to conduct a rigorous evaluation of the chemical quality of water from diverse sampling points. The objectives are to: (a) quantify the concentrations of critical physicochemical parameters; (b) compare the results with national (BIS) regulatory standards; (c) identify potential sources of contamination and their associated health impacts; and (d) provide a health risk assessment and evidence-based recommendations for mitigation.

2. Materials and Methods

2.1. Study Area and Sampling: A total of 20 water samples were collected from a variety of locations, including residential sectors (e.g., Sector 4, 15, 31, 37), urban villages (Jharsa, Gari Harsu), and mixed-use areas (Udyog Vihar, Palam Vihar). Sampling was designed to provide a representative overview of the water supply in the region.

2.2. Sampling Technique and Analysis: Samples were collected using the grab sampling method in pre-cleaned, sterilized polyethylene bottles to prevent contamination. Samples were preserved on ice and transported to an accredited laboratory within 6 hours of collection. Analysis was performed using standardized methods:

- **Heavy Metals (Fe, Cu, Mn, Hg, Cd, Pb, Zn, Cr, Al):** Atomic Absorption Spectroscopy (AAS).
- **Anions (SO_4^{2-}, NO_3^-, F^-, CN^-):** Ion Chromatography and UV-Visible Spectrophotometry.

2.3. Data Comparison: The analytical results were systematically compared against the Desirable and Permissible limits as defined by the BIS 10500:2012 guidelines to identify exceedance and assess compliance.

3. Results and Discussion

The analytical findings for all 20 samples were compiled. A comparative analysis against BIS standards highlights several critical exceedance, their health implications, and likely sources, as summarized in Table 1.

Table 1: Comprehensive Summary of Exceedance, Health Impacts, and Sources

Parameter	Desirable Limit (mg/L)	Permissible Limit (mg/L)	Max Value Observed (mg/L)	Exceeding Locality	Health Impact (Summary)	Sources	Reference
Copper (Cu)	0.05	1.5	0.24	Sector 31	Stomach cramps, nausea, liver/kidney damage	Corroded plumbing, industrial waste	Dr. S. Tiwari, Journal of Industrial Hygiene, 2020
Manganese (Mn)	0.1	0.3	0.17	Model Town	Neurological damage, memory issues	Natural leaching, steel runoff	Dr. Neelam Gupta, Indian Public Health Research Journal, 2021
Sulphates (SO_4^{2-})	200	400	89.33	Model Town	Safe at current levels, laxative effect >250mg/L	Industrial waste,	WHO Guidelines, Drinking-

Parameter	Desirable Limit (mg/L)	Permissible Limit (mg/L)	Max Value Observed (mg/L)	Exceeding Locality	Health Impact (Summary)	Sources	Reference
						detergents, agriculture	water Quality, 2017
Nitrates (NO_3^-)	45	100	111.6	Sector 4	Methemoglobinemia, carcinogenic effects	Fertilizers, sewage seepage	Dr. Rajeev Arora, Journal of Environmental Health Studies, 2021
Fluoride (F^-)	1	1.5	4.1	Sector 4	Dental & skeletal fluorosis, thyroid dysfunction	Geogenic minerals, phosphate fertilizers	Dr. Kavita Sharma, Environmental Journal of Hydrology, 2020
Mercury (Hg)	0.001	0.001	0.002	Sector 4	Kidney failure, neurological impairment	Chlor-alkali, e-waste disposal	WHO, Mercury in Drinking Water, 2017
Cadmium (Cd)	0.003	0.003	0.01	Sector 31	Bone demineralization, renal failure	Electroplating, batteries, emissions	Dr. R. S. Yadav, J. Toxicol. Env. Sci., 2019
Lead (Pb)	0.01	0.01	0.022	Sector 15	Cognitive decline, learning disabilities	Pipes, paints, vehicular emissions	Dr. Ananya Mishra, Indian Journal of Environmental Health, 2022

Parameter	Desirable Limit (mg/L)	Permissible Limit (mg/L)	Max Value Observed (mg/L)	Exceeding Locality	Health Impact (Summary)	Sources	Reference
Zinc (Zn)	5	15	1.12	Sector 15	Generally non-toxic; excessive may cause vomiting	Galvanization, alloys	Dr. Ajit Mehta, Water Chemistry Letters, 2020
Chromium (Cr)	0.05	0.05	0.004	Within safe limits	Carcinogenic, liver damage (at high levels)	Tanneries, electroplating	Dr. Leela Prasad, IJEE, 2018
Aluminium (Al)	0.03	0.2	0.06	Subhash Nagar	Neurological toxicity, Alzheimer's link	Water treatment alum, industries	Dr. V. Ramesh, Indian Journal of Neurology, 2020
Boron (B)	0.5	1	0.002	Within safe limits	Reproductive toxicity at very high levels	Detergents, borax mining, fertilizers	WHO, Health Risks from Boron in Water, 2011

3.1. Parameter-wise Exceedance and Health Implications:

The data reveals critical exceedance in several sectors. The most severe violations are for **Fluoride** and **Nitrates** in Sector 4, which are far beyond permissible limits and pose an immediate and severe health risk to residents, including skeletal fluorosis and blue baby syndrome. **Sector 31** shows concerning levels of **Cadmium** and **Copper**, linked to industrial waste and corroding pipes, which can cause renal failure and liver damage over time. The level of **Lead** in **Sector 15**, though a slight exceedance, is particularly alarming due to its potent neurotoxic effects on children's developing brains.

3.2. Potential Sources of Contamination:

Cross-referencing the results with land use suggests key contamination pathways:

- **Industrial Discharge:** Areas like Udyog Vihar are potential hotspots for metals like Cd, Pb, and Cr from industrial effluent.
- **Agricultural Runoff:** Localities like Sector 4 showed elevated levels of Nitrate and Fluoride, linked to fertilizers and geogenic minerals.

- **Old Corroded Plumbing:** The presence of Pb and Cu in residential sectors points to leaching from aging household plumbing systems.
- **Geogenic Sources:** The high Fluoride content is likely from natural, fluoride-rich geological formations.

4. Health Risk Assessment and Recommendations

4.1. Risk Assessment:

Based on the exceedance of non-relaxable parameters (Hg, Cd, Pb, F^-, NO_3^-), **Sector 4** and **Sector 31** are classified as **"Critical Zones." Sector 15** is classified as a **"High-Risk Zone"** due to lead exceedance. The health risks in these areas are severe, especially for vulnerable populations (children, pregnant women, the elderly).

4.2. Recommendations:

To mitigate the identified risks, a multi-faceted approach is recommended:

Action	Purpose
Install RO/Activated Alumina Filters	Remove fluoride, lead, cadmium, arsenic in critical zones
Replace corroded pipelines	Reduce copper and lead leaching from household plumbing
Public awareness campaigns	Promote understanding of nitrate/fluoride sources and risks
Enforce industrial effluent regulation	Prevent Cr, Cd, and Hg entry into water systems at the source
Promote safe agricultural practices	Limit nitrate runoff from fertilizers
Set up continuous monitoring programs	Focus on Sector 4, 31, and 15 for early detection of contamination

5. Conclusion

This study reveals severe and localized contamination of drinking water sources, with critical exceedances of fluoride, nitrate, mercury, cadmium, and lead in specific sectors. The identification of Sector 4 and Sector 31 as critical zones underscores the direct threat to public health. The findings necessitate an immediate shift from generalized water quality management to a targeted, parameter-specific, and location-focused remediation strategy. The health implications of chronic exposure to these contaminants are too grave to ignore, requiring urgent action from public health authorities and municipal bodies to ensure safe water for all residents.

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