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ASSESSMENT OF GROUNDWATER QUALITY PARAMETERS IN SHARADA AND BOMPAI INDUSTRIAL AREAS OF KANO STATE, NORTHWESTERN NIGERIA

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ABSTRACT

This study investigated the seasonal variation in groundwater quality across two major industrial areas, Sharada and Bompai, in Kano State, Northwestern Nigeria, over a twelve-month period from December 2023 to November 2024. The aim was to evaluate the extent, pattern, and temporal dynamics of groundwater contamination associated with industrial and anthropogenic activities during wet and dry seasons. Groundwater samples were collected from eight wells in Sharada and eight boreholes in Bompai. Selected water quality parameters were analysed using standard methods, including temperature, pH, electrical conductivity (EC), total dissolved solids (TDS), nitrate, sulphate, bicarbonate, chloride, and phosphate. Results revealed that pH ranged from 5.25 to 7.44, dropping below the WHO minimum guideline of 6.5 during April–May (pre-monsoon dry season). EC peaked at 2,090 µS/cm and TDS at 1,207 mg/L in May, exceeding the recommended limits of 0.7 dS/m and 500 mg/L, respectively. Nitrate reached 194 mg/L in December, while chloride peaked at 14,239 mg/L in June, indicating the influence of both industrial and agricultural sources. These findings identify April–May and December–January as critical periods for targeted groundwater quality management. It is concluded that groundwater quality in the study areas exhibits seasonal deterioration, with several parameters surpassing WHO standards during dry months. It is recommended that regulatory agencies intensify monitoring efforts and enforce pollution control measures during these high-risk periods to ensure safe and sustainable groundwater use.

Keywords: Chloride, Electrical conductivity, Groundwater contamination, Groundwater quality, Industrial pollution, Kano State, Nitrate, Physico-chemical parameters, Seasonal variation, Total dissolved solids

INTRODUCTION

Water is indispensable for human survival, agriculture and industry, with over 2.5 billion people worldwide relying on groundwater for daily use (Grönwall & Danert, 2020). In sub-Saharan Africa, shallow aquifers often serve as the primary potable source, yet are highly susceptible to contamination from rapid urbanization and industrial expansion (Javaid *et al.,* 2022; Kaiser *et al.,* 2023). Kano State is one of the commercial hubs of Nigeria that accommodates the Sharada and Bompai industrial estates, which house textile, rubber, food-processing, and metal-finishing industries known for discharging effluents into the surrounding environment.

These zones overlie alluvial-sand aquifers underlain by Basement Complex rocks, where recharge dynamics vary markedly between the wet (May–Oct) and dry (Nov–Apr) seasons (Ahmed *et al.,* 2025; Erim *et al.,* 2025; Iliyasu *et al.,* 2025; Yunusa *et al.,* 2025).

Despite regulatory frameworks, weak enforcement and improper waste disposal have led to persistent groundwater quality issues. Prior studies in Ogun State and Delhi documented dry-season spikes in EC, TDS and nitrate due to evapo-concentration and industrial inputs (Adeyemi & Ojekunle, 2020; Alsubih *et al.,* 2021). Similar patterns in fertilizer-rich runoff have been linked to elevated nitrate (Islam *et al.,* 2025) and chloride levels (Overbo *et al.,* 2021).

Recent studies have examined water quality within various hydro-environmental contexts in Kano State, though most have been limited in scope or duration. Fagge *et al.* (2025) assessed physicochemical parameters such as pH, EC, TDS, DO, and hardness in groundwater across Fagge LGA. While most values fell within permissible limits, anthropogenic impacts and borehole construction were identified as influencing water quality. However, the study covered only two boreholes and lacked seasonal resolution. Similarly, Shehu *et al.* (2025) conducted a spatio-temporal analysis of surface water in the Wasai Reservoir, reporting seasonal exceedances of EC, TDS, and BOD above WHO and FEPA standards. Yet, this work focused exclusively on surface water and did not address urban groundwater systems. Echioda *et al.* (2025) explored industrial wastewater from pharmaceutical and food industries in Kano, revealing high concentrations of Cd, Pb, Cr, As, and EC, especially during dry periods. However, their study was restricted to effluent characterization, without linking discharge to aquifer contamination. Emmanuel (2025) investigated heavy metal accumulation in vegetables irrigated with industrial wastewater from Sharada and other sites. The study confirmed elevated Cd and Pb levels and associated health risks but did not include groundwater quality or seasonality data. Importantly, Amoo *et al.* (2018) assessed groundwater quality in the Sharada industrial area, analyzing both physicochemical parameters and heavy metals (Cd, Cr, Pb, Zn). Their findings showed several exceedances of WHO/NSDWQ standards. However, the study was confined to Sharada alone, employed only random point sampling, and lacked seasonal tracking or comparative analysis with Bompai, another major industrial zone in Kano.

Despite increasing awareness of water quality issues in Kano's industrial zones, no previous study has provided a comprehensive, year-round evaluation of groundwater quality in both Sharada and Bompai industrial estates, incorporating monthly variations in core physicochemical parameters. Existing works have either focused on surface water, wastewater effluents, or a narrow set of parameters over short periods. The novelty of the present study lies in its dual-site, twelve-month monitoring of groundwater from