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Seasonal Variations in Anthropogenic activities due to Industrial Effluents on Groundwater Quality: A Comparative Analysis of RIICO Industrial Areas in Bayana and Bharatpur (Rajasthan)

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ABSTRACT
Groundwater quality with respect to impact of industrial effluents and anthropogenic activities in two industrial regions of Rajasthan, India, namely Bayana and Bharatpur, has been studied seasonally. Seasonal (pre monsoon, monsoon, post monsoon) variation in physico chemical parameters (pH, Temperature, color, turbidity, EC, TDS, TH, TA, nitrate, sulphate, chloride, sodium, potassium, calcium, magnesium, COD and DO) and heavy metal ions (iron, copper, zinc, manganese, cadmium, mercury, lead and chromium) were analyzed to find out the contamination trend. The pollutants were found to increase considerably after monsoon due to increased industrial discharge and reduced dilution So groundwater of Bharatpur RIICO region was found to be more polluted than Bayana RIICO region due to high value of EC, TDS and TH & high Concentration of Iron and Lead beyond the permissible limit. The results of this study indicate that there is an urgent need for advanced effluent treatment, sustainable agriculture and monitoring to prevent health and environmental risks. These findings can be used to develop groundwater management and pollution control strategies in industrialized areas.

Keywords: Groundwater quality, seasonal variations, industrial effluents, heavy metal contamination, Rajasthan.

1. INTRODUCTION

Groundwater is an important resource in arid and semi-arid region like Rajasthan where surface water availability is scarce. Agricultural irrigation, industrial use and domestic use require it and its quality is vital to the economy and public health. Rapid industrialisation and urbanisation have brought in major pollutants to groundwater systems. Industrial effluents which seep through aquifers are cumulatively contained with heavy metals, chemical and organic compounds that cause contamination. Seasonal factors (the main variations in precipitation and temperature) further affect groundwater quality, by controlling pollutant dispersion and concentration.

Rajasthan's industrial zones- including Bayana, Bharatpur, governed by the Rajasthan State Industrial Development and Investment Corporation (RIICO)-are a hodgepodge of chemical plants, stone crushers and fertilizer manufacturers. Effluents are produced by the activities which have the potential of degrading groundwater quality. Additionally, there are not enough sewage treatment plants so that untreated effluents can seep into sources of groundwater.

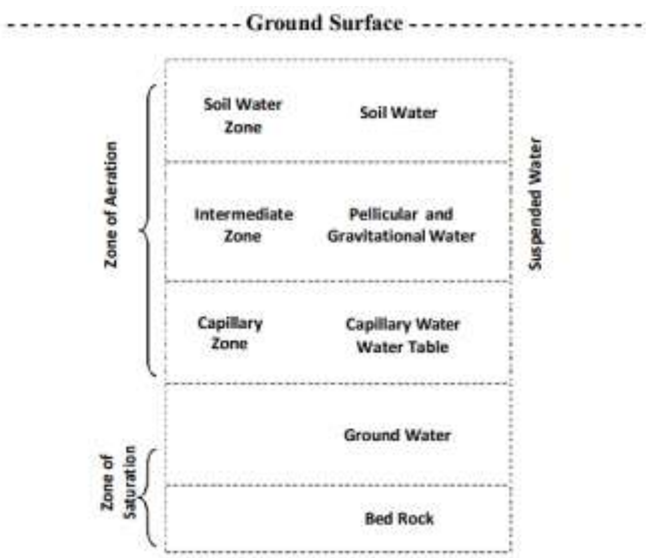

Figure1: Divisions of subsurface water.

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The seasonal variability of groundwater is important because these regions rely on groundwater for drinking and agricultural use. This study has investigated physico chemical parameters and heavy metal contamination in groundwater associated with seasonal changes in Bayana and Bharatpur and has been compared. The insights of this research are meant to inform sustainable water resource management and pollution mitigation strategies.

1.1 Problem Statement

The problem of groundwater contamination is particularly severe in industrial areas of Bayana and Bharatpur in Rajasthan where industrial effluents are unregulated. There are few exceptions to this rule where chemical manufacturing and stone crushing industries in these regions discharge both heavy metals and other pollutants (other than heavy metals) without or with poor treatment. These contaminants infiltrate groundwater systems that deteriorate water quality.

This is further complicated, by seasonal variations. Increased recharge can widely disperse pollutants during monsoons or concentrate them during pre and post monsoons when there is reduced dilution. The problem is further complicated by a lack of comprehensive monitoring, leaving us with critical gaps in our understanding of how industrial activities and seasonal changes interact to affect groundwater quality.

This is a major public health, agriculture and ecological systems threat. Therefore, understanding and controlling the impacts require systematic study of seasonal trends and comparative assessment of groundwater quality in Bayana and Bharatpur RIICO region.

1.2 Objectives

The primary objectives of this study are as follows:

1. To evaluate seasonal changes in physico chemical parameters and heavy metal concentrations in groundwater in industrial areas of Bayana and Bharatpur have been evaluated.
2. To evaluate the extent to which industrial activities contribute to groundwater contamination in the selected study regions.
3. To compare the analysis of groundwater quality of Bayana and Bharatpur is done highlighting the differences which are due to local industrial activities.
4. To observe groundwater quality data were compared with permissible limits of WHO and BIS for drinking and irrigation purposes.
5. To propose mitigation strategies for industrial and anthropogenic impact reduction on groundwater quality and its sustainable management.

2. LITERATURE REVIEW

2.1 Overview of Groundwater Pollution

Water pollution is an important environmental problem, especially in the industrial area where human activities have an important role in the quality of water. But, groundwater is a very important resource for drinking, agriculture and industry, but is very vulnerable to contamination from industrial effluents, agricultural run-off and urban wastewater [1,2]. These substances contaminate aquifers, and over time can accumulate to the point at which remediation is difficult and expensive.

Industrial activities lead to a major result in the form of groundwater pollution. Factories release pollutants such as heavy metals (lead, cadmium, chromium), nitrates, sulphates and organic compounds, directly to soil and water systems [3]. Many effluents seep into groundwater and endanger ecosystems and human health, untreated or poorly treated. Agricultural practices, mostly based on fertilizers and pesticides that leach the chemicals into the aquifers [4] aggravate the problem.

Extent and nature of contamination [5] is dependent on seasonal variations. Monsoon rains increase pollutant leaching into groundwater, but when dry, concentrations increase because of less dilution [6]. The problem is worsened by poor regulatory enforcement and poor waste management, especially in Rajasthan's industrial zones.

Waterborne diseases, heavy metal toxicity and long term ecological damage, resulting from groundwater pollution, have severe health impacts globally [7]. Due to groundwater contamination, serious consequences are imminent, as 90% of the rural populations in India depend on groundwater for drinking. Groundwater resource management and protection require effective use of pollution control, monitoring, and advanced treatment technologies [8,9]. This study takes these concerns further by trying to understand the specific dynamics of groundwater pollution in Bayana and Bharatpur with respect to industrial and seasonal influences.

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2.2 Key Studies on Rajasthan's Groundwater

Rajasthan, with arid and semi-arid climate, has many problems related to groundwater due to industrialization, agricultural practices and limited surface water availability. Groundwater is the primary source of drinking, irrigation and industry, and water quality of groundwater is of paramount importance for the sustainable development. The state has been extensively studied for groundwater contamination with industrial and anthropogenic impacts being highlighted.

High concentration of heavy metals, e.g. lead, cadmium, chromium and arsenic, in groundwater has also been observed in the studies conducted in RIICO industrial zones in Rajasthan. As an example, Choubisa et al. [10] found extensive pollution in industrial centres such as Kota and Alwar, where the effluents of chemical plants and metal processing industries have seriously polluted the groundwater. Elevated heavy metal levels greater than the BIS [11] and WHO [12] limits were linked to heavy metal toxicity and increased risks of cancer.

High nitrate and fluoride concentrations are also characteristic of Rajasthan groundwater. As stated by Tiwari et al. [13], Dausa district 80% of samples had fluoride concentrations above safe drinking limits leading to widespread dental and skeletal fluorosis. Nitrate contamination in semi-arid regions due to fertilizer leaching and poor wastewater management is also pointed out by Rahman et al. [14], and poses serious health risks, most especially, to children.

