Evaluation of Water Quality in the Agricultural Fields Surrounding the Rajpura Dariba Mining Region

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Abstract: ***The areas surrounding the mining region often bear the increased burden of mining waste, even with the implementation of waste management practices. Heavy metal contamination and disturbance in normal physicochemical characteristics pose a serious threat to the ecosystem. Consequently, regular monitoring and management of susceptible environmental systems are essential to prevent the harmful effects of waste exposure on local flora and fauna. This instigated the inception of the present study to assess the water quality indices (WQI) in the region surrounding the Rajpura Dariba mining area, in Rajsamand district, Rajasthan, India. Water samples were collected from croplands and dumping sites near the mining area during the pre-monsoon and post-monsoon seasons. These samples were analysed for quality parameters like pH, EC (Electrical conductivity), TDS (total dissolved solids), Cl^- (chloride), TH (Total Hardness), Mg^{+2} (Magnesium), Ca^{+2}(Calcium), and F^- (fluoride), using standard procedures. The samples were also assessed for lead, Cadmium and Zinc contamination levels using Atomic Absorption Spectrometry (AAS) methods. The results indicate that the water quality parameters significantly deviated from the standards established by the World Health Organisation (WHO) and the Bureau of Indian Standards (BIS). Furthermore, the water quality indices suggest that the water samples are of poor quality and unsuitable for drinking purposes. Hence, the study concludes that the water in this area needs to be treated before being used for agricultural and domestic purposes to prevent severe toxicological implications.***

Keywords: Rajpura Dariba, Water quality, Heavy metal, toxicological implications, WQI

1. Introduction

Water is a crucial resource for all living organisms, as social and economic progress relies on this vital resource(1). This vital resource is severely threatened by resource exploitation and human activities, which exacerbate environmental degradation(2). The release of toxic elements from mining and industrial operations severely compromises water quality, leading to the contamination of nearby water bodies with pollutants such as heavy metals, suspended solids, acidic runoff, and other toxic compounds(3) .Mining activities pollute surrounding water bodies, either through the extraction of heavy metals or the use of compounds in metal processing (4).

Numerous research studies have highlighted the potential health risks associated with heavy metals, particularly due to prolonged and repeated exposure. These toxic elements, which can accumulate in various environmental components, raise significant concerns regarding their long-term effects on overall well-being and disease susceptibility.(5)

Therefore, the monitoring of metal load and physicochemical parameters, such as pH, temperature, TDS, TH, and salts present in water can provide valuable details about the status of water quality (6). Further, these assessments help in the timely adoption of various water management and remediation strategies (6,7).

Mining activities are often associated with significant environmental issues, particularly concerning water contamination and its impact on living organisms. Therefore, the monitoring of water quality in the region surrounding mining area Rajpura Dariba in Rajsamand district of Rajasthan, India is necessary. This mining region is known for the extraction and processing of metals such as zinc, cadmium, and lead, and has been commissioned since 1983 by Hindustan Zinc Limited. Despite the proper waste management practices, the possibility of waste leakage cannot be omitted in the vicinity of the site. Therefore, this study focuses on assessing the physicochemical parameters of samples collected from water bodies located around the Rajpura Dariba mining region. Samples were collected in two seasons and were compared with the standard values provided by BIS(8) & WHO(9,10) The primary objective of this investigation is to examine the state of water quality degradation in water bodies resulting from mining activity and its impact on the ecosystem. The findings of this study have the potential to significantly contribute to a better understanding of the environmental consequences of mining. It establishes a framework for future research on water resource protection and prepares prospective remediation strategies to enhance the quality of the water in these impacted areas. Such methods are desperately needed, and our research attempts to achieve this vital aim.

2. Material & Method

2.1 Study Area and Sampling

Water samples were collected from the Rajpura Dariba mining area, located in the Railmagra tehsil of Rajsamand, near Udaipur, Rajasthan, for a water quality assessment. All samples were taken from groundwater sources, including borewells, wells, and natural water bodies such as ponds. These sampling sites were located on agricultural land, at various distances (ranging from 50 to 100 meters) from the dumping yards of metal mining and processing units. The sampling area is defined between 24°58' North latitude and 74°08' East longitude, to 24°57' North latitude and 74°08' East longitude. 30 water samples were collected during the pre-monsoon and post-monsoon seasons in June 2021 and December 2021, respectively. Samples for physicochemical and metal analysis were obtained in sterilised glass bottles. Before sample collection, the water was run for 5 to 10 minutes to avoid contamination from agricultural activity or other external sources.

