FishTaxa - Journal of Fish Taxonomy
Vol 38, ISSN: 2458-942X

Assessment of heavy metal contamination in freshwater ponds of Durg district of Chhattisgarh, india

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Abstract
Heavy metal contamination of freshwater ecosystems is a serious environmental and public health issue, particularly where agriculture is intensifying, industrialization and urbanization is occurring quickly. This study examines the levels of selective heavy metals in freshwater ponds like Kalyan Sagar Pond (KSP), Maroda Reservoir (MR), Tandula Canal (TC) and Risali Pond (RP) located throughout the Durg district of Chhattisgarh, India, during the pre-monsoon season. These metals include Lead (Pb), Mercury (Hg), Cadmium (Cd), Arsenic (As), Chromium (Cr), and Zinc (Zn) and some selective pond fishes. Inductively Coupled Plasma-Optical Emission Spectrometry (ICP-OES) was used to measure the concentrations of heavy metals in water samples taken from several representative ponds. The findings showed that metal concentrations varied geographically, such as Ca (26.12ppm) and Hg (0.0002ppm) at KSP while Hg (0.0003ppm) in MR. Similarly, Mg level in KSP, MR, TC, and RP respective 7.19ppm, 4.1ppm, 3.55ppm, and 1.06ppm having major impact like osmoregulation issue and effect. with some locations having levels above the World Health Organization's (WHO) and Bureau of Indian Standard (BIS) acceptable limits for drinking and irrigation water. The findings highlight the need for stronger pollution control, regular monitoring, and better water management to reduce heavy metal contamination and protect aquatic ecosystems.

Keywords: Heavy metals, ICP-OES, pond water, environmental pollution, water quality.

Citation: Rashmi Kujur, Ajay Kumar Harit. 2026. Assessment of heavy metal contamination in freshwater ponds of Durg district of Chhattisgarh, india. FishTaxa 38: 1-9

Introduction
Freshwater ecosystems are essential for maintaining ecological balance and supporting human livelihoods, especially in rural and semi-urban regions where ponds serve as primary sources for irrigation, aquaculture, domestic use, and groundwater recharge (Singh et al., 2020). However, pollution from human activity, especially the buildup of heavy metals—non-biodegradable substances that linger in the environment and bioaccumulate through the food chain—is posing a growing threat to these ecosystems (Kumar and Yadav, 2019).

In Durg district, pollution from heavy metals in water bodies is becoming a serious problem, especially in areas where industries and cities are growing fast. Harmful metals like Lead (Pb), Mercury (Hg) Cadmium (Cd), Arsenic (As), Chromium (Cr), and Zinc (Zn) often enter aquatic environments through point and non-point sources, including industrial effluents, vehicular emissions, mining activities, agricultural runoff, and untreated domestic wastewater (Rai et al., 2019; Sharma and Tripathi, 2021). These include waste from factories, chemicals used in farming, mining operations, untreated sewage, and improper disposal of waste (Trivedi *et al.*, 2010). Because of their toxicity, persistence, and bioaccumulative nature, heavy metals are particularly concerning among other pollutants (Tchounwou et al., 2012). Heavy metals do not break down naturally and stay in the environment for a long time. They can build up inside aquatic animals and become more concentrated as they move up the food chain, a process called biomagnification. Even small amounts can harm aquatic life because they are toxic and can cause genetic mutations or even cancer (Bhuiyan *et. al.*, 2007). Indeed, after being released, these metals have the potential to build up in sediments and aquatic life, upsetting the natural equilibrium and endangering human health by way of the food chain (Jaishankar et al., 2014).

However, high levels of heavy metals can change the water’s natural balance, affecting things like its acidity (pH) and clarity. These changes harm plants and animals living in the water, damaging their habitat. Heavy metals also disrupt important body functions in fish and other aquatic creatures, such as digestion, energy production, and reproduction. If exposed for a long time, these metals can cause stress, damage organs, and even lead to death in species that are more vulnerable (Chiranjeev et. al., 2025). Polluted water bodies can disturb the balance of nature. Some delicate species may die, while others may change or grow stronger, upsetting the natural order. This affects predator-prey relationships and may even cause food chains in the water to break down. People who use polluted water for drinking, farming, or fish farming are at risk of health problems because fish living in contaminated water can carry harmful heavy metals (Kumar et al., 2011). Heavy metal pollution is a worldwide issue, but its seriousness depends on location and economic conditions. In India, water bodies in industrial and mining areas, like Chhattisgarh, are especially at risk. Since Durg district is highly developed and industrialized, it is an important area to study and find solutions to this problem.

