

# Water Quality and Heavy Metals Analysis of Ramgarh Lake, Gorakhpur: Ecological risk assessment

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## **Abstract**

Ramgarh Lake is a shallow urban wetland located at Gorakhpur, Uttar Pradesh, India. It receives domestic and municipal drainage throughout the year. We sampled at seven sites in Ramgarh Lake from April 2024 to March 2026. Three samples were taken from each site and analysed. Seven physico chemical parameters (pH, total solids, total suspended solids, total dissolved solids, chemical oxygen demand, biochemical oxygen demand, dissolved oxygen) were measured. Six heavy metals (Pb, Cd, As, Cu, Cr, Zn) were analyzed using standard procedures.

Water levels are low during the hot pre-monsoon (April) concentrating the pollutants. Biochemical oxygen demand (BOD) was as high as 210 ppm, dissolved oxygen (DO) plummeted below 0.5 ppm (anoxic) and lead (Pb) reached 4.34 ppm - over 400 times the World Health Organisation drinking water standard. Post-monsoon (October) dilution briefly improves the quality of water but metals are beyond permissible limits. One way ANOVA indicated strong seasonal changes ( $p < 0.001$  for all parameters). Principal component analysis (PCA) revealed three components explaining 78% of variance. The first component (47%) related organic pollution (BOD, COD) to Pb, Cd and Zn — an obvious sewage signal. Water Quality Index (WQI) found 54 per cent of the samples “unsuitable for drinking” and another 31 per cent “very poor”. The average Potential Ecological Risk Index (PERI) was 387 which represented a high ecological risk. Cd had the biggest contribution ( $E r i = 197$ ). Hierarchical clustering clustered stations S2, S5 and S6 as hotspots of pollution.

Hence, it is concluded that Ramgarh Lake is hyper eutrophic and severely contaminated with heavy metals throughout the year. Immediate diversion of sewage, engineered wetlands, targeted dredging and summer aeration are urgently needed to protect aquatic life and public health.

**Keywords:** Ramgarh Lake, heavy metals, water quality index, ecological danger, eutrophication, seasonal variation, sewage pollution.

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## **I. Introduction**

Most of the urban lakes in India have become dumping grounds for raw rubbish. Ramgarh Lake is located among the residential communities and is supplied by a number of drains conveying domestic sewage, kitchen trash and street runoff.

Ramgarh, like other lakes of tropics, shows severe seasonal fluctuations. In summer the weather is hot and dry and evaporation reduces the volume of water greatly. During monsoon time the lake is flooded and everything is diluted. The winter is not hard. Water quality is subject to significant variations due to natural cycles and a continuous influx of contaminants.

In summer the same amount of garbage is added to a considerably smaller volume of water and the concentrations of all the contaminants are increased. High temperatures also accelerate bacterial decay, which uses up oxygen and can leach harmful metals from the bottom mud. Heavy metals such as lead, cadmium and arsenic are especially harmful since they do not decompose. They are stored in the sediments and can be released back into the water if the oxygen level drops or the pH changes. They then get into the food chain.

Reports on metal contamination of Indian urban lakes are common but relatively few research have combined extensive seasonal monitoring with multiple pollution indices and multivariate statistics in one study. The work was intended to solve practical problems such as how water quality and metal levels change from season to season and from place to place. What are the reasons behind the poor condition of the lake? The total water quality index and ecological risk is what? Where are the worst hot spots? Our responses give definitive evidence that can inform restoration efforts.

## II. Literature Review

### 2.1 Eutrophication and Deoxygenation

Warm climate, shallow lakes are susceptible to eutrophication because high temperature and long hours of daylight are conducive to algae development. Algae die and, in their decomposition, oxygen is consumed. During summer in Dal Lake, Kashmir, BOD often crosses 15 ppm and DO goes down below 3 ppm (Rashid et al., 2019; Wani et al., 2020). Bottom water anoxia at Hussain Sagar, Hyderabad lasted for several months of the year due to urban runoff (Reddy et al., 2020). In our earlier investigation on tiny ponds around Gorakhpur, an obvious negative relationship was seen between water temperature and DO (Singh & Verma, 2018).

The difference with Ramgarh is the scale of organic load. BOD concentrations up to 216 ppm are more like raw sewage than natural lake. Such extremes have been observed only in few highly contaminated systems such as the Bellandur Lake in Bengaluru where industrial effluents have caused frothing and even occasional fires (Ramachandra et al., 2016; Sudarsan et al., 2018).

### 2.2 Heavy metal pollution of urban wetlands

Many lakes in India have heavy metals over permissible limits. For example in upper lake Bhopal, lead ranges from 0.08 to 0.42 ppm (Malik and Maurya, 2014). Lead in Loktak Lake, Manipur is 0.12-0.35 ppm (Singh & Singh, 2017). Vembanad Lake, Kerala contained 0.012 ppm of cadmium (Harikumar et al., 2009). In comparison, Ramgarh has an order of magnitude higher average lead (2.48 ppm) and cadmium (0.023 ppm).