2.2 Physicochemical Analysis

The samples were examined for physicochemical parameters, including pH, EC (Electrical conductivity), TDS (total dissolved solids), Cl^- (chloride), TH (total hardness), Mg^{+2} (Magnesium), Ca^{+2}(Calcium), and F^- (fluoride), using standard procedures described in BIS series 3025(Table 1). Metals such as Lead (Pb), Cadmium (Cd), and Zinc (Zn) were estimated using a furnace Atomic Absorption Spectrophotometer (AAS, model A Analyst 100, Perkin Elmer) with standard methodologies of APHA at Team Test House, Jaipur. pH, EC, and TDS were analyzed at the sampling site using a water analyzer kit (Konvio neer portable pH, EC meter). TH, Cl^-, Ca^{+2}, and Mg^{+2} were evaluated using the titrimetric method. The analysis results were assessed and compared with the desirable limits of BIS (2012) and the guidelines provided by WHO (2011 and 2022).

Table 1: Methods used for physicochemical and metal analysis

S. No	Parameter	Method	References
1	pH	Apparatus pH meter	-
2	EC and TDS	Apparatus EC meter	-
3	TH	EDTA titrimetric method	IS 3025(Part 21) of BIS
4	Calcium	EDTA titrimetric method	BIS manual IS 3025(Part 21)
5	Magnesium	EDTA titrimetric method	BIS manual IS 3025(Part 21)
6	Chloride	Mohar's method	BIS manual IS 3025(Part 32)
7	Fluoride	Electrochemical Probe method	BIS manual IS 3025(part 60)
8	Metal estimation	AAS	-

1.3 Statistical Analysis

Triplicates of each sample were used to determine the average value. The data are reported as Mean ± Standard deviation. The statistical comparison was performed between the studied samples and the Standard by Student's t-test at a high significance level of $p< 0.001$, a significant level of $p<0.01$, and a statistically significant level of $p< 0.05$. The WQI was calculated by using the formula of Brown et al.(11) The quality rating scale (Qn) for each parameter was calculated by dividing its mean concentration in each water sample (Vn) by its respective standard value (Sn) as per BIS 2012, and the results were multiplied by 100.

$$Qn = \frac{Vn}{Sn} \times 100$$

The WQI for each sample was calculated with the following formula(11,12)

$$WQI = \frac{\sum WnQn}{\sum Wn}$$

Where Wn=K/Sn

K in this formula is the constant of proportionality, which is calculated by $K = \frac{1}{\sum Sn}$

WQI was compared to the water quality classification ranges and types of water based on WQI values, as mentioned in research reports(6,13)

Table 2: Types of water quality according to the range of WQI [6]

Range of WQI	Type of water quality
50	Excellent
50-100	Good
100-200	Poor
200-300	Very Poor
>300	Unsuitable for drinking purposes

3. Result & Discussion

pH: The water was slightly alkaline, with pH levels of the samples ranging from 7.35±0.30 to 8.69±0.26 during the pre-monsoon season, and from 6.81±0.2 to 8.28±0.03 during the post-monsoon season (Figure 1A). The alkaline nature of the water may be attributed to the inflow of bicarbonate ions into the groundwater as rainwater penetrates through the soil(14,15). Except two samples from the pre-monsoon season, all collected samples were within the permissible limits set by the Bureau of Indian Standards (BIS) and the World Health Organization (WHO)(Table 3).

EC: Electrical Conductivity (EC) is the indicator of water salinity. EC is either the capacity of a substance or the ability of a solution to conduct an electric current. The EC of samples ranged between 2445±5 and 5624±5.29 µS/cm in pre-monsoon and between 1705±4.04 and 4626±7.09µS/cm in post-monsoon season (Figure 1B). WHO does not set specific limits for electrical conductivity but recommends that water samples having EC between 500 to 1000µS/cm can be considered safe for drinking(10). Since the results indicate high conductivity compared to the range set by the WHO (Table 3) so water is not suitable for drinking. High electrical conductivity indicates that the water contains a large amount of dissolved ions, which can be due to salts, minerals, and pollutants.