Durg district in Chhattisgarh is an important place for studying environmental changes because of its location, industries, and economy. The district is growing fast, with many factories and industrial areas. Some of these industries release waste containing heavy metals into nearby water without proper treatment. Farming also adds to pollution, as pesticides and fertilizers wash into water bodies, bringing harmful metals with them (Ali *et. al.*, 2005). People in Durg depend on these water bodies for drinking, farming, fish farming, and fishing. This makes it very important to keep the water clean and protect the ecosystem. Since fish from these waters are a major source of protein, there is a risk that harmful heavy metals could build up in the food chain and affect human health.

When fish absorb heavy metals from polluted water and people eat them, it can cause serious health problems like brain damage, kidney issues, and growth disorders. By studying these water bodies, scientists can find out how dangerous the pollution is and suggest ways to prevent harm. Research on contamination levels can help leaders make and enforce environmental laws that protect the region. These studies also help plan better ways for industries and farms to work without causing pollution in the future. Heavy metal pollution in water is a worldwide problem, but studying Durg district gives important local information that can help both the region and global research (Shaji et. al., 2009).

The purpose of this study was to evaluate the distribution and concentration of specific heavy metals in Durg district's freshwater ponds. The study sheds light on the effects of heavy metal contamination on the environment and public health by comparing measured quantities to the Bureau of Indian Standards (BIS) and World Health Organization (WHO) guidelines.

Materials and Methods

1. Study Area

The study was conducted in the Durg district (figure 1) of Chhattisgarh, India, which lies between latitudes 20.1°N to 21.2°N and longitudes 80.5°E to 81.5°E. The region has a tropical climate with a distinct pre-monsoon season (March–June) characterized by high temperatures and low rainfall. Four freshwater ponds (table 1 and figure 2), located in both urban and peri-urban areas of Durg, were selected for sampling based on accessibility, usage (agricultural, domestic, or aquaculture), and potential pollution sources.