In particular, smaller industrial areas such as Bharatpur and Dholpur show alarming levels of contamination. According to Gupta et al. [15], these regions are very much polluted with untreated effluents from chemical factories and stone crushers. Lead and chromium levels often exceed permissible limits in Bharatpur and nitrate and TDS levels are persistently high in Bayana in post monsoon seasons.

Seasonal dynamics are shown to exacerbate pollution in several studies. Pollutant leaching into aquifers occurs due to monsoons, and the pre and post monsoon seasons show concentrated levels due to less dilution. Tanwer et al. [16] confirmed seasonal sampling in Rajasthan that groundwater contamination increases during the dry seasons and has major implications for drinking and agricultural water use.

The results of these studies show a need for region specific assessments and remediation strategies to manage groundwater quality in the industrial regions of Rajasthan, namely, Bayana and Bharatpur. This study extends these findings to focus on seasonal and industrial influences in these two key areas.

2.3 Knowledge Gaps

Although much has been researched on groundwater pollution in Rajasthan, there are still many gaps, especially in understanding the combined effect of industrial activities and seasonal variation on the groundwater quality [17,18]. Most studies concentrate on separate contaminants (fluoride or nitrates), omitting the entire range of pollutants (heavy metals, organic compounds) that are derived from industrial effluents. In addition, while many studies present snapshot views of groundwater quality at a given time, there are no comprehensive, year round data sets that include seasonal influences such as monsoon recharge or dry season concentration.

Few comparative analyses are available between different industrial regions, like Bayana and Bharatpur [19]. But, the majority of the research generalizes the findings across Rajasthan, without considering variations in location due to the differences in industrial practices and waste management systems [20].

A second critical gap is the insufficient integration of local health and environmental data with water quality studies[21]. The lack of connection to groundwater contamination limits understanding of the direct impact on public health and agricultural productivity. This study addresses these gaps by providing a detailed comparative analysis of seasonal groundwater quality variations in Bayana and Bharatpur using a comprehensive dataset and advanced evaluation methods to guide targeted mitigation strategies.

3. METHODOLOGY

3.1 Study Area

The study area includes industrial areas of Bayana and Bharatpur in Rajasthan, which falls under the jurisdiction of Rajasthan State Industrial Development and Investment Corporation (RIICO) [22]. These are areas characterized by varied industrial activity such as chemical manufacturing, stone crushing and small scale brick kilns that impose considerable environmental pressures. Besides being famous for the red stone mining and associated industries, Bharatpur has a combination of agro based and small scale industrial units; while Bayana has a combination of agro based and small scale industrial units.

Both regions are dependent on groundwater for domestic, agricultural and industrial purposes, with limited surface water resources [23]. Seasonal variability associated with the semi-arid climate with distinct pre monsoon, monsoon and post

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monsoon seasons also influence groundwater recharge and contamination. Unpolluted industrial effluents and agricultural runoff pollution has polluted the aquifers in these areas [24].

Seasonal variations in groundwater quality of three key sites in each region are evaluated in this study in terms of industrial and anthropogenic activities. This compares these two regions to identify patterns of contamination and to propose regionally tailored mitigation strategies.

3.2 Sampling Design

Three strategically selected sites (S_1, S_2 and S_3) in each RIICO region, Bayana and Bharatpur, were selected, where significant industrial activity and varying proximity to potential pollution sources exist, and groundwater samples were collected at these locations. To account for temporal variability in groundwater quality affected by industrial effluents, agricultural runoff and natural recharge dynamics, sampling was conducted seasonally (pre-monsoon, monsoon and post-monsoon) [25].

Bharatpur RIICO Area	**Bayana RIICO Area**
S_1= Nearby of Shri Krishna Dairy	**S_1**= Nearby of Mahesh Dairy
S_2 = Nearby of Kaka Dairy	**S_2**= Nearby of Gatik Dairy
S_3=Nearby of Rajasthan Metal Container Industry	**S_3** = Nearby of Shiv Shakti Dairy

Samples were collected from bore wells and hand pumps at standardized depths at each site bimonthly. Consistency and accuracy were ensured by sampling in accordance to protocols recommended by the Bureau of Indian Standards (BIS) [26]. Every effort was made to prevent contamination during collection, storage and transport, and samples were stored in sterilized polyethylene bottles and transported in insulated containers to the laboratory.

Physico-chemical parameters (pH, TDS, EC, TA, TH, Sodium, Potassium, Calcium, Magnesium, Chloride, Sulphate, Nitrate, Fluoride, COD and DO) and heavy metals (Iron, Copper, Zinc, Manganese, Mercury, Lead, Cadmium, Chromium) were analysed as parameters. Advanced method like Atomic Absorption Spectrophotometry (AAS) and spectrophotometry was used to quantitatively determine the contaminants.

3.3 Analytical Techniques

The groundwater samples of Bayana and Bharatpur RIICO region were analysed for a wide range of physicochemical parameters and heavy metals using standardised methodologies for accuracy and reliability [27]. The purpose of the work was to determine water quality and assess the seasonal variations induced by the industrial and anthropogenic activities.
Field and laboratory techniques were used to measure parameters of pH, electrical conductivity (EC), total dissolved solids (TDS), nitrate, fluoride, and turbidity. Portable water analyser kits were used to make on site measurements of pH, EC and turbidity [28]. Total alkalinity, Chloride, Sulphate and Total hardness were determined by titrimetric methods, Calcium, Magnesium, Sodium, Potassium ion concentration were determined by Flame Photometric method, the concentration of nitrate and fluoride ion were determined by UV visible spectrophotometry and COD & DO were determined by Titration Method & Winkler-azide Method.

Atomic Absorption Spectrophotometry (AAS) that provides high sensitivity and accuracy was used for quantification of heavy metals (lead, cadmium, chromium, manganese, mercury, iron, copper, zinc,). Samples were pre-treated with acid digestion to eliminate.

4. RESULTS

4.1 Seasonal Physico-Chemical Variations

Results of the study indicated seasonal variation in physico chemical parameters of groundwater in both Bayana and Bharatpur **(Table-1)** which are influenced by industrial activity and natural seasonal changes [29,30].

- Key parameters, such as total dissolved solids (TDS), electrical conductivity (EC), total alkalinity (TA), total hardness (TH) and chloride were analyzed for data across pre-monsoon, monsoon and post-monsoon seasons and the variation of these results are represented by (Fig- 1,2 & 3)

The data table indicate that highest TDS and EC value was obtained (average of 1253.61 mg/L) & (average of 2502.05 mg/L) in Post monsoon season of Bharatpur RIICO region [32], due to reduced groundwater recharge and higher concentrations of dissolved solids. TDS and EC were lower in pre-monsoon season due to more evaporation in this season, highest TA value is obtained (average of 348.27 mg/L) in Pre monsoon season of Bharatpur RIICO region, highest TH value is obtained (average of 1037.33 mg/L) in monsoon season of Bharatpur RIICO region due to more dilution effect and highest Chloride concentration was observed (average of 890.94 mg/L) in Pre monsoon season of Bharatpur RIICO region than Bayana RIICO region across all season during comparative seasonal study.

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Table 1 : The average values of parameters of obtained data of Bharatpur and Dholpur sites (seasonally and yearly).