There are similar concerns around the world. For example, Lake Chapala, Mexico, has roughly 0.08 ppm of lead (Hansen & van Afferden, 2001). Lake Taihu in China is extensively polluted by industry with lead up to 0.22 ppm (Wang et al., 2015). The figures we saw in Ramgarh are exceptional by worldwide standards.

Many scholars have pointed out that cadmium and lead are the most damaging to the environment, due to their high toxicity and accumulation in living creatures. In a risk assessment of Chilika Lake Pandey et al. (2021) revealed that cadmium contributed >60% of the overall PERI similar to what we see in Ramgarh. Insects and other tiny animals in contaminated urban wetlands can accumulate cadmium and lead at rates that may impact fish that eat them (Nair & Balakrishnan, 2018).

### 2.3 Seasonal remobilization of metals from sediments

The release of metals from sediments during anoxia of the bottom water is an essential phenomenon in shallow lakes. In normal, oxygen-rich environments, iron and manganese oxides operate like sponges, soaking up dissolved metals. In the absence of oxygen, the oxides are dissolved and the metals are set free again into the water. This has been established in laboratory experiments (Choudhury et al., 2022) and in field studies of European lakes (Salomons & Förstner, 1984). In the Indian setting, summer anoxia in a Delhi lake caused a threefold increase in dissolved lead in just weeks (Joshi & Kumar, 2019).

### 2.4 Water quality indices and multivariate statistics

The use of indices like WQI, HPI and PERI has become a norm in communicating pollution levels to policy makers. Indices have been applied successfully for ranking pollution hotspots in Ganga River (Singh & Gupta, 2020) and Yamuna River (Sharma & Kansal, 2019). Multivariate approaches like PCA and cluster analysis are now commonly used for source identification of pollution. PCA was employed by Kumar et al. (2019) to distinguish between urban sewage and agricultural run-off in a lake in Punjab. This is the foundation of our work.

## III. Materials And Methods

### 3.1 Study area and sampling locations

Ramgarh Lake (area ~723 ha) is located in Gorakhpur district, Uttar Pradesh (latitudinal extent 26°42'–26°45' N, longitudinal extent 83°23'–83°25' E). The climate in the area is subtropical monsoon type. Seven sites were selected to represent different types of pollutant input (Figure 1):

- S1 (Mohddipur)
- S2 (Padleganj)
- S3 (Nauka Vihar)
- S4 (Yaman Block)
- S5 (Veer Bahadurpuram)
- S6 (Avash Vikas Colony)
- S7 (Palm Paradise)

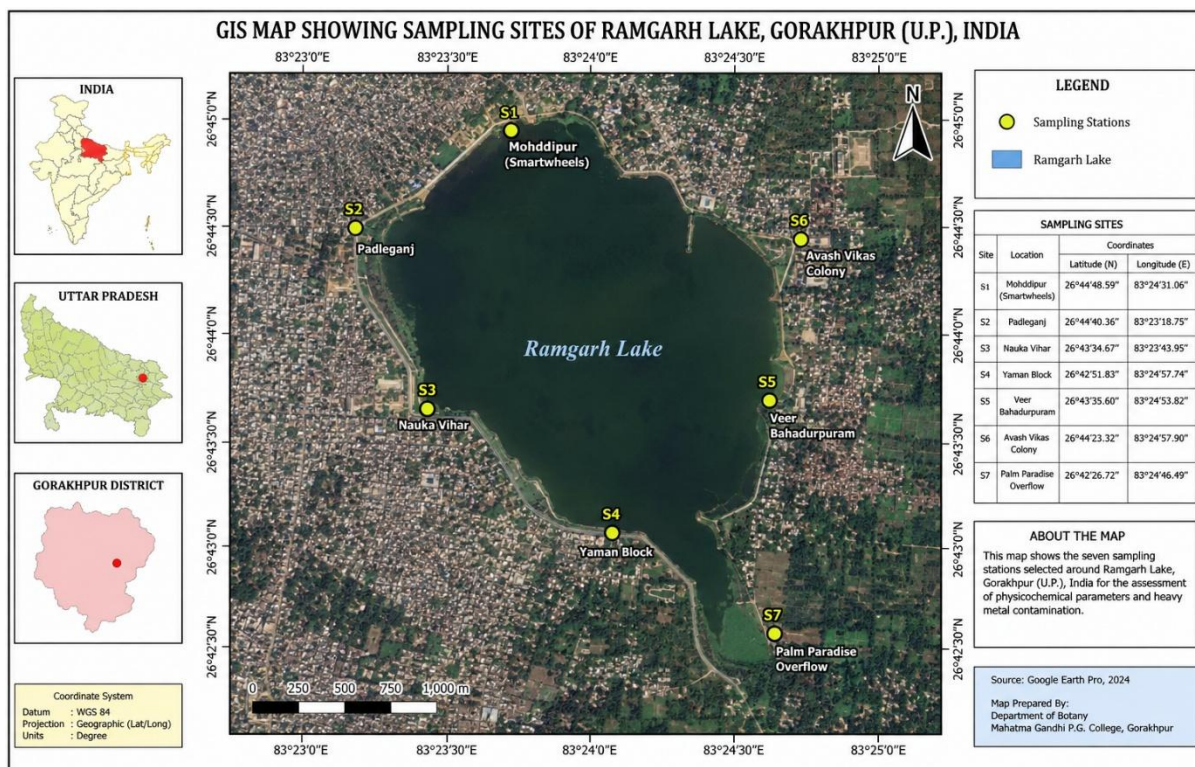


Figure 1. GIS map showing the sampling locations of Ramgarh Lake, Gorakhpur (U.P.), India.