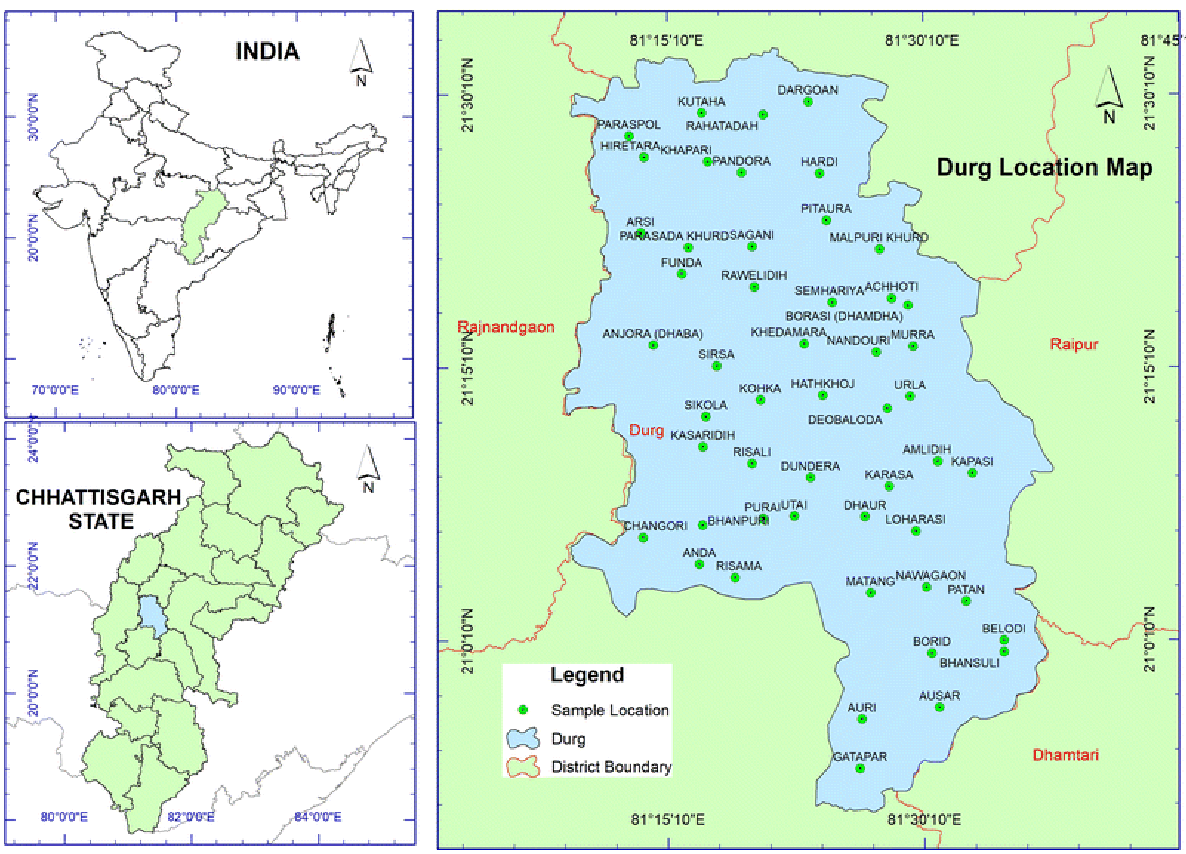

Figure 1: Map of Durg District (https://www.google.com/search/durgdistrict)

Table 1: Location of fresh water ponds of Drug district selected for the study

Pond Name	Latitude	Longitude
Kalyan Sagar Pond (KSP)	21.153737N	81.337986N
Maroda reservoir (MR)	21.161342N	81.348924N
Tandula canal (TC)	21.151777N	81.362799N
Risali Pond (RP)	21.155737N	81.335584N

2. Sampling collection

A total of four freshwater ponds were selected across different parts of the district (Table 1). Triplicate water samples were collected from each pond during the pre-monsoon season (April–May 2025). Samples were collected from the surface (10–15 cm depth) using pre-cleaned polyethylene bottles. All bottles were acid-washed, rinsed with distilled water, and finally rinsed with the pond water at the sampling site before final collection. To preserve dissolved metal ions, the obtained samples were promptly acidified to pH <2 with pure nitric acid (HNO_3) and kept in an icebox until analysis.