TDS: Total dissolved solids (TDS) in a water sample indicate the dissolved amount of various inorganic salts such as sulphate, phosphate, carbonate, bicarbonate, chloride, etc, in water. The TDS of samples ranged between 1225± 4.35 and 2811±1.52 mg/L in pre-monsoon and between 823±1.02 and 2310±1.04mg/L in post-monsoon season (Figure 1C). All the water samples had TDS above the acceptable limits when compared to standard values of BIS & WHO (Table 3). High concentration of TDS can affect people suffering from chronic health problems such as kidney and heart diseases, and can cause a laxative effect on human.(16)

TH: Total Hardness (TH) is the demonstration of the total concentration of Mg^{+2} and Ca^{+2} mg/L which are equivalent to $CaCO_3$(17). All the water samples that were collected in the pre-monsoon season had TH values between 608.61±1.20 and 3344.57±51.14 mg/L, whereas in the post-monsoon season, TH values ranged between 731.02±0.63 and 2847±0.63 mg/L (Figure 1D). The total hardness (TH) of the water samples was evaluated against the standard values set by the Bureau of Indian Standards (BIS) and the World Health Organization (WHO) (see Table 3). The results obtained from both seasonal assessments exceeded the permissible limits established by these organizations. So, these samples fall under the hard category for consumption, as per studies, water is considered hard above 180 ppm(6) , and their consumption can cause various diseases such as cardiovascular disorders, renal dysfunction, reproductive abnormalities, etc(18).

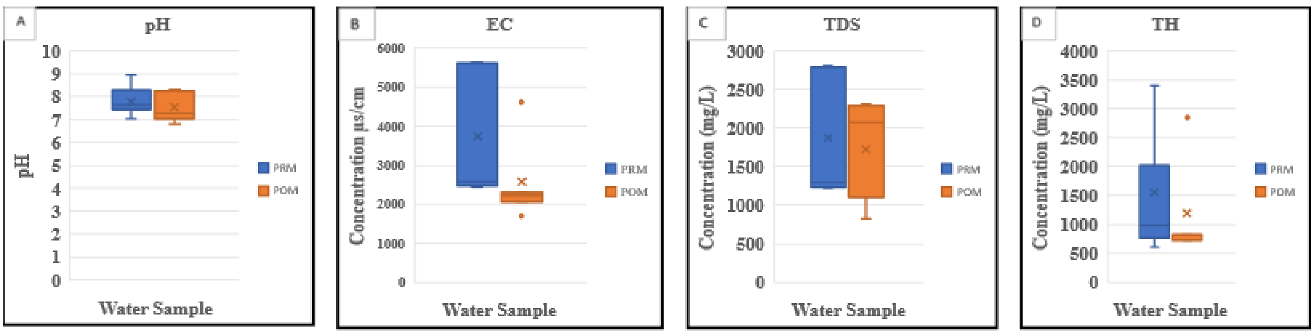
Magnesium: Magnesium (Mg^{+2}) in water can originate from the natural weathering of rocks, mine drainage, and the dissolution of magnesium-containing minerals (19). Magnesium was available in abundance in the sampling area. The magnesium content in water samples ranged between 77.02±0.88 and 462.48±2.53 mg/L in the Pre-monsoon season and between 89.26±0.65 and 379.16±0.76 mg/L in the Post-monsoon season (Figure 1E). The level of magnesium in the water exceeds the permissible levels set by the WHO and BIS (Table 3). High amounts of magnesium and calcium, commonly referred to as hard water and can cause renal dysfunction, and in some cases, this hypermagnesemia can cause cardiovascular complications(20).

Calcium: Calcium (Ca^{+2}) can occur either by the decomposition of phosphate and sulfate minerals or in groundwater through the dissolution of carbonate minerals(21). The calcium content in water ranged from 165.33±0.84 to 598.25±2.06 mg/L during pre-monsoon sampling and from 134.53±0.51 to 185.00±0.95mg/L during post-monsoon sampling (Figure 1F). The results indicate a higher amount of calcium than the standard limits of WHO and BIS (Table 3). Calcium in moderation is considered beneficial for humans, but in the case of hypercalcemia, it can cause kidney stones and other health issues. It can cause negative health effects when combined with magnesium(22).