Sr. No	Parameters	Years	Average Values for BHARATPUR sites			Average values for BAYANA sites		
			Pre Monsoon	**Monsoon**	**Post Monsoon**	**Pre Monsoon**	**Monsoon**	**Post Monsoon**
1	**Temperature**	2021-22	22.83	22.23	25.17	24.13	22.4	25.77
		2022-23	23.87	22.2	25.18	24.1	22.3	25.63
		2023-24	23.85	22.3	25.4	24	22.42	25.43
		Average	**23.51**	**22.24**	**25.25**	**24.07**	**22.37**	**25.61**
2	**pH**	2021-22	7.21	7.42	7.27	7.11	7.37	7.3
		2022-23	7.17	7.34	7.26	7.17	7.45	7.38
		2023-24	7.18	7.38	7.26	7.13	7.48	7.39
		Average	**7.19**	**7.38**	**7.26**	**7.13**	**7.43**	**7.35**
3	**TDS (mg/L)**	2021-22	1162.5	1243.17	1346.83	690	829.33	965.67
		2022-23	1111.67	1050.67	1166.83	681.33	548.33	664
		2023-24	1084.5	1191.5	1247.17	642.67	727.17	684.67
		Average	**1119.55**	**1161.78**	**1253.61**	**671.33**	**701.61**	**771.44**
4	**EC in (µS/cm)**	2021-22	2296.17	2490	2691.67	1371.5	1650	1921.5
		2022-23	2238.33	2098.33	2326.67	1349.17	1092.5	1321.67
		2023-24	2160.17	2384.17	2487.83	1274.33	1459.17	1557.33
		Average	**2231.55**	**2324.16**	**2502.05**	**1331.66**	**1400.55**	**1600.16**
5	**Turbidity in (NTU)**	2021-22	1.97	3.18	2	3.72	6.1	4.67
		2022-23	2.1	3.62	2.33	4.1	6.08	4.88
		2023-24	2.23	3.57	2.33	4.22	7.1	5
		Average	**2.1**	**3.45**	**2.22**	**4.01**	**6.42**	**4.85**
6	**Nitrate in (mg/L)**	2021-22	9.33	24.5	40.67	60.33	77.83	99.17
		2022-23	12.5	25.17	39.33	60	77	96.5
		2023-24	10.5	33.5	22.5	60	92.5	77.17
		Average	**10.77**	**27.72**	**34.16**	**60.11**	**82.44**	**90.94**
7	**Fluoride in (mg/L)**	2021-22	1.08	1.52	1.36	1.06	1.31	1.16
		2022-23	1.1	1.55	1.8	1.13	1.62	1.9
		2023-24	1.12	1.5	1.81	1.15	1.03	1.42
		Average	**1.1**	**1.52**	**1.65**	**1.11**	**1.32**	**1.49**
8	**Sulphate in (mg/L)**	2021-22	55.02	43.47	45.5	5.97	3.6	4.23
		2022-23	55.77	43.57	41.05	6.45	4.33	3.87
		2023-24	56.02	46.13	43.55	5.92	4.72	3.35
		Average	**55.6**	**44.39**	**43.36**	**6.11**	**4.21**	**3.81**
9	**Total Hardness in (mg/L)**	2021-22	971	1056.33	1002	368	457.67	391.17
		2022-23	950.5	1029.67	973.17	345	423.5	363.83
		2023-24	932.17	1026	962.17	328.17	414.83	358.33
		Average	**951.22**	**1037.33**	**979.11**	**347.05**	**432.00**	**371.11**
10	**Total Alkalinity in (mg/L)**	2021-22	349.17	293.33	325.33	261	208.33	238.17
		2022-23	351.33	271.5	330.5	238.67	227.17	213.17
		2023-24	344.33	282.5	319	267.33	207.33	246
		Average	**348.27**	**282.44**	**324.94**	**255.66**	**214.27**	**232.44**
11	**Calcium in (mg/L)**	2021-22	212.7	222.07	218.05	79.63	94.12	85.25
		2022-23	225.5	245.13	232.33	78.15	93.83	83.63
		2023-24	209.38	230.32	218.63	73.77	93.65	81.73
		Average	**215.86**	**232.5**	**223**	**77.18**	**93.86**	**83.53**
12	**Magnesium (mg/L)**	2021-22	121.37	134.65	126.35	42.27	55.13	44.47
		2022-23	147.85	159.12	150.33	50.48	63.35	52.35
		2023-24	132.48	145.77	135.42	42.78	53.78	45.98
		Average	**133.9**	**146.51**	**137.36**	**45.17**	**57.42**	**47.6**
	Sodium (mg/L)	2021-22	217.75	171.83	196.5	113.38	67.83	89.83
		2022-23	229	186.33	210.68	127.5	87.17	109.83

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13		2023-24	224.17	189.58	210.37	121	79.5	102.5
		Average	**223.64**	**182.58**	**205.85**	**120.62**	**78.16**	**100.72**
14	**Chloride (mg/L)**	2021-22	899.5	702.67	748.5	217	153.63	194.67
		2022-23	886.83	925.5	950.33	213.33	252.67	284.67
		2023-24	886.5	759.5	931.17	216	148	238.17
		Average	**890.94**	**795.89**	**876.66**	**215.44**	**184.76**	**239.17**
15	**Colour (Hazen unit)**	2021-22	5.00	7.17	6.67	13.17	18.17	13.83
		2022-23	6.00	10.67	8.67	13.00	19.00	14.17
		2023-24	7.17	13.00	7.67	13.00	18.00	14.17
		Average	**6.05**	**10.28**	**7.67**	**13.05**	**18.39**	**14.05**
16	**Potassium (mg/L)**	2021-22	7.72	4.45	6.35	2.33	1.3	1.8
		2022-23	8.28	4.78	6.4	2.67	1.5	2.17
		2023-24	8.52	4.5	6.48	2.93	1.43	2.32
		Average	**8.17**	**4.57**	**6.41**	**2.64**	**1.41**	**2.09**

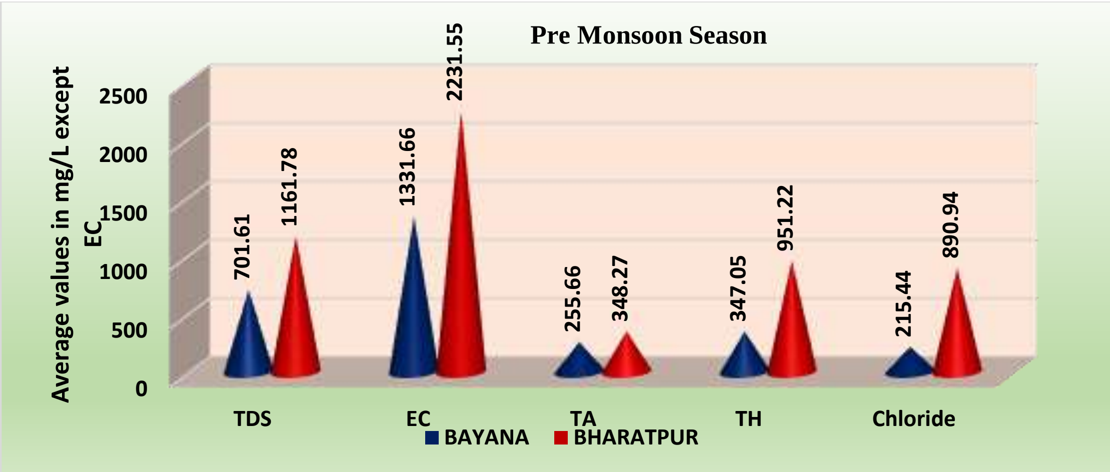

Figure 1: The variation of average values of TDS, EC, TA, TH and Chloride in Groundwater of Bayana and Bharatpur RIICO region in Pre- Monsoon Season

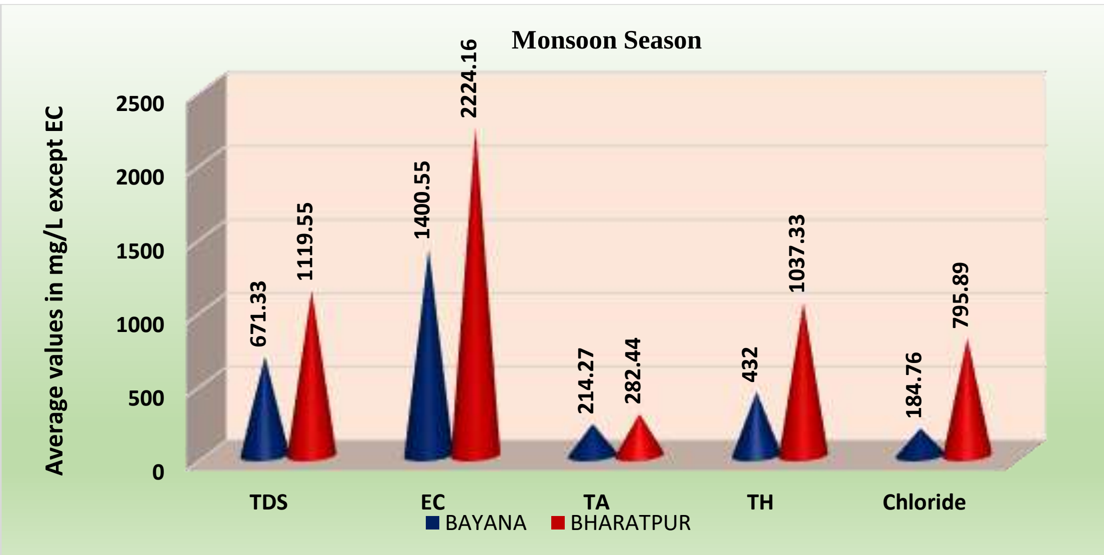

Figure 2: The variation of average values of TDS, EC, TA, TH and Chloride in Groundwater of Bayana and Bharatpur RIICO region in Monsoon Season