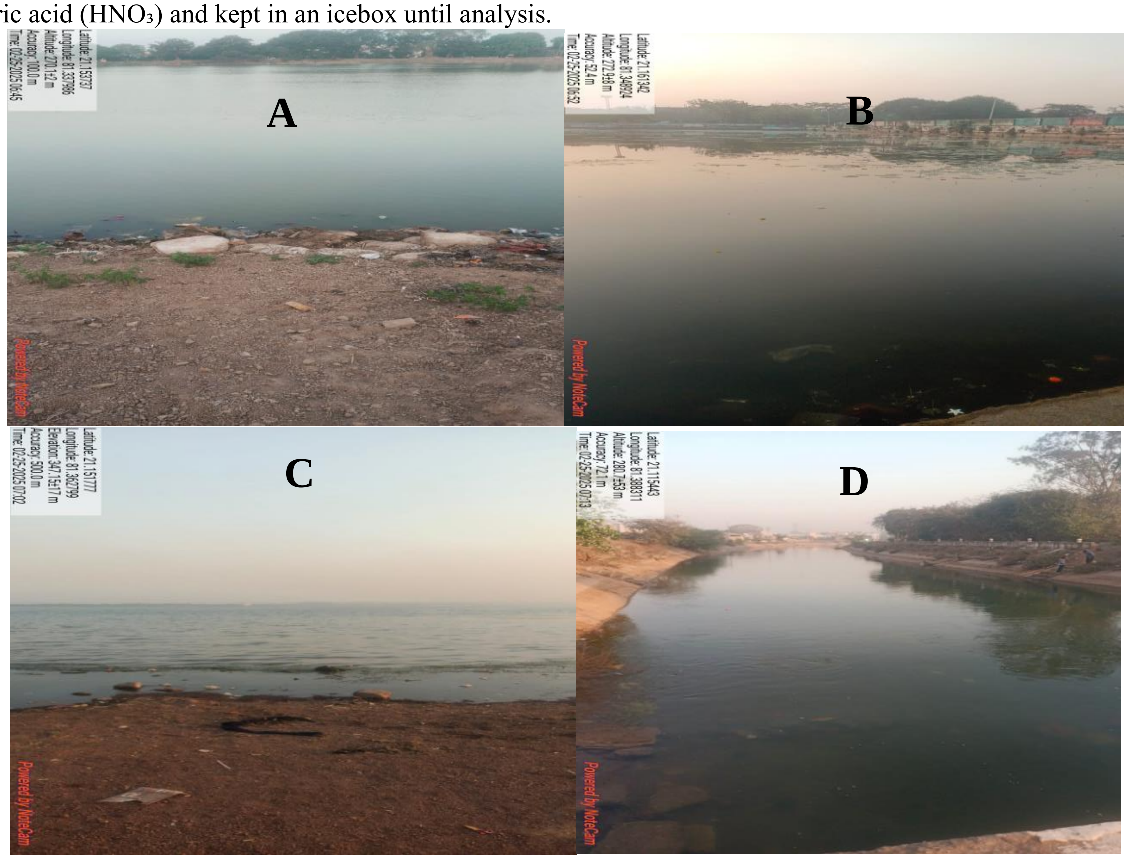

Figure 2: Study area site of Durg District (A) Kalyan Sagar pond (B) Maroda reservoir (C) Tandula canal (D) Risali Pond

2.2 Heavy metals analysis

The analysis of heavy metals in water samples using **Inductively Coupled Plasma (ICP)** is a highly effective and widely adopted technique due to its sensitivity, precision, and ability to detect multiple elements simultaneously. The process begins with the collection of water samples in clean, acid-washed polyethylene bottles, typically preserved with nitric acid (HNO_3) to prevent metal precipitation or adsorption onto the container. Before analysis, the samples are filtered to remove suspended solids and sometimes digested using acids to ensure all metals are in dissolved form. In the ICP instrument, the sample is converted into an aerosol and introduced into a high-temperature plasma (approximately 10,000 K), where the atoms are excited and ionized. These ionized atoms either emit light at specific wavelengths (in the case of ICP-OES) or are detected based on their mass-to-charge ratio (in ICP-MS). The intensity of the emitted light or ion count is directly proportional to the concentration of the metal in the sample. A calibration curve using known standards was used to quantify the metal concentrations. ICP is particularly useful for detecting trace levels (ppb to ppt) of heavy metals such as lead (Pb), cadmium (Cd), arsenic (As), mercury (Hg), chromium (Cr), and others.

Sample digestion and analysis were performed using ICP-OES instrumentation (Perkin Elmer, Optima 4100DV), following standardized methodologies outlined by the American Public Health Association (2005) and the United States Department of Agriculture (2008).

Lead (Pb), Cadmium (Cd), Chromium (Cr), Iron (Fe), Mercury (Hg), Arsenic (As), Tin (Sn), Copper (Cu), Molybdenum (Mo), Barium (Ba), and Manganese (Mn) are commonly heavy metals and Aluminum (Al), Calcium (Ca), Potassium (K), Magnesium (Mg), Sodium (Na), Phosphorus (P), and Boron (B) are generally considered essential elements in biological systems rather than toxic heavy metals, and Some elements like Iron (Fe), Copper (Cu), and Manganese (Mn) are essential micronutrients but can be toxic at high concentrations effect the fish species.

Results

The concentrations of 25 elements measured in four water samples—KSP, MR, TC, and RP—reveal distinct geochemical fingerprints. Many heavy metals (Al, Ti, Cd, Co, Cr, Ga, Ge, Ni, Pb, V, Zn) remained non-detected (ND) across all samples, indicating values below detection thresholds and suggesting minimal contamination. Major cations—Ca, Mg, K, Na—displayed pronounced differences among sources. Calcium (Ca) ranged from 26.12 ppm in KSP to 16.04 ppm in TC, with MR and RP at 19.21 ppm and 19.89 ppm respectively. Magnesium (Mg) declined consistently from KSP (7.19 ppm) through MR (4.10 ppm) and TC (3.55 ppm), reaching its lowest in RP (1.06 ppm). Conversely, Potassium (K) surged dramatically in RP (25.37 ppm), compared to modest values in KSP (3.94 ppm), MR (2.31 ppm) and TC (1.78 ppm). Similarly, Sodium (Na) is highest in RP (44.21 ppm), intermediate in KSP (24.49 ppm), and lowest in MR and TC (~7–8 ppm).