### 3.2 Analysis and Sampling

Sampling was performed five times in April 2024 (peak summer), October 2024 (post monsoon), February 2025 (winter), September 2025 (late monsoon) and March 2026 (early summer). At each site three replicate water samples (1 litre) were taken immediately below the surface. Samples were kept in a cold box and delivered to the laboratory within 24 h.

Physico chemical characteristics were analyzed by conventional procedures (APHA, 2017) The pH was measured by a calibrated digital pH meter. Total solids (TS), total suspended solids (TSS) and total dissolved solids (TDS) were assessed by gravimetry. The chemical oxygen demand (COD) was measured by dichromate digestion. Biochemical oxygen demand (BOD) was determined as oxygen utilized in 5 days at 20 °C. Dissolved oxygen (DO) was estimated by Winkler's azide technique.

The heavy metals, lead (Pb), cadmium (Cd), arsenic (As), copper (Cu), chromium (Cr) and zinc (Zn) were measured by atomic absorption spectrophotometry after digestion with a mixture of nitric and hydrochloric acids (3: 1). Detection limits were 0.0005 to 0.003 parts per million. Recovery of spiked samples was between 94 and 103 %. All metal concentrations reported in this research are in parts per million (ppm), which is comparable to mg/L for water samples. All analyses were performed in triplicate and are presented as means.

### 3.3 Analyzing data

All statistical analyses were performed using R version 4.3.1 (R Core Team, 2023).

- Data was summarized using descriptive statistics (mean, standard deviation, minimum, maximum, coefficient of variation).
- Seasonal changes were analyzed using one-way ANOVA followed by Tukey's honest significant difference (HSD) post hoc test. Shapiro Wilk test was used to establish normality and Levene's test was used to check homoscedasticity. Assumptions were satisfied by log transforming some variables.
- Relationships between the 13 variables were examined using Pearson correlation.
- Principal component analysis (PCA) was conducted on standardised data (z scores). Suitability was tested using the Kaiser Meyer Olkin (KMO) measure (cut-off > 0.60) and the Bartlett's test of sphericity ( $p < 0.05$ ). Components with eigenvalues >1 were kept.
- Cluster analysis (hierarchical) (Ward, method) using Euclidean distance. The number of clusters was optimized using silhouette width.

We also computed four commonly used pollution indices:

**Water Quality Index (WQI)** – weighted arithmetic index (Brown et al., 1972) with respect to Indian drinking water standards (BIS IS 10500:2012). WQI classes: <50 excellent, 50-100 good, 100-200 poor, 200-300 very poor, >300 unsuitable for drinking.

**Heavy Metal Pollution Index (HPI)** – weighted arithmetic mean of the metal concentrations considering the permissible limits (Mohan et al., 1996). HPI <100 low pollution 100-200 medium >200 high.

**Pollution Load Index (PLI)** – geometric mean of the contamination factors ( $CF = C_{metal} / C_{background}$ ). The background values (ppm) of WHO (2017) and CPCB used by us were: Pb 0.01, Cd 0.003, As 0.01, Cu 0.05, Cr 0.05 and Zn 0.10. PLI <1 no pollution, 1-2 moderate, 2-3 high, >3 very high.

**Potential Ecological Risk Index (PERI)** –  $\sum E_{ri}$  where  $E_{ri} = T_{ri} \times CF$ . Toxic response factors ( $T_{ri}$ ) (Hakanson, 1980) Cd = 30 As = 10 Pb = 5 Cu = 5 Cr = 2 Zn = 1. Risk categories:  $E_{ri}$  <40 low, 40-80 moderate, 80-160 considerable, 160-320 high,  $\geq 320$  very high; PERI <150 low, 150-300 moderate, 300-600 considerable,  $\geq 600$  high.

#### IV. Results

##### 4.1 General water quality

The complete dataset (105 samples) is presented in Table 1. The numbers range widely. BOD ranges from 10.7 to 216 ppm, DO from 0.49 to 8.30 ppm, lead from 1.35 to 4.34 ppm. The coefficients of variation (CV) are over 70% for BOD, TSS, lead, cadmium, copper and zinc – indicating that the lake is not uniformly polluted. Pronounced seasonal and spatial variations are observed. Only pH (CV=8.2 %) and TDS (CV=29 %) are relatively stable.