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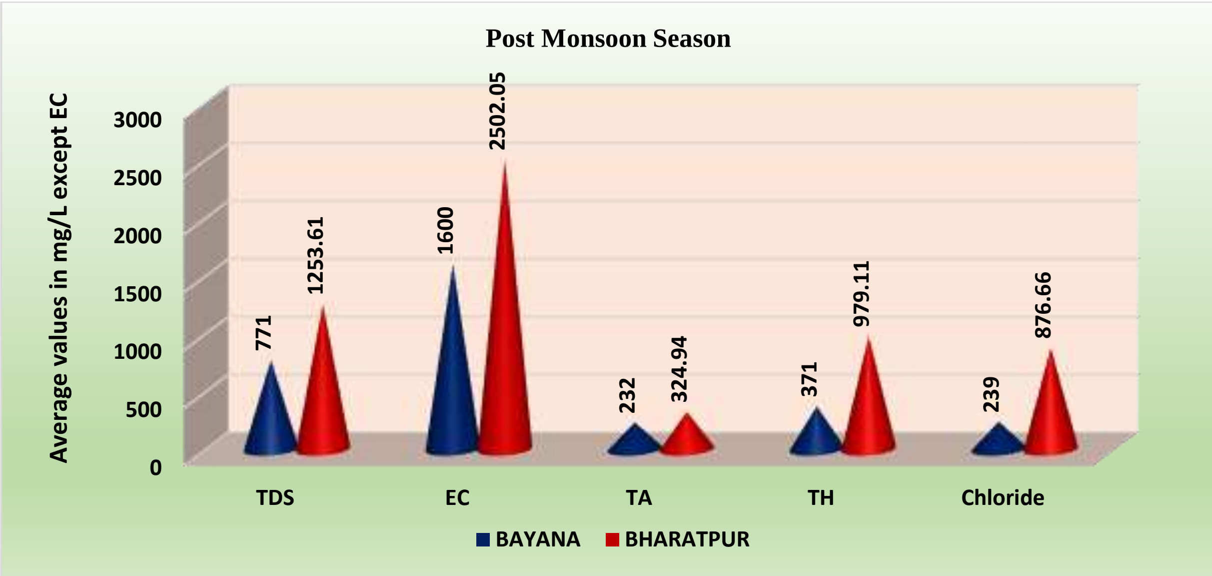

Figure 3: The variation of average values of TDS, EC, TA, TH and Chloride in Groundwater of Bayana and Bharatpur RIICO region in Post Monsoon Season

- Key parameters such as pH, Temperature, Color, Turbidity, Fluoride and Potassium were analyzed for data across pre-monsoon, monsoon and post-monsoon seasons, and the variation of these results are represented by (Fig- 4, 5 & 6) and data reveals that pH levels were within permissible limits in both regions, but highest pH, Turbidity values was obtained in monsoon season 7.43, 6.42 of Bayana, Fluoride concentration was obtained highest in post monsoon season of Bharatpur region and potassium conc. was highest in pre monsoon of Bharatpur region. In case of pH samples taken prior to the monsoon had slightly acidic tendencies, while monsoon samples tended towards neutrality because of the dilution from rainfall [31]. Post monsoon saw a marginally increased temperature, a seasonal climate pattern.

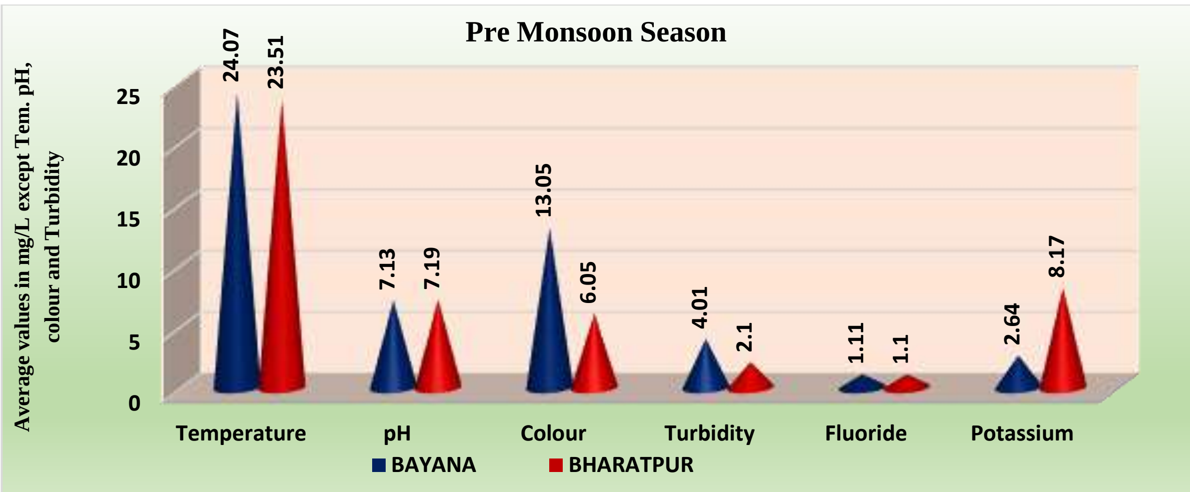

Figure 4: The variation of average values of Temperature, pH, Colour, Turbidity, Fluoride and Potassium in Bayana & Bharatpur in Pre-Monsoon season

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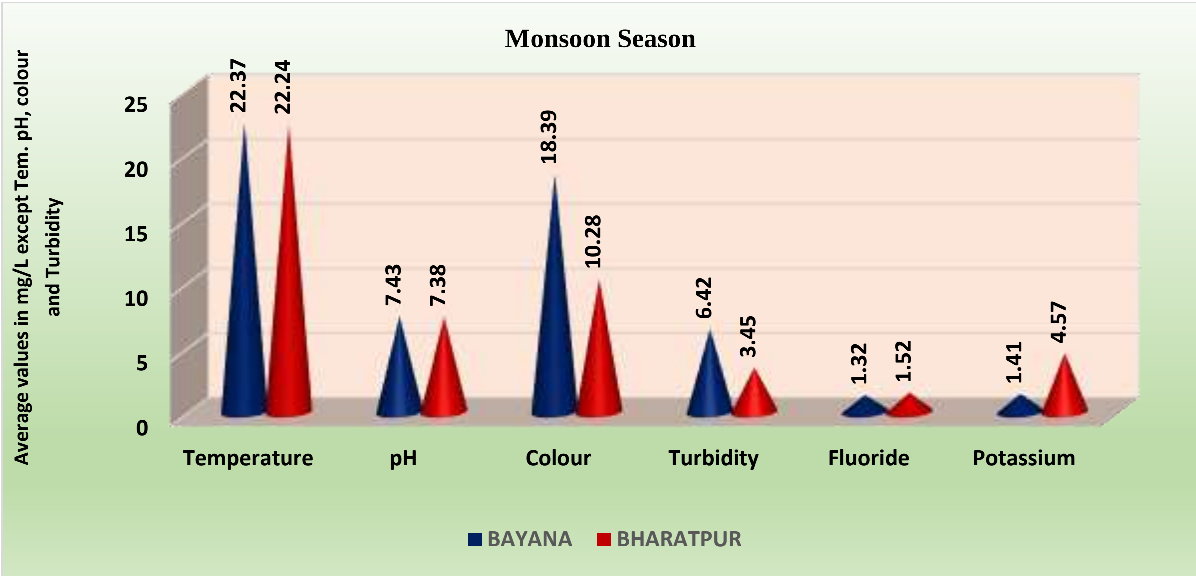

Figure 5: The variation of average values of Temperature, pH, Colour, Turbidity, Fluoride and Potassium in Bayana & Bharatpur in Monsoon season