Table :2 Heavy metal concentration found in different fresh water ponds of Durg district.

S.No.	PARAMETERS (ppm)	KSP	MR	TC	RP	Permissible Limit (BIS)
1	Al	ND	0.02	0.2	0.07	0.2
2	Ca	26.12	19.21	16.04	19.89	200
3	Fe	0.06	0.08	0.12	0.14	1.0
4	K	3.94	2.31	1.78	25.37	12
5	Mg	7.19	4.1	3.55	1.06	100
6	Mn	0.12	0.04	ND	0.06	0.3
7	Na	24.49	7.8	7.13	44.21	200
8	P	0.01	ND	ND	0.01	0.1
9	Ti	ND	ND	ND	ND	0.1
10	B	0.0217	0.0088	0.0071	0.0444	5.0
11	Ba	0.1521	0.0387	0.0333	0.2018	1.3
12	Cd	ND	ND	ND	ND	0.003
13	Co	ND	ND	ND	ND	0.05
14	Cr	ND	ND	ND	ND	0.05
15	Cu	0.001	ND	ND	ND	1.5
16	Ga	ND	ND	ND	ND	0.01
17	Ge	ND	ND	ND	ND	0.001
18	Mo	0.0031	0.0001	0.0005	0.0006	0.07
19	Ni	ND	ND	ND	ND	0.02
20	Pb	ND	ND	ND	ND	0.01
21	V	ND	ND	ND	ND	0.01
22	Zn	ND	ND	ND	ND	15
23	As	0.005	0.0051	0.0041	0.0079	0.01
24	Hg	0.0002	0.0003	ND	ND	0.001
25	Sn	ND	0.0248	ND	ND	2.0

KSP=Kalyan Sagar Pond;MR= Maroda Reservoir;TC=Tandula Canal;RP=Risali Pond;ND= Not dectected;BIS=Bureau of Indian Standard.

Among trace elements, Iron (Fe) increased from 0.06 ppm in KSP to 0.14 ppm in RP. Manganese (Mn) was detected in KSP (0.12 ppm), MR (0.04 ppm), and RP (0.06 ppm), but ND in TC. Boron (B) followed a rising trend: MR (0.0088 ppm), TC (0.0071 ppm), KSP (0.0217 ppm), and RP (0.0444 ppm). Likewise, Barium (Ba) rose from MR (0.0387 ppm) and TC (0.0333 ppm) to KSP (0.1521 ppm) and RP (0.2018 ppm). Arsenic (As) ranged from 0.0041 ppm (TC) to 0.0079 ppm (RP). Molybdenum (Mo) and Mercury (Hg) appeared in trace amounts: Mo peaked at 0.0031 ppm in KSP, while Hg was detected only in KSP (0.0002 ppm) and MR (0.0003 ppm). Tin (Sn) was detected only in MR (0.0248 ppm) (table 1).