Chloride: Chloride is present in all water bodies, resulting from both natural and anthropogenic activities. The major source of chloride in water is industrial effluents, discharge from metal smelting, flue gas desulfurization, and inland seawater desalination(23). The chloride content in water samples ranged between 327±2.26 and 2292.38±3.99 mg/L in the pre-monsoon season and between 273.96±0.45 and 2054.68 ±0.96mg/L in the post-monsoon season (Figure 1G). Thus, a high quantity of chloride was observed in the studied water samples as compared to BIS and WHO (Table 3). The high chloride content in water indicates water pollution and the presence of a high amount of organic matter(24). The lower the chloride content in water, the less polluted it is.

Fluoride: Fluoride contamination in water primarily originates from the weathering of fluoride-bearing minerals in the surrounding rocks and industrial discharge(25) The fluoride content in the water sample ranged between 3.80±0.02 and 5.59±0.35 mg/L in the pre-monsoon season and between 1.53±0.005 and 2.08 ±0.02mg/L in the post-monsoon season (Figure 1H). All the water samples had a high quantity of fluoride compared to the permissible limits set by BIS (1 mg/L) and WHO (1.5 mg/L) (Table 3). Fluoride ions are highly significant in water quality monitoring. High fluoride concentration in water can cause damage to the skeleton and tooth decay(26). Thus, high concentrations of fluoride ions in water can be harmful to humans.

Comparison of physicochemical analysis in Pre-monsoon (PRM) and Post-monsoon (POM) is explained by the following graphs (Figure 1 A to H).



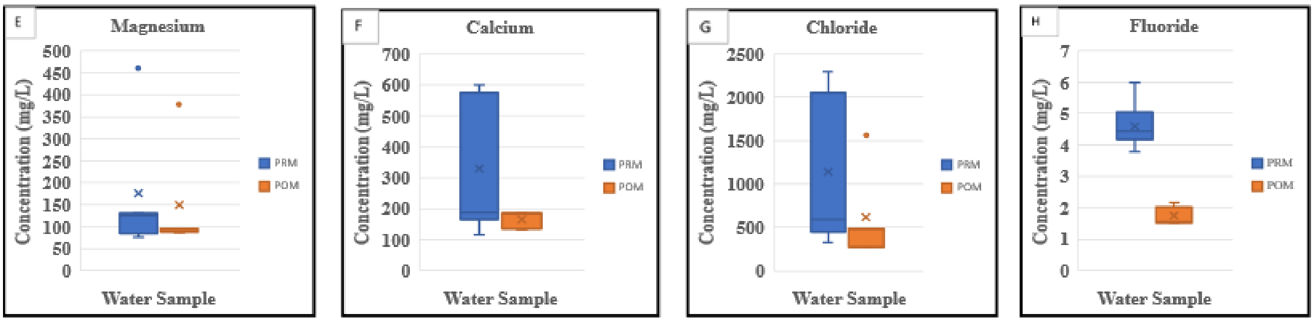


Figure 1: Comparison of the physicochemical characteristics of between pre-monsoon (PRM) and post-monsoon (POM) water samples

Metal content estimations

Lead: All the collected water samples were highly contaminated with heavy metals. The samples collected from borewells near the dumping yard had more lead than other water samples. The quantity of lead in water ranged between 0.01±0.001 and 0.57±0.020mg/L in pre-monsoon and between 0.02±0.001 and 0.25±0.019 mg/L in post- monsoon season (Figure 2A). All the water samples had Lead (Pb) above the acceptable limits of BIS & WHO, which is 0.01mg/L (Table 3). The high concentration can be due to weathering or leaching of rocks, tailings, and improper disposal of waste. This high amount of lead causes various health issues, such as cardiovascular disorders, cancer, and other abnormalities in organisms (27, 28).