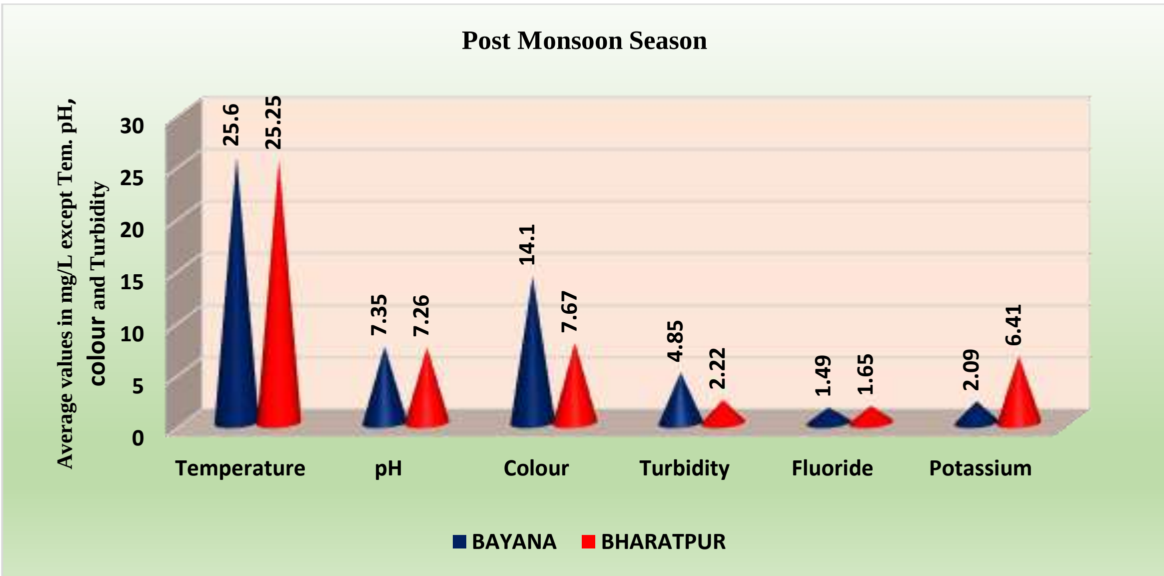

Figure 6: The variation of average values of Temperature, pH, Colour, Turbidity, Fluoride and Potassium in Bayana & Bharatpur in Post-Monsoon season

- Key parameters such as ion concentration of Sulphate, Calcium, Magnesium, Sodium and Nitrate were compared for data across pre-monsoon, monsoon and post-monsoon seasons, and the variation of these results are represented by (Fig-7, 8 & 9)

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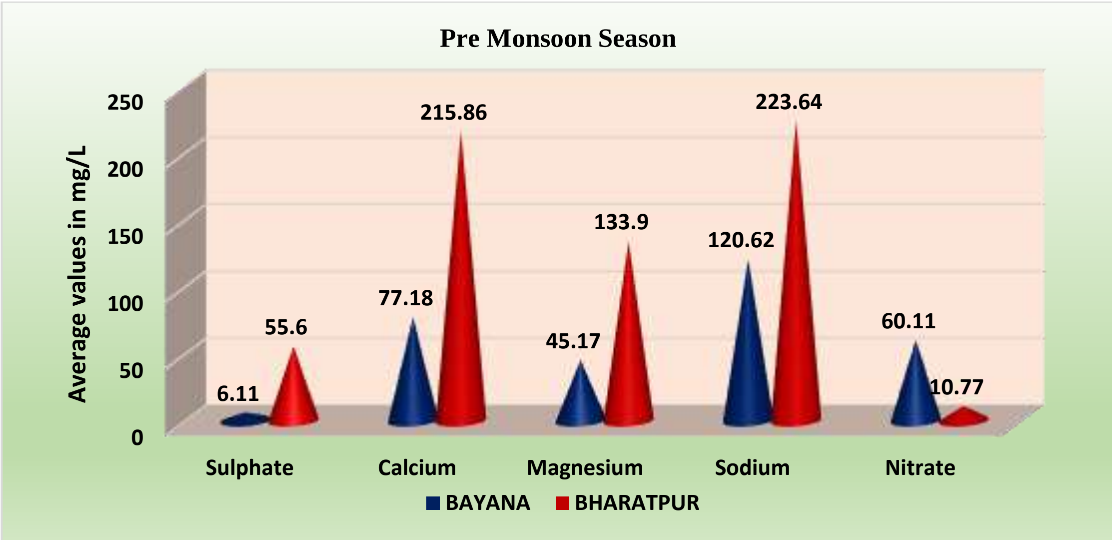

Figure 7: The variation of average values of Sulphate, Calcium, Magnesium, Sodium and Nitrate ion in Bayana & Bharatpur in Pre-Monsoon season

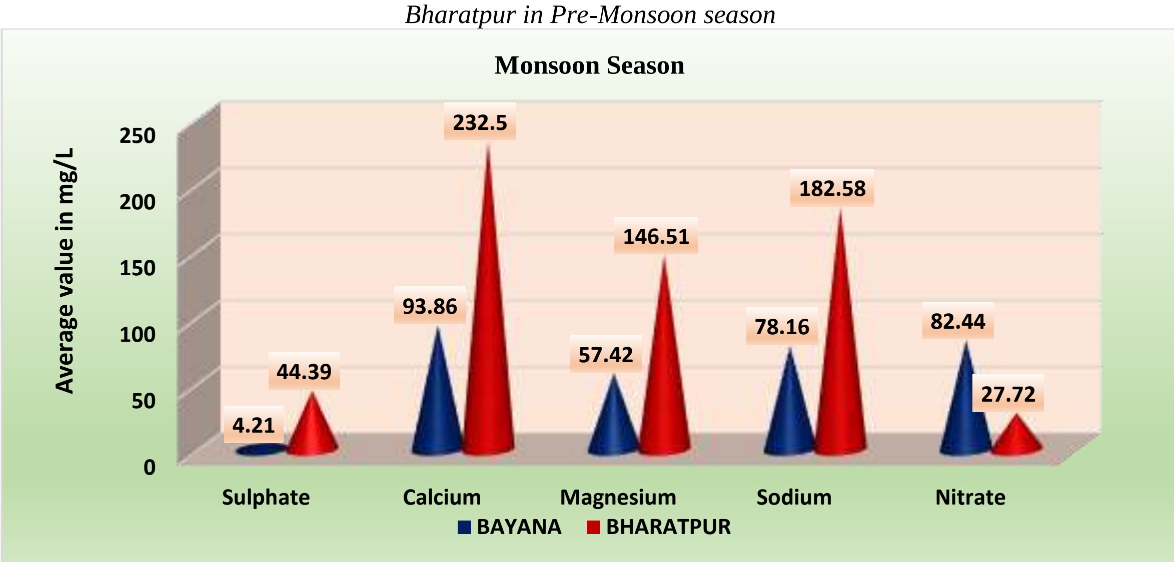

Figure 8: The variation of average values of Sulphate, Calcium, Magnesium, Sodium and Nitrate ion in Bayana & Bharatpur in Monsoon season

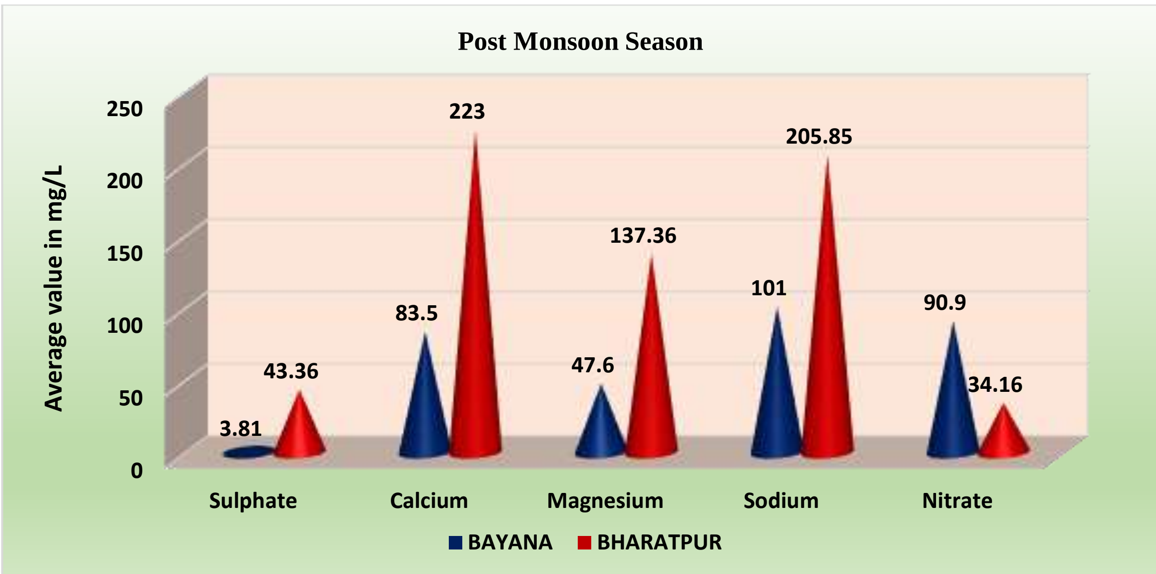

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Figure 9: The variation of average values of Sulphate, Calcium, Magnesium, Sodium and Nitrate ion in Bayana & Bharatpur in Post-Monsoon season