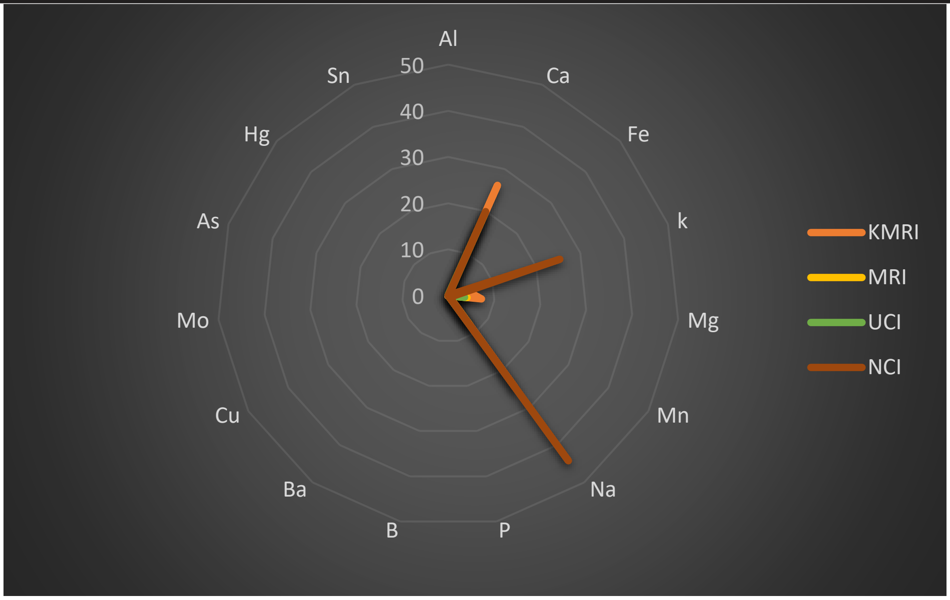

Figure 3: Concentration of heavy metals(ppm) in different water bodies of Durg district.

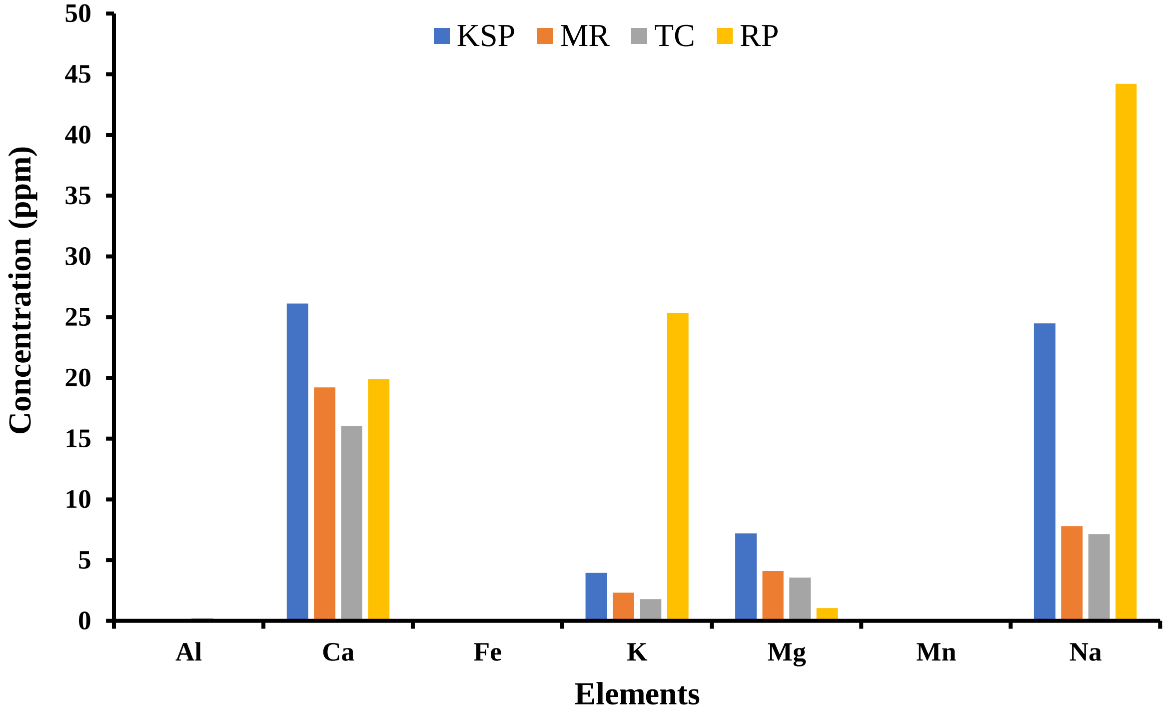

Figure 4: Concentration of various elements determine in fresh water bodies of Durg district.

The elevated Na, K, B, and Ba concentrations in RP mark it as chemically distinct. Such high ionic content suggests influence from saline or mineral-rich sources either geological (e.g., evaporite strata) or anthropogenic (e.g., agricultural runoff). In contrast, KSP's higher Ca and Mg indicate harder water, likely reflecting interactions with carbonate minerals. MR and TC consistently show lower levels of both macro- and trace-elements, possibly representing cleaner baseline or less impacted sources.