Cadmium: The samples collected from the mining region had a high amount of Cadmium as compared to the standard value. The amount of Cadmium ranged between 0.01±0.004 and 0.09±0.003 mg/L in the pre-monsoon season and between 0.001±0.0001 and 0.01±0.0019mg/L in the post-monsoon season (Figure 2B). Almost all the water samples were contaminated with cadmium and exceeded the permissible limits of 0.003mg/L, as per BIS and WHO (Table 3). The level of cadmium in water can be higher due to weathering of rocks, industrial discharge, mining, and smelting of metals such as zinc and lead(29). High amounts of cadmium can cause kidney disease, osteoporosis, cardiovascular diseases, cancer, and infertility in humans(30,31).

Zinc: Naturally, zinc is found in mineral deposits and rocks that can be released in water through weathering of rocks or anthropogenic sources such as mining, agricultural run-off, pesticides, and industrial discharge(32)**.** The content of Zinc in the water samples ranged between 0.01±0.002 to 0.06±0.0013 mg/L in the pre-monsoon season and between 0.01±0.004 to 0.04±0.019 mg/L in the post-monsoon season (Figure 2C). All the water samples are within the permissible limits, which is 5 mg/L according to BIS & WHO (Table 3). According to WHO level of zinc below 5mg/L is considered safe.

Comparison of metal analysis in Pre-monsoon (PRM) and Post-monsoon (POM) is explained by the following figure 2(A to C).

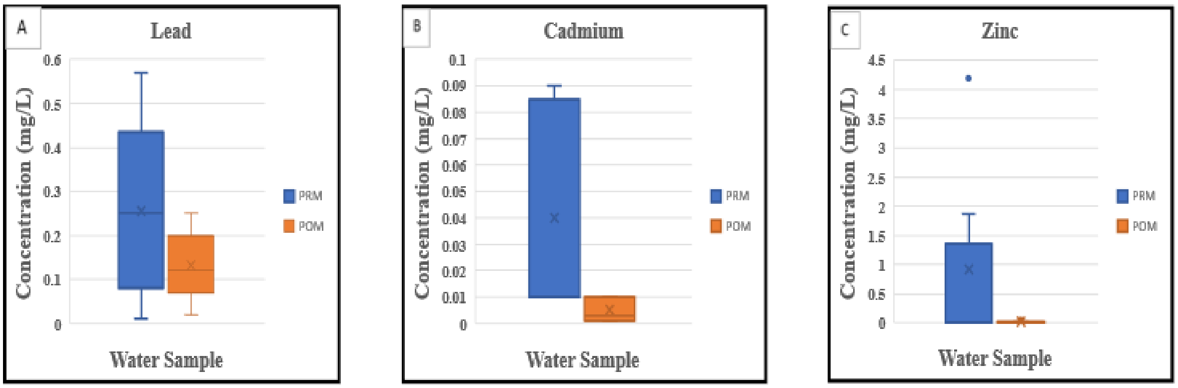


Figure 2: Comparison of the metal load between pre-monsoon (PRM) and post-monsoon (POM) water samples

Table 3: Water quality matrix of Pre-Monsoon and Post-Monsoon water samples collected from the area around Rajpura Dariba mining region (All the values are expressed in mean ± SD).

S. No	Parameter	Pre-Monsoon	Post-Monsoon	BIS	WHO
1	pH	7.79±0.55	7.53 ±0.64	6.5-8.5	6.5–8.5
2	Temp(°C)	33.30±1.162	20.45±1.80	-	-
3	EC (µS/cm)	3748.66±3748.66^{x}	2581.6±1078^{z}	-	500-1000
3	TDS (mg/L)	1870.4±784.09^{az}	1720.26±651^{az}	500	600
4	TH(mg/L)	1545.57±1061.31^{ay}	1190.41±857^{az}	300	600
5	Mg^{+2} (mg/L)	175.98±149.83^{by}	149.37 ±118^{ay}	30	50
6	Ca^{+2} (mg/L)	328.3±219.18^{az}	164.61±25^{az}	75	75
7	Cl^{-} (mg/L)	1045.89±789.12^{az}	714.35±700.23^{cx}	250	250
8	F^{-} (mg/L)	4.59±0.67^{az}	1.75±0.25^{ay}	1.0	1.5

9.	Lead (mg/L)	0.256±0.20[ay]	0.132±0.082[az]	0.01	0.01
10.	Cadmium(mg/L)	0.04±0.03[az]	0.005±0.004	0.003	0.003
11.	Zinc (mg/L)	0.022±0.019	0.018±0.013	5	5

Statistical comparison: The values (mean ± SD) of water samples have been compared with permitted values recommended by BIS ([a]$p<0.001$, [b]$p<0.01$, [c]$p<0.05$) and WHO ([x]$p<0.05$, [y]$p<0.01$, [z]$p<0.001$) using one-tailed students t-test.