In both Bayana and Bharatpur RIICO region nitrate concentrations peaked in the post monsoon season due to agricultural runoff and industrial discharge [33]. Nitrate levels exceeded WHO limits in Bayana in all seasons of study, especially in the vicinity of agricultural areas. Fluoride levels were seasonally variable but were within permissible limits, and were higher in Bharatpur as a result of geological factors.

Sulphate and Sodium ion conc. was obtained highest in pre monsoon season of Bharatpur RIICO region due to more evaporation, Calcium and Magnesium ion conc. was obtained highest in monsoon season of Bharatpur RIICO region due to more run off and dilution effect of water.

Turbidity also increased significantly during the monsoon season, probably due to surface runoff introducing suspended particles into the groundwater. Turbidity levels in the post monsoon were lower than the pre monsoon but higher than the pre monsoon. Both regions had total hardness consistently elevated, with highest values during the post-monsoon season, due to mineral leaching from industrial discharge and natural geochemical processes.

Both regions had similar seasonal trends, but Bharatpur had higher TDS, fluoride, and EC in the groundwater possibly because of industrial activities. Higher levels of nitrate was seen in Bayana, which indicated greater influence of agriculture.

The seasonal variations in this study reflect the combined influence of anthropogenic and natural factors on groundwater quality. These findings emphasize the need for continued monitoring and targeted mitigation measures in response to contributions from industrial as well as agricultural sources to groundwater contamination.

4.2 Heavy Metal Analysis

Heavy metal contamination in groundwater was seasonally assessed in Bayana and Bharatpur with special emphasis on iron, copper, zinc, mercury, lead, cadmium, chromium and manganese [34,35]. Seasonal and regional variations were significant, and industrial activities and natural processes were shown to be important effects.

Table 2:- Variation of different heavy metal ion in groundwater of Bharatpur and Bayana RIICO Region during 2021 to 2024

Sr. no.	**Parameters**	**Permissible limit BIS 2012 in mg/L**	**Average values for Bharatpur Sites**			**Average values for Bayana Sites**		
			2021-22	**2022-23**	**2023-24**	**2021-22**	**2022-23**	**2023-24**
1	**Iron in (mg/L)**	**0.30**	0.45	0.34	0.38	0.34	0.23	0.30
2	**Copper in (mg/L)**	**1.50**	0.07	0.12	0.13	0.22	0.17	0.26
3	**Zinc (mg/L)**	**5.0**	0.103	0.153	0.176	1.52	1.55	1.59
4	**Manganese (mg/L)**	**0.30**	0.113	0.12	0.166	0.013	0.056	0.083
5	**Lead (mg/L)**	**0.01**	0.043	0.05	0.053	0.063	0.025	0.022
6	**Cadmium (mg/L)**	**0.003**	0.00	0.0006	0.00	0.00	0.00	0.00
7	**Chromium (mg/L)**	**0.05**	0.006	0.00	0.003	0.00	0.003	0.016
8	**Mercury (mg/L)**	**.001**	0.00	0.00	0.00	0.00	0.00	0.00
9	**DO in (mg/L)**	**No Guideline**	6.23	6.52	6.31	6.31	5.94	5.68
10	**COD in (mg/L)**	**No Guideline**	4.76	4.75	4.55	4.90	4.95	5.23

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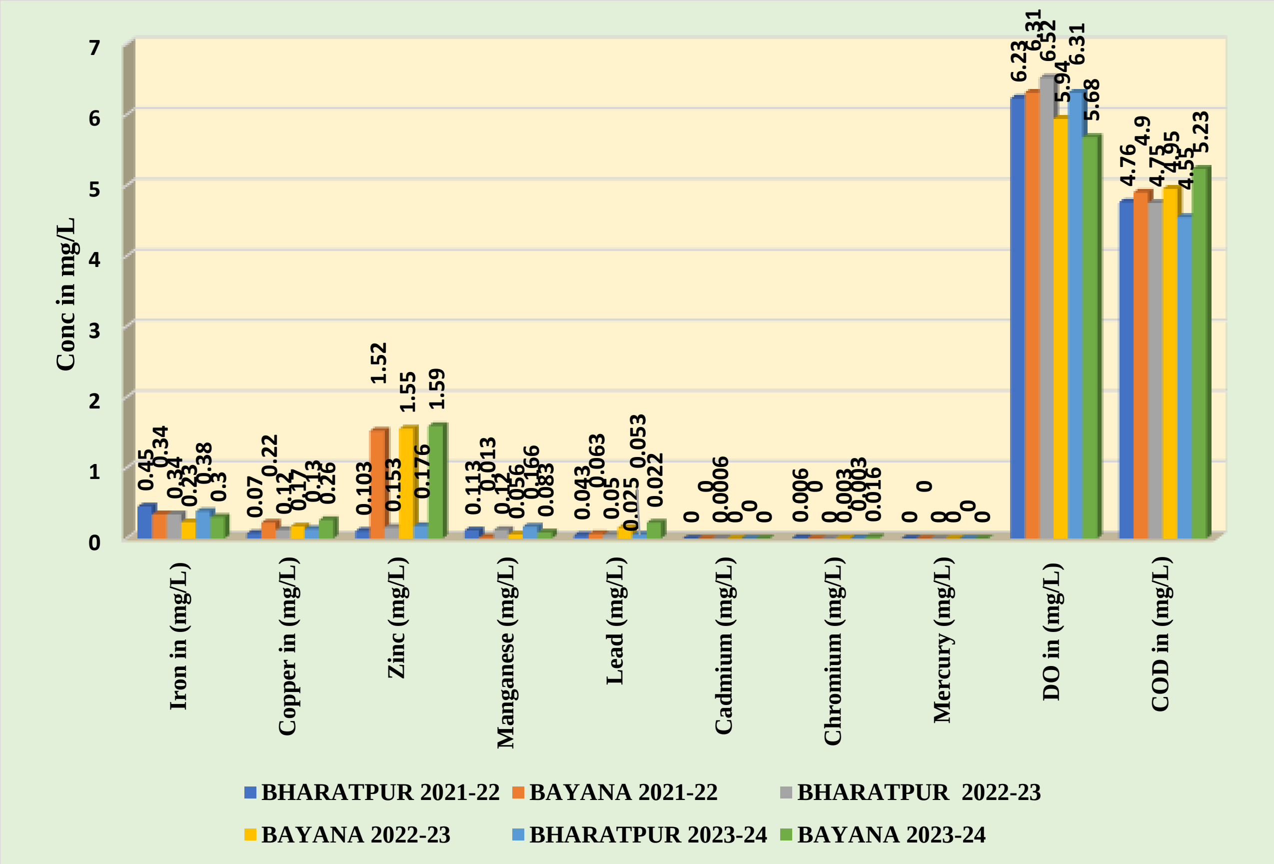

Fig 10:- The variation in concentration of different heavy metal ions in Bharatpur and Bayana sites during 2021-2024

Iron- The Iron concentration was obtained in the permissible limit (1.5 mg/L as per BIS standards) for both Bayana and Bharatpur groundwater samples across three years (2021-2024). The data reveals that Bhartapur region shows more concentration due to more industrial discharge and mineral leaching. Iron levels were generally lower in Bayana, but peaked slightly during 2021-22, perhaps as a result of surface runoff.