Comparing these results with WHO(World Health Organisation) and EPA(Environmental Proctection Agency) guidelines helps evaluate potential health and environmental implications. For instance, the WHO guideline for Arsenic is 0.01 mg/L (0.01 ppm). All measured as values (0.0041–0.0079 ppm) fall below this threshold, suggesting no immediate health risk. Barium guideline is 1.3 mg/L (1.3 ppm) by WHO and 2.0 ppm by EPA. With Ba values of ~0.15–0.20 ppm in KSP/RP, levels remain well under regulatory limits. Boron guideline (WHO) is 2.4 mg/L (2.4 ppm). All measured B (~0.007–0.044 ppm) is far beneath safety thresholds. Mercury guideline (WHO) is 0.006 ppm; detected Hg in KSP and MR (0.0002–0.0003 ppm) is more than an order of magnitude lower(Fig 3 and 4).

Regarding aesthetic or operational standards, the EPA recommends secondary levels for Manganese at 0.05 mg/L (0.05 ppm) to avoid taste, odor, or discoloration. KSP slightly exceeds this at 0.12 ppm, suggesting minor aesthetic concern, though still well below toxic thresholds. Iron secondary standard under EPA is 0.3 mg/L; measured Fe peaks at only 0.14 ppm in RP, acceptable both for health and taste.

There is no WHO limit for Na or K, but aesthetic and dietary considerations are relevant. Some state guidelines suggest sodium in drinking water ideally below ~20 mg/L (ppm). RP's Na (44.21 ppm) and K (25.37 ppm) exceed this aesthetic guideline and could impact taste or exacerbate dietary sodium intake. Elevated Na/K may also reduce the suitability of RP water for irrigation due to potential soil salinization or sodicity, impacting crop health and soil structure.

Overall, RP merits attention due to its significantly elevated Na, K, B, and Ba, even though all values remain within broader health-based limits. KSP shows moderate hardness (higher Ca/Mg) and low trace contaminants, representing a typical moderately mineralized water. MR and TC display minimal elemental content, suggesting relatively pristine sources.

Discussion

In summary, distinct compositional profiles are evident: RP is enriched in alkali and alkaline-earth elements, possibly reflecting mineral or anthropogenic inputs; KSP is characterized by consistent hardness indicators; MR and TC remain low-impacted. Although all measured trace elements fall below WHO/EPA health limits, RP's elevated ionic load raises aesthetic and agricultural suitability concerns. Mn in KSP slightly exceeds an EPA secondary standard, suggesting minor cosmetic issues. Regular monitoring—ideally including seasonal variations and additional parameters—is recommended, especially if RP water is considered for consumption or irrigation. These results offer a geochemical baseline useful for guiding further analysis, treatment strategies, and environmental assessment. Your data across KSP, MR, TC, and RP indicate notably low concentrations for both macro- and micro-elements. For instance, calcium (Ca) values range from ~16 ppm to ~26 ppm, and potassium (K) from ~1.8 ppm to ~25 ppm—much lower than levels reported in medicinal herbs, where Ca commonly reaches several thousand ppm (e.g., up to 18,300 ppm) and K up to ~21,600 ppm in savory and fenugreek (Pourimani . et al. (2019). Similarly, magnesium (Mg) in your samples ranges from ~1 to ~7 ppm, whereas comparable studies report Mg in the hundreds of ppm (e.g. ~177 ppm in fenugreek, even higher in other taxa).

Iron (Fe) in your sample's spans ~0.06–0.14 ppm, dramatically lower than the up-to-8,789 ppm observed in Caraway by Pourimani et al. Manganese (Mn), B, Ba, and Mo are present at sub-ppm levels in your data, whereas standards like the Long Ashton nutrient solution specify Mn ~0.55 ppm, B ~0.54 ppm, and Mo ~0.048 ppm in plant culture systems Hewitt indicating your samples are deficient even compared to ideal nutrient media. Sodium (Na) levels in your samples (~7–44 ppm) are again much lower than typical medicinal plant values, which can exceed 400 ppm or more.