**Table 1** Summary statistics of water quality of Ramgarh Lake (n = 105 samples). All heavy metal values in ppm.

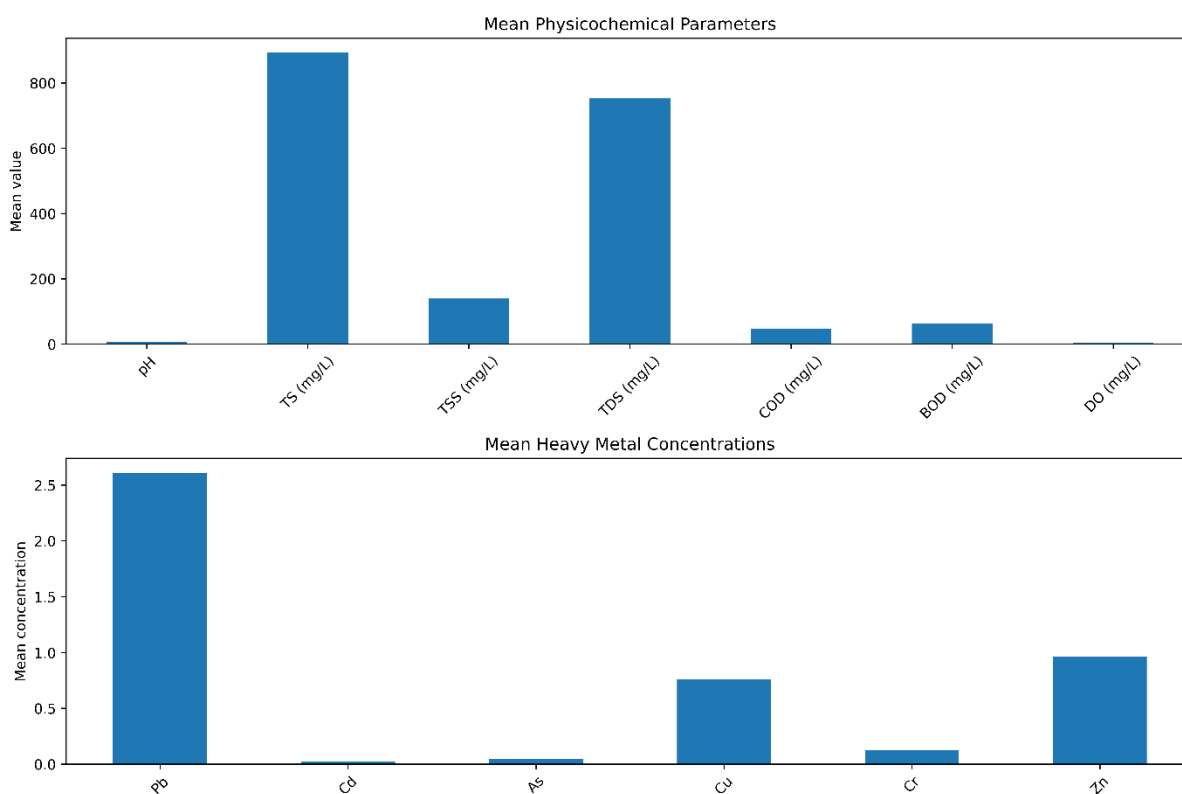
Parameter	Unit	Mean	SD	Min	Max	CV (%)
pH	–	6.34	0.52	4.87	7.31	8.2
TS	mg/L	890	342	419	1570	38
TSS	mg/L	156	110	21	310	71
TDS	mg/L	734	213	363	1273	29
COD	mg/L	52.8	35.4	13.9	113.8	67
BOD	mg/L	62.5	55.6	10.7	216	89
DO	mg/L	4.12	2.78	0.49	8.30	68
Pb	ppm	2.48	2.04	1.35	4.34	82
Cd	ppm	0.023	0.018	0.011	0.043	78
As	ppm	0.049	0.032	0.024	0.083	65
Cu	ppm	0.752	0.542	0.343	1.317	72
Cr	ppm	0.120	0.082	0.061	0.228	68
Zn	ppm	0.942	0.679	0.435	1.773	72

**4.2 Seasonal patterns**

One way ANOVA (Table 2) shows that season has a very strong effect ( $p < 0.001$ ) for each and every single parameter. April 2024 is by far the worst month. The average lead in April is 4.01 ppm, about three times higher than in February (1.4 ppm) and six times higher than in October (0.7 ppm). BOD averages 120 ppm in April at all stations and 23 ppm in October. DO shows the opposite trend with the highest DO in February (~7.1 ppm on average) and the lowest in April (~1.2 ppm).

**Table 2. Seasonal variations of selected parameters and pollution indices.**

Season	BOD (ppm)	DO (ppm)	Pb (ppm)	Cd (ppm)	Zn (ppm)	WQI	PERI
Apr 2024	120.2	1.23	4.01	0.038	1.58	428	612
Oct 2024	23.1	6.21	1.55	0.014	0.61	214	218
Feb 2025	33.4	7.10	2.79	0.025	1.02	268	302
Sep 2025	56.8	4.21	1.96	0.017	0.75	254	286
Mar 2026	84.2	2.85	2.99	0.027	1.15	386	498



**Figure 2. Physicochemical characteristics and heavy metal concentrations of Ramgarh Lake during the period of study: Seasonal variation.**