Water Quality Index (WQI)

The calculated WQI of the Rajpura Dariba region ranged between 350.08 and 497.50 in the pre-monsoon season and between 150.20 and 193.19 in the post-monsoon season. After comparing the results with range for water quality (Table 2) the overall values of WQI falls in poor quality and unsuitable for drinking purposes (Table 4). The results of the WQI demonstrate that the quality of water in the pre-monsoon period is poorer compared to the post-monsoon period. It can be due to dilution of water by rainfall and other water geochemistry activities (33). WQI is a numerical representation of the overall quality of water that simplifies the complex data of physicochemical analysis in a simplified form, making it easy for policymakers and the public to assess(34).

Table 4: WQI with the state of water quality in the pre-monsoon and post-monsoon seasons

S. No	Sampling Site	Location	Water sample	WQI	Water quality PRM
1	Site 1	24°58'08.3"N 74°07'18.8"E	Pre-monsoon	497.64	Unsuitable for drinking purposes
			Post-monsoon	193.19	Poor
2	Site 2	24°58'10.9"N 74°08'21.8"	Pre-monsoon	392.93	Unsuitable for drinking purposes
			Post-monsoon	177.80	Poor
3	Site 3	24°58'12.4"N 74°08'25.5"E	Pre-monsoon	392.49	Unsuitable for drinking purposes
			Post-monsoon	150.20	Poor
4	Site 4	24°57'32.8"N 74°08'05.5"E	Pre-monsoon	497.49	Unsuitable for drinking purposes
			Post-monsoon	192.21	Poor
5	Site 5	24°57'30.6"N 74°08'05.3"E	Pre-monsoon	350.08	Unsuitable for drinking purposes
			Post-monsoon	152.32	Poor

Water samples from agricultural fields in proximity to the mining region underwent physicochemical analysis during two distinct seasons (pre-monsoon and post-monsoon). The analysis indicated that the water exhibited slightly alkaline characteristics in both seasons. All the physicochemical parameters, including TDS, EC, TH, anions and cations, showed marked deviation from the standard values of BIS & WHO. Based on comparison of WQI with standard WQI classification, the majority of samples were found to be 'poor' to 'Unsuitable' for drinking purposes in both seasons, and hence water in this area is not suitable for consumption. They also indicate that the WQI values follow the seasonal trend: Post-monsoon< pre-monsoon, this may be due to dilution of water in the monsoon season. In the present study, we have compared the results of all three metals found in this area, as Lead and Zinc are the main components extracted from this area, and Cadmium is a byproduct of the smelting of lead and zinc. We found that all the samples were highly contaminated with Lead, as the results of metal analysis are much higher (0.256±0.20 mg/L) in the case of pre-monsoon and post-monsoon (0.132±0.082 mg/L) when compared with BIS and WHO standards. The level of cadmium, 0.04±0.03mg/L in pre-monsoon and 0.005±0.004 mg/L is also above the permissible limits of WHO and BIS, which is 0.003mg/L. Similar results have been reported from the metal mining area of Zawar, Udaipur, which is also a Pb-Zn mine(35). Metal pollutants such as lead and cadmium can cause drastic effects on wildlife & human health.

4. Conclusion

Physicochemical parameters of water in this area are deviated from the standard values, which may be due to metal mining and other pollutants associated with the mining and processing of metals. Therefore, the water of the Rajpura Dariba mining region is not suitable for domestic and agricultural use. Sustainable mining practices, followed by regular monitoring and remediation strategies, are required to protect water quality in this area. Bioremediation can be an eco-friendly, sustainable, and cost-effective method to minimize the negative impact of hazardous waste present in the water of this area.

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