Trace heavy metals such as lead (Pb), cadmium (Cd), Co, Cr, Ni, Zn, and Ti are mostly not detected in your samples, and arsenic (As), mercury (Hg), and copper (Cu) are present in trace sub-ppm levels—As around 0.004–0.008 ppm and Hg ~0.0002–0.0003 ppm. These values are consistent with expectations for low-contamination plant materials and notably below WHO/FAO permissible limits in herbal matrices (Ramsiya . et al. 2024). As per the samples taken during pre-monsoon the metals Mn and Cr resulted higher concentration and at the same time metals; Cu, Fe and Pb resulted in lower concentrations. Similarly, for the post monsoon samples, Mn, Cr and Fe found with higher concentration, while Cu and Pb resulted with lower concentration. (Tiwari et al 2015) Metals present in the water bodies in minute quantities become part of various food chains through bio magnification and their concentration increases to such a level that may prove to be toxic to both humans and other living organisms (Gupta et al., 2008) The increasing concentration of heavymetal has been correlated with the mining practices and growing population. The results shown in table1 indicates that the concentration of lead (Pb), Cadmium (Cd), Copper (Cu) Chromium (Cr)and iron (Fe)Ishihara theater sample of Mainpat. Cr, Zn and Pb are higher in the waters ample of Bhatgaon. Untether hand water sample of Kushmi contains higher proportions of iron and copper.

Ecological Consequences and Environmental Risk

As per the studies done in other parts of Chhattisgarh especially the industrial belts near Korba region close to Hasdeo River the water quality is getting worsened due to pollutant discharges. The detection of heavy metals like Cd & Cr are marginal and within limits but presence of Fe. And Pb. Are more than the desirable limits as per WHO. Mn is also found upto certain levels not permitted for washing of clothes. (Bhaskar et al 2020).

In another study done in Pakistan where sample was taken and certain parameters like temperature, transparency and the pH values were observed but the most important factor like salinity ie the concentration of ions in water showed varied fluctuations and also showed the variation of dissolved oxygen due to change in temperature (Ali et al 2005).

In the northern part of India, the river Ganga whose water is mainly used for irrigation, it was observed that the crops had high value of contamination and vegetables were not fit for use to human being because of the presence of heavy metals like Zn, Pb, Cu and Cd in the river Ganga (Sharma et al 2021).

The presence of heavy metals in aquatic habitats can lead to significant ecological disturbances. Sensitive fish species may be eliminated, reducing biodiversity and altering trophic dynamics. Chronic exposure to contaminated water can disrupt ecological balance and lead to the decline of fish populations. Furthermore, heavy metal pollution compromises water quality, affecting not only aquatic life but also agricultural practices and human health through drinking water contamination. Continuous monitoring and detection of these pollutants are thus essential for effective environmental management and biodiversity conservation. Contaminated water sources can lead to widespread ecological disruption, reducing fish populations and altering ecosystem balance. Heavy metal pollution can affect water quality, impacting agriculture, drinking water safety, and overall biodiversity conservation efforts.

Conclusion

This research underscores the critical impact of heavy metal contamination in the water bodies of Durg district, Chhattisgarh. Elevated concentrations of toxic metals such as Lead (Pb), Mercury (Hg), Cadmium (Cd), and Arsenic (As) were detected in all water samples, frequently exceeding permissible safety thresholds. The presence of these contaminants has led to various physiological and behavioral disruptions in fish, including organ damage, reduced reproductive performance, and altered swimming and feeding behaviors—clear indicators of toxic stress. These findings also raise serious public health concerns, as consumption of contaminated fish could lead to neurological disorders, kidney dysfunction, developmental abnormalities, and increased cancer risk in humans. Beyond individual species, heavy metal pollution poses a broader ecological threat by destabilizing aquatic biodiversity and disrupting food web dynamics. These disturbances ultimately affect water quality, agricultural productivity, and conservation efforts. Urgent and sustained intervention is essential to monitor and mitigate heavy metal pollution, ensuring the protection of aquatic ecosystems and public health

Acknowledgements
Authors are thanks to higher authorities of Kalinga University Naya Raipur, for their support and encouragement.

Declaration of Competing Interest
The authors declare that they have no known competing financial interests or personal relationships.

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