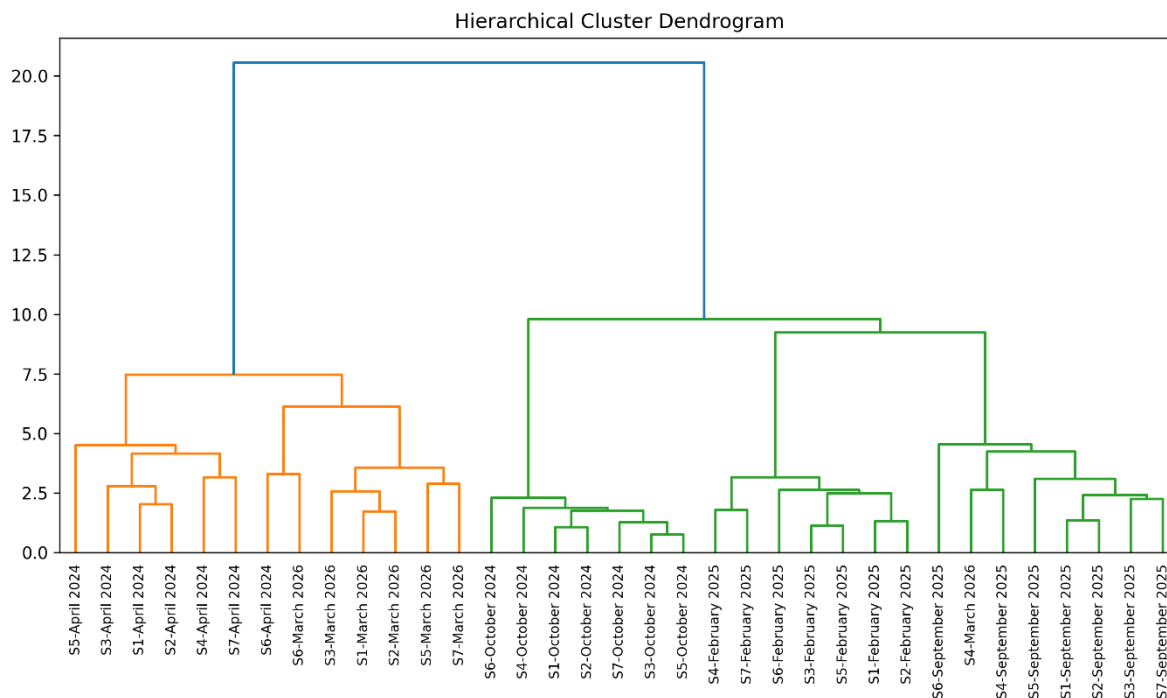
The cleanest is time October (post monsoon). Rain dilutes the lake, and all contaminant concentrations are reduced by 40-60% relative to April. Oxygen is brought back by mixing and lower temperatures. But in October, lead (1.55 ppm) was still 155 times the WHO drinking water guideline of 0.01 ppm. So “clean” is relative. The highest DO is in Winter (February), due to cooler water and less biological activity. But BOD is still over 30 ppm, ten times the standard for healthy aquatic life (3 ppm as per CPCB). March 2026 shows the first signs of summer stress. Water levels are now receding and BOD is back to > 80ppm. The lake begins to go downhill long before the height of summer heat.

### 4.3 Spatial patterns – pollution hotspots

Stations near the sewage inlets (S2, S5, S6) are always more polluted than the others. The average lead in S2 is 3.21 ppm and in S4 2.31 ppm. BOD was highest at S5 (max. 216 ppm in April) and DO was lowest at S6 (0.50 ppm in April). Station S4 (Yaman Block) is comparatively less contaminated probably due to more agricultural runoff and less raw sewage.

Hierarchical cluster analysis (dendrogram in Figure 3) resulted in three clusters of stations:

- Cluster 1 (high pollution): S2, S5, S6
- Cluster 2 (moderate pollution): S1, S3, S7
- Cluster 3 (least pollution): S4



**Figure 3. Hierarchical cluster analysis of the sampling observations.**

Hierarchical clustering was performed using Ward’s minimum variance method on Euclidean distance. The dendrogram classifies the sampling stations according to the similarities in physicochemical properties and heavy metal concentrations, differentiating highly polluted, moderately polluted and relatively less polluted groups. We noticed this in field observations: S2 is a direct drain outlet; S5 and S6 are shallow stagnant zones where organic matter accumulates.

### 4.4 Correlation and principal component analysis

A heatmap of the correlation matrix is plotted in Figure 4 showing very strong positive correlations ( $r > 0.80$ ) between BOD, COD, TS, lead, cadmium, zinc and copper. These all originate from the same source – untreated sewage. DO is strongly negative with these variables ( $r$  about  $-0.85$ ), confirming that oxygen depletion is the main symptom of organic loading.