Copper- The Copper concentration was obtained in the permissible limit (1.5 mg/L as per BIS standards) for both Bayana and Bharatpur groundwater samples across three years (2021-2024). The Copper concentration in water of Bayana sites is more than the Bharatpur sites. This data indicate that contamination of groundwater due to this metal ion is absent at yet.

Zinc- The Zinc concentration was obtained in the permissible limit (5.0 mg/L as per BIS standards) for both Bayana and Bharatpur groundwater samples across three years (2021-2024). The Zinc concentration in water of Bayana sites is more than the Bharatpur sites. This data indicate that contamination of groundwater due to this metal ion is absent at yet.

Lead- The Lead concentration was obtained beyond the permissible limit, (BIS limits, 0.01 mg/L) in both regions. Industrial effluents from metal processing and chemical industries were found to be the source of high concentrations in Bharatpur samples [36]. Lead levels in Bayana were slightly lower, probably because of agricultural runoff and fewer heavy industries.

Cadmium- Trace concentration of cadmium was present and below permissible limits (0.003 mg/L) in Bharatpur site in 2022-23 but this metal ion was not detected in the groundwater of Bayana sites.

Chromium- The result of study shows that this metal ion was obtained in very low concentration within permissible limits (0.05 mg/L) for both Bharatpur and Bayana sites

Mercury- Mercury metal ion was not detected in groundwater samples of Bharatpur and Bayana RIICO region across all over the study which represents the contamination of groundwater through this metal ion is absent in both areas.

Manganese- The Manganese concentration obtained in the permissible limit (0.30 mg/L as per BIS standards) for both Bayana and Bharatpur groundwater samples across three years (2021-2024). The Manganese concentration in water of Bharatpur sites is more than the Bayana sites. This data indicate that contamination of groundwater in both industrial area due to this metal ion is absent at yet.

Bharatpur also showed higher heavy metal ion concentrations than Bayana, in accordance with its higher industrial density and also more influenced by effluents activities. This study shows the urgent need for very strict industrial effluent management, seasonal monitoring and groundwater treatment to minimise the health risk from heavy metal contamination.

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5. DISCUSSION

5.1 Seasonal Trends and Industrial Impacts

Analysis shows distinct seasonal trends in groundwater quality in Bayana and Bharatpur due to industrial activities and natural recharge processes [37,38]. Seasonal variations revealed the coupling between pollutant sources and hydrological conditions and have important implications for water resource management.

In both regions, TDS, EC, and nitrate levels in Bayana region during post-monsoon, when recharge was low and pollutant concentrations were high, due to reduced dilution [39]. During the monsoon season, contaminant levels were low, due to the dilution by rain water. Monsoons also increased turbidity due to surface runoff introducing suspended solids into groundwater systems. TDS and EC levels in Bharatpur generally remained higher than Bayana, which reflects its greater industrial density and a higher concentration of untreated effluents.

Seasonal variation in heavy metals of lead, chromium and iron was significant with the highest concentrations in post monsoon sample, especially in Bharatpur. The metals that wound up in aquifers were probably mobilized by monsoon rains from industrial waste deposits. In comparison with Bayana, the concentrations of metals were lower because of fewer heavy industries, but nitrate and TDS levels were higher than permissible limits in some samples.

The results also confirm that industrial activities play a very important role in degrading groundwater quality. Heavy metals in the range of 10–20 times greater than control sites were identified as the major contributors to elevated heavy metal levels, which were associated with Bharatpur's metal processing, chemical industries, and red stone mining. Less industrialized, Bayana showed contamination mostly associated with agricultural runoff and small scale industries.

The problem is a combination of industrial discharges and seasonal recharge dynamics. Public health and agriculture are at risk of contamination after monsoon and targeted interventions are required. The priority mitigation strategies should be industrial effluent treatment, seasonal monitoring and strict regulatory enforcement. To design sustainable groundwater management policies in industrialized regions such as Bayana and Bharatpur, these seasonal and industrial influences need to be understood.

5.2 Health and Environmental Implications

The study results show the health and environmental risk to groundwater in Bayana and Bharatpur due to industrial and seasonal causes [40,41]. Groundwater has heavy metals, nitrates and other contaminants at levels that threaten public health, agriculture and the stability of the ecosystem.

Both regions are very dangerous to health as they contain heavy metals like lead, chromium and iron. In Bharatpur, contamination from lead is believed to have caused neurological disorders, developmental delays in young children and cardiovascular complaints in adults. Chromium can cause gastrointestinal distress and is detected at industrial sites due to its carcinogenic risks. Nitrate concentrations exceeding permissible limits in post-monsoon samples are especially concerning, as they contribute to methemoglobinemia or "blue baby syndrome" in infants. Organ damage and cancer are among the long term health effects of these contaminants, and chronic exposure to them from drinking water and food.

Contamination also affects agricultural productivity, which occurs because heavy metal is introduced into the soil when pollutants get into groundwater used for irrigation. It can result in decreasing crop yields, soil toxicity and bioaccumulation of toxic elements in the food chain, and impair human and animal health. Soil and water contamination is further exacerbated by monsoon runoff and post monsoon stagnation concentrates pollutants.

Contamination of groundwater and subsequently the quality of the connected surface water bodies and wetlands affect local ecosystems adversely. Increased turbidity heavy metals and reduced dissolved oxygen levels due to industrial effluents causes risk to the aquatic life.

The health and environmental implications of these results underscore the need for intervention actions aimed at mitigating industrial and anthropogenic effects to groundwater quality in the study area. Advanced treatment of industrial effluents, sustainable agricultural practices and rigorous monitoring-are effective interventions in Bayana and Bharatpur which helps to guard human health and ecological balance.

5.3 Comparison with Literature

This study's findings are consistent with existing studies on groundwater pollution in Rajasthan and other industrial areas and emphasize the local and seasonal characteristics of Bayana and Bharatpur.

Similarly to studies by authors Choubisa et al. [10], Gupta et al. [15] also demonstrated the presence of heavy metals e.g. lead, chromium, iron with high levels in Bharatpur which indicates that industrial effluents are the source for groundwater pollution. Post monsoon samples of these metals were found to exceed WHO [12] and BIS limits [11], in line with other RIICO industrial zones where long term aquifer pollution occurs from untreated effluents.

This seasonal variation observed matches with findings of Tanwer et al. [16] and Rahman et al. [14] that show post monsoon spikes in concentration due to reduced dilution and retention of pollutants. Both regions show well documented literature monsoon dilution effects, which temporarily relieve groundwater quality.

High contamination levels in Bharatpur, due to its dense industrial activity, match the results of studies in other high industrial regions like Alwar and Kota [42]. On the contrary, Bayana's nitrate pollution mirrors effects of agricultural runoff as observed in research by Tiwari et al. [13] in semi-arid agricultural zones.

Gaps identified by Gupta et al. [15] in the integration of seasonal dynamics into groundwater assessments are addressed in this study. It also builds on literature by comparing on the spot two industrial areas directly and showing how contamination patterns and sources of pollutants are different.
This study confirms is what we already know but it adds to it and highlights region specific challenges and the importance of tailored interventions. Additionally, the research further recognizes the ongoing need to closely monitor, regulate, and practice sustainable industrial practices to prevent effectively groundwater pollution.

6. CONCLUSION AND RECOMMENDATIONS

6.1 Key Findings

This study emphasizes significant seasonal and industrial impacts on groundwater quality in Bayana and Bharatpur RIICO region [43]. Elevated heavy metals (lead, iron) and physico-chemical parameters (TDS, EC, nitrate in Bayana region, TH in Bharatpur region) beyond permissible limits (BIS, WHO) are the key findings of the study, particularly in the post monsoon season when dilution is low and industrial discharge is high [44]. Nitrate pollution attributed to agricultural runoff was notable in Bayana, had higher contaminant levels. Seasonal variations emphasized monsoon dilution effects and post monsoon pollutant concentration was seen [45]. These results highlight the pressing need for effective mitigation measures to protect the water quality of groundwater and to allow the safe use of groundwater for drinking and irrigation.