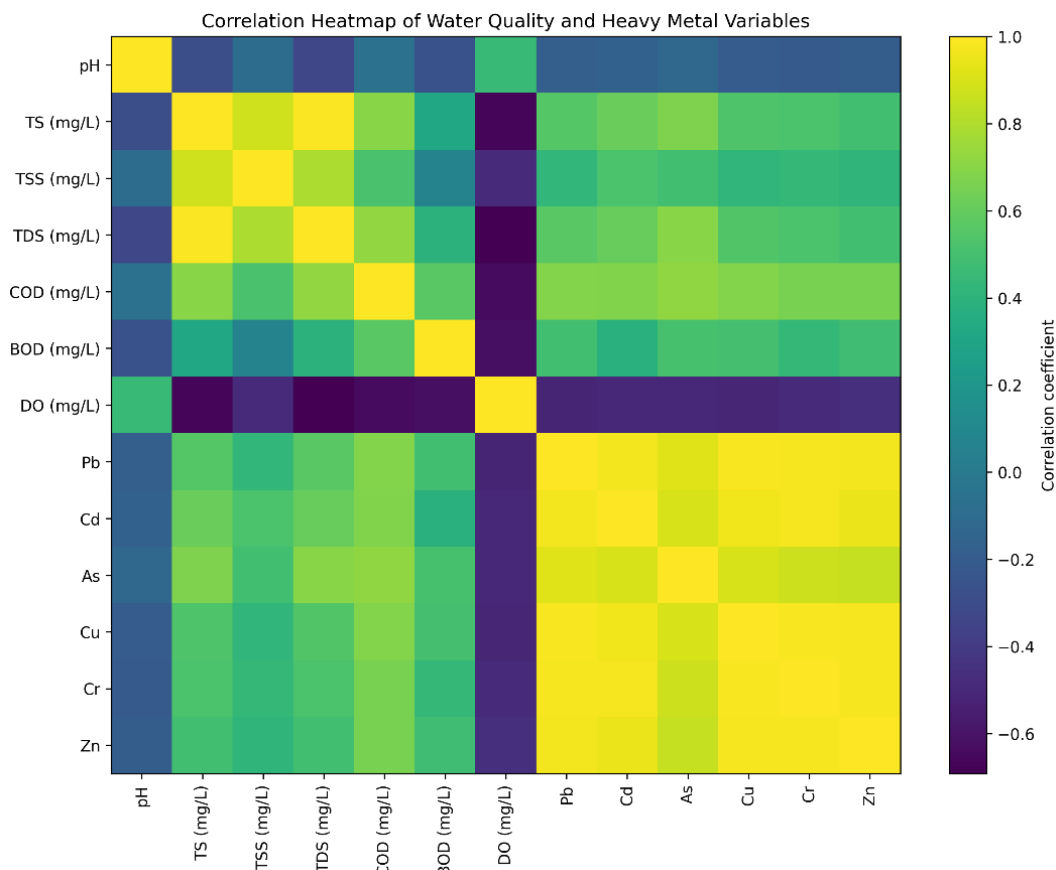


Fig. 4. Heatmap of correlation between heavy metals and physicochemical parameters in Ramgarh Lake. Positive correlations show co-occurrence patterns and possible common sources of pollution, while negative correlations show inverse relationships like that between dissolved oxygen and pollution indicators.

PCA extracted three principal components explaining 78% of the total variance (Table 3).

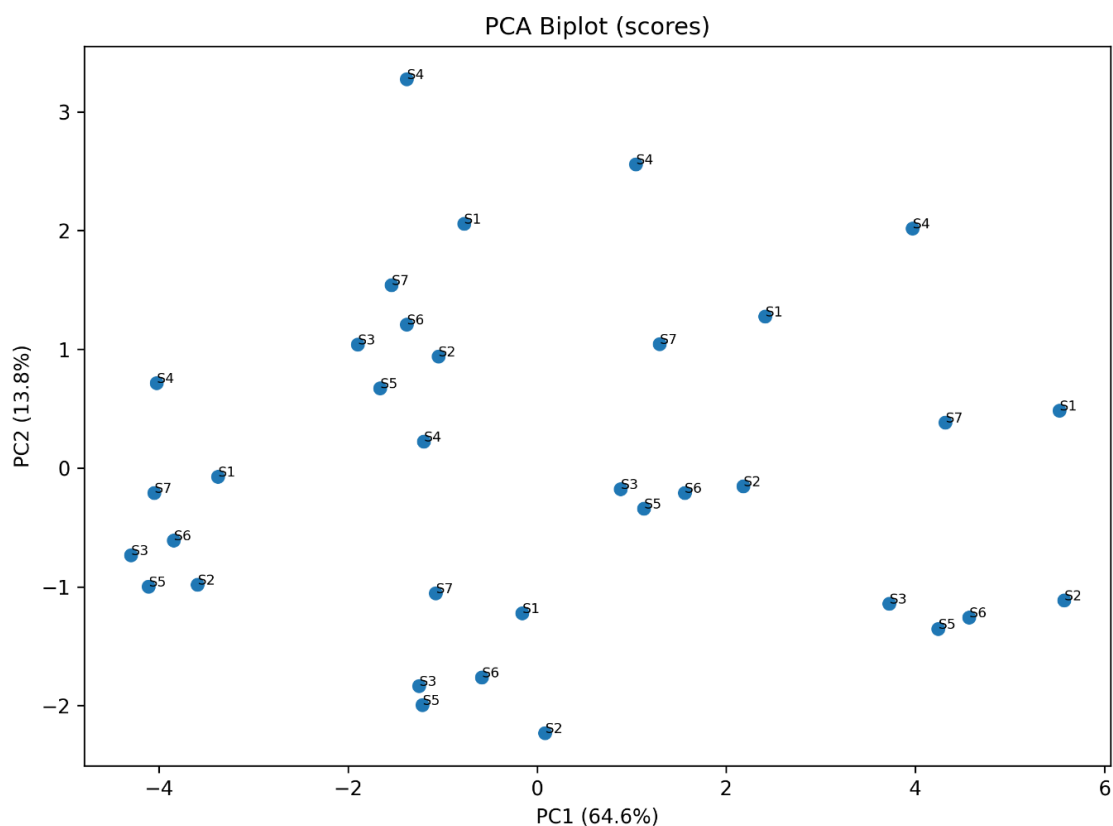
- PC1 (47% of variance): characterized by high positive loadings of BOD, COD, lead, cadmium, zinc, copper and negative loading of DO. We interpret this as an axis of “sewage + metals”.
- PC2 (20% of the variance): high loadings on chromium, arsenic and TSS. This may be a different source – possibly small scale electroplating or residues of pesticides in the past.
- PC3 (11% variation): pH and DO – the natural buffering and re-aeration process.

**Table 3: PCA rotated component loadings. Loadings above 0.70 are in bold.**

Parameter	PC1 (47%)	PC2 (20%)	PC3 (11%)
pH	-0.22	-0.18	<b>0.81</b>
TS	<b>0.86</b>	0.21	-0.24
TSS	0.45	<b>0.72</b>	0.11
TDS	0.68	0.19	-0.43
COD	<b>0.91</b>	0.12	-0.18
BOD	<b>0.94</b>	0.08	-0.22

Parameter	PC1 (47%)	PC2 (20%)	PC3 (11%)
DO	<b>-0.88</b>	-0.15	0.31
Pb	<b>0.89</b>	0.24	-0.11
Cd	<b>0.92</b>	0.19	-0.08
As	0.36	<b>0.77</b>	-0.05
Cu	<b>0.83</b>	0.33	-0.09
Cr	0.41	<b>0.81</b>	0.07
Zn	<b>0.90</b>	0.22	-0.14

The PCA biplot (Figure 5) clearly separates April samples (high PC1) and October samples (low PC1). Winter- and spring samples are intermediate.



**Figure 5. Water quality parameters: Principal component analysis (PCA)**

(A) Scree plot of percentage of total variance explained by each principal component. Components with eigenvalues >1 were retained using the Kaiser criterion.

(B) PCA biplot displaying the spatial distribution of the sampling observations and the loadings of the variables on the first two principal components. The vectors indicate the magnitude and direction of the contribution of variables. Samples are grouped due to similar physico-chemical characteristics. Variables with similar direction are positively correlated.

4.5 Water quality and risk indices

#### 4.5 Water quality and risk indicators

**Water Quality Index (WQI)** - Samples of October (post monsoon) only fall under the “poor” category (WQI 100-200). During summer, winter, and most of the spring, samples are either “very poor” (200–300) or “unsuitable” (>300). The overall mean WQI is 342 which describe the water is not safe for drinking and even for direct contact recreation.

**Heavy Metal Pollution Index (HPI):** Critical value is 100. Our HPI is 245 overall – well above threshold. April samples 387, October 118. The best season is still over the critical index.

**Pollution Load Index (PLI):** A value greater than 1 indicates human caused enrichment. Our PLI is from 2.34 (October) to 4.56 (April). The entire PLI is 3.48 indicating very high pollution load.

**Potential Ecological Risk Index (PERI):** An aggregate PERI of 387 indicates “considerable to high ecological risk”. Cadmium alone accounts for 197 points (very high risk), followed by lead (118). Zinc and chromium add very little. It is the most important concern for risk management to reduce cadmium and lead.

### V. Discussion

#### 5.1 Why is Ramgarh Lake so polluted in summer?

Two things are happening at the same time. Firstly, there is a loss of water by evaporation. Concentrations increase. The same waste load goes into less water. Secondly, warm water and a large amount of organic matter start a chain reaction where bacteria quickly break down the organic waste and use up all the available oxygen. If the DO concentration drops below roughly 2 ppm, the surface of the sediment becomes anoxic. Under these conditions the iron and manganese oxides that usually bind the heavy metals dissolve and release the toxic metals back into the water column. This is why the levels of lead and cadmium in April are much higher than could be accounted for by evaporation alone.

This seasonally occurring “trap” is common in shallow tropical lakes, but the severity at Ramgarh is exceptional. BOD levels above 200 ppm are indicative of raw sewage, not a natural lake. In effect, during summer the lake acts as an open waste stabilisation pond.

#### 5.2 What makes Ramgarh different from other lakes?

**Similar cycles of reduced intensity have been reported in Bangalore for Bellandur Lake**, with BOD values of 80–120 ppm in summer (Ramachandra et al., 2016) and in Manipur for Loktak Lake with peak values of 18 ppm in BOD (Singh & Singh, 2017). Ramgarh is unusual in having both extreme BOD (>200 ppm) and extreme metal contamination (lead >4 ppm). We are unaware of any other Indian lake with routine lead levels in the water column above 1 ppm; most studies report values below 0.5 ppm (Malik & Maurya, 2014; Harikumar et al., 2009).

And there is also post-monsoon recovery elsewhere. After monsoon flushing, Dal Lake has better DO and lower nutrients (Wani et al., 2020). But even the ‘clean’ October water in Ramgarh has lead at 1.55 ppm – still 150 times the WHO guideline. This indicates that the background metal load from sediments is already very high and that dilution alone will not restore the lake to a safe state.

DO is highest in winter (Feb) in Ramgarh (upto 8.3ppm) similar to temperate lakes but BOD is still more than 30ppm. In a healthy lake winter BOD should be < 3 ppm (CPCB, 2012). So, Ramgarh never really recovers.

#### 5.3. Source of heavy metals

The high correlations of lead, cadmium, zinc and copper with one another and with BOD and COD (PC1) unambiguously indicate the main source as untreated sewage. This is consistent with the observations in Vembanad Lake, where a similar metal organic consortium was associated with municipal waste (Harikumar et al., 2009). However, in Chilika Lake metals were more associated with industrial effluents (Pandey et al., 2021). There are no major industries around Ramgarh, which supports our sewage hypothesis.

The secondary axis (PC2) is more puzzling with chromium and arsenic. Chromium is often a reference to leather tanning or chrome plating. Gorakhpur does not have any big tannery but there are small scale electroplating units and metal finishing workshops in the city. Arsenic may be of agricultural pesticides (used in the past) or from natural sources – the Gangetic plains are known to have arsenic in groundwater (Chakraborti et al., 2016). This is where sediment core analysis comes in.

The sharp increase in metals between March and April, before peak evaporation, is a strong signal for remobilization of sediment in anoxic conditions. Similar observations have been reported from lake Erie (USA) where summer hypoxia triggers iron bound metal release (Biddanda et al., 2018). Anoxic events in Lake Taihu (China) resulted in a five-fold increase in dissolved cadmium over two weeks (Wang et al., 2015). Our data show similar trend.

#### 5.4. Ecological and Public Health Hazards

The PERI value of 387 pointed out high ecological risk for Ramgarh Lake. By way of comparison, PERI in Chilika Lake is 150-300 (moderate to considerable risk) (Pandey et al., 2021). The PERI of Upper Lake, Bhopal is about 120 (low to moderate) (Malik & Maurya, 2014). Ramgarh is one of the most dangerous lakes in India.

Cadmium is the highest contributor of PERI ( $E r i = 197$ ) followed by lead (118). Cadmium is a known carcinogen and causes kidney damage. Even a long term exposure to a mean Cd concentration of 0.023 ppm can be detrimental. The WHO drinking water guideline is 0.003 ppm – the lake has an average of almost eight times excess than that and 14 times in April.

People eating fish from Ramgarh are under threat. The accumulation of cadmium and lead in the muscles and liver of fish caught from contaminated lakes has been reported by various studies. Lead levels in *Labeo rohita* from a polluted tank in Hyderabad were 1.2 ppm (wet weight) which is above the FAO/WHO limit (Murtaza et al., 2015). No fish were measured here but given the water concentrations, we strongly suspect that fish from Ramgarh would also exceed safe limits.

#### 5.5 Comparison with Drinking Water Standards.

A quick comparison makes the severity clear:

Parameter	WHO drinking water guideline	Ramgarh (mean)	Ramgarh (April max)	Typical range in other Indian lakes
Pb (ppm)	0.01	2.48	4.34	0.05–0.50
Cd (ppm)	0.003	0.023	0.043	0.002–0.010
As (ppm)	0.01	0.049	0.083	0.005–0.030
DO (ppm)	>5 (for aquatic life)	4.12	0.50	3.0–6.0

The levels in Ramgarh Lake are one to two orders of magnitude higher than normal polluted Indian lakes. This isn't just a local problem; it's a public health emergency waiting to happen.

## VI. Conclusions

The lake in Ramgarh is in a bad condition. Based on two years of monitoring, supported by statistical analysis and multiple pollution indices, the lake undergoes an extreme seasonal cycle, from a highly toxic, anoxic state in pre monsoon to a moderately polluted, but still unsafe state in post monsoon. No season fits drinking water or even aquatic life criteria.

Contamination by heavy metals is serious. Lead and cadmium are the most hazardous at 150–400 times higher than WHO guideline levels. The Potential Ecological Risk Index (387) shows a high risk to the ecosystem – more than many other polluted Indian lakes.

The primary culprit is untreated sewage. BOD, COD, lead, cadmium and zinc strongly correlate, which directly points to municipal drainage. Three stations (S2, S5, S6) are hotspots and should be focused on for intervention.

We did not analyze sediments, which probably have 100-1000 times higher metal concentrations than water. These sediments may be long-term internal source of heavy metals. Flow measurements of incoming drains would allow for mass loading calculations. These are guidelines for future work.

Our study recommends diversion of the main sewage carrying drains into settling ponds or constructed wetlands before they reach the lake. Regular monitoring programme (monthly sampling at key stations) and enforcement of pollution control regulations on nearby colonies may be useful for the health of Ramgarh Lake. It can also remove some metals by means of phytoremediation.

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