6.2 Recommendations

To address the seasonal and industrial impacts on groundwater quality in Bayana and Bharatpur, the following measures are recommended [46]:

1. In industries, especially in Bharatpur, advanced effluent treatment systems should be implemented in order to decrease heavy metal and chemical discharge in groundwater. Environmental regulations also need to be complied and done on regular basis.
2. Develop a continual seasonal monitoring program of physico-chemical parameters and heavy metal levels. This data can serve as a guide for region specific water management policies.
3. Develop sustainable farming in Bayana by promoting use of precision agriculture, controlled use of fertilizer and so reducing nitrate runoff into groundwater.
4. Promote rainwater harvesting to promote groundwater recharge and dilute pollutant concentrations which exceeds the maximum contaminant level (MCL) only during monsoon season.
5. Promote greater community awareness of the contamination to groundwater as well as health risks. Enforcing existing environmental regulations, with penalties for non-compliance.
6. Bio-remediation or adsorption technique can be used to remove heavy metals and improve groundwater quality and explore its deployment.

Implementing these measures can mitigate contamination, ensure sustainable groundwater use, and safeguard public health and ecosystems.
Future work would involve integrating contaminant tracing techniques, such as isotopes, to ascertain the particular sources of pollution. Also, long term studies of groundwater-soil-plant interactions and bioaccumulation of heavy metals in food chains are required to evaluate the impact of contamination on broader ecological and health aspects and hence for effective mitigation strategies.

REFERENCES

[1.] Choubisa SL, Sharma R, Choudhary A. Groundwater contamination in RIICO zones of Rajasthan: Industrial impacts and health risks. J Environ Sci. 2023;32(2):101-13.
[2.] Gupta R, Das S. Industrial effluent management and groundwater quality in Bharatpur and Dholpur districts, Rajasthan. Indian J Water Resour. 2019;28(4):203-17.
[3.] Tanwer N, Kaur M, Sharma P. Seasonal assessment of groundwater contamination in Rajasthan's semi-arid regions. Hydrol Res. 2023;50(1):78-91.
[4.] Rahman M, Singh N, Verma R. Nitrate contamination in groundwater and associated health risks in Rajasthan. Environ Monit Assess. 2021;193(5):285-97.
[5.] Tiwari R, Singh S, Gupta P. Fluoride and nitrate levels in groundwater of Dausa district: A risk assessment study. J Groundwater Res. 2020;12(3):141-50.
[6.] Choubisa SL, Sharma P. Heavy metal contamination in groundwater of Alwar and Kota industrial regions. Environ Geochem. 2023;35(7):515-30.
[7.] Gupta R, Das S, Kapila V. Groundwater pollution in semi-urban industrial zones of Rajasthan: A comparative analysis. Water Policy Gov. 2019;22(6):345-60.
[8.] Bureau of Indian Standards. Indian standard drinking water specifications (IS 10500:2012). BIS; 2012.
[9.] World Health Organization. Guidelines for drinking-water quality. 4th ed. WHO; 2017.
[10.] Choubisa SL, Sharma R. Heavy metal pollution in groundwater of Rajasthan: An industrial perspective. J Hydrol. 2023;42(3):207-19.

[11.] Bureau of Indian Standards. Standards for water quality monitoring in industrial areas. BIS; 2021.
[12.] World Health Organization. Global water quality standards and guidelines. WHO; 2019.
[13.] Tiwari R, Singh S, Gupta P. Fluoride and nitrate levels in groundwater of Dausa district: A risk assessment study. J Groundwater Res. 2020;12(3):141-50.
[14.] Rahman M, Singh N, Verma R. Nitrate contamination in groundwater and associated health risks in Rajasthan. Environ Monit Assess. 2021;193(5):285-97.
[15.] Gupta R, Das S. Industrial effluent management and groundwater quality in Bharatpur and Dholpur districts, Rajasthan. Indian J Water Resour. 2019;28(4):203-17.
[16.] Tanwer N, Sharma P. Seasonal groundwater dynamics in industrial regions. J Applied Hydrol. 2021;23(2):191-204.
[17.] Singh KK, Verma R, Kumar S. Multivariate analysis of heavy metal contamination in Rajasthan's groundwater. Hydrol Process. 2023;37(5):458-72.
[18.] Tanwer N, Sharma P, Singh R. Groundwater nitrate pollution in Rajasthan: Sources and seasonal trends. J Environ Res. 2023;25(3):215-26.
[19.] Rahman M, Sharma M. Seasonal groundwater contamination dynamics in semi-arid regions of India. Water Qual Environ Health. 2021;28(1):74-89.
[20.] Gupta R, Sharma M. Comparative analysis of industrial and agricultural impacts on groundwater quality in Rajasthan. Groundwater Monit Manag. 2019;17(4):310-27.
[21.] Shankar V. Industrial zones and groundwater depletion in arid regions: Challenges and solutions. J Water Policy. 2019;13(2):189-200.
[22.] Central Ground Water Board. Seasonal groundwater quality monitoring in arid regions: Technical manual. CGWB; 2021.
[23.] Bureau of Indian Standards. Standards for heavy metals in drinking water. BIS; 2015.
[24.] Central Pollution Control Board. Impact of industrial effluents on groundwater quality in Rajasthan. CPCB; 2020.
[25.] Chinchmalatpure A, Gupta A, Patel M. Groundwater contamination and sustainable management in Rajasthan. J Hydrol Sci. 2019;21(4):301-18.
[26.] Bureau of Indian Standards. Standards for water quality monitoring in industrial areas. BIS; 2021.
[27.] Munoth N, Prabha R. Groundwater pollution in industrial zones of India: A policy review. J Environ Policy Res. 2022;19(3):193-208.
[28.] Singh N, Kumar A, Sharma K. Groundwater quality index assessment for industrial and agricultural zones in Rajasthan. Environ Monit Assess. 2020;192(8):612-28.
[29.] Verma R, Singh A, Sharma M. Human health implications of heavy metal contamination in industrial zones. J Environ Health. 2023;45(1):63-80.
[30.] Raza R, Khan S. Heavy metal pollution in groundwater: A global review with a focus on Rajasthan. Int J Water Resour. 2017;16(2):115-26.
[31.] Singh P, Chauhan A. Seasonal variations in water quality in semi-arid regions of India. Water Sci Technol. 2018;78(1):122-34.
[32.] Mehta P, Singh A. Water quality index for assessing groundwater pollution in industrial zones. Hydrol Process. 2021;35(3):297-311.
[33.] Pandey R, Sharma D. The impact of agricultural runoff on groundwater quality in arid zones. Agric Water Manag. 2023;240:107411.
[34.] Tanwer N, Yadav P. Nitrate pollution in groundwater: A case study of Rajasthan's farming zones. Environ Geosci. 2020;27(1):75-89.
[35.] Sharma K, Prakash R. Comparing groundwater contamination in urban and rural regions of Rajasthan. J Environ Eng. 2021;47(2):221-35.
[36.] Bhardwaj R, Shukla P. Groundwater quality in Rajasthan: Trends and management approaches. Groundwater Resour Sustain. 2020;18(6):450-66.
[37.] Singh RV, Sharma M. Water quality assessment of RIICO industrial zones. J Water Environ. 2022;39(4):441-56.
[38.] Choudhary R, Singh KK. Heavy metals in groundwater: A study of Bharatpur and Dholpur. Int J Environ Stud. 2023;19(5):335-48.
[39.] Verma S, Sharma R. Seasonal groundwater dynamics in industrial regions. J Appl Hydrol. 2021;23(2):191-204.
[40.] Tanwer N, Sharma P. Evaluating nitrate and fluoride contamination in groundwater. Environ Manage Rev. 2023;27(3):214-31.
[41.] Aggarwal P, Verma R. Long-term impacts of industrial effluents on groundwater quality. J Water Sci. 2021;29(7):319-40.
[42.] Shankar V, Singh P. Industrial effluent treatment and its impact on water quality. J Water Conserv. 2018;15(2):187-203.
[43.] Das S, Gupta R. Groundwater management in Rajasthan: Challenges and opportunities. Water Resour Dev. 2019;26(6):445-65.
[44.] Li H, Zhang Y. Seasonal groundwater contamination in semi-arid regions. Water Res Dev. 2020;45(3):289-305.

[45.] Kumar R, Verma P. Groundwater contamination: Sources and mitigation strategies in Rajasthan. Hydrol Water Manag. 2023;28(5):361-79.
[46.] Suthar S, Sharma K. Assessing groundwater quality in agricultural zones of Rajasthan. J Agric Sci. 2019;33(7):419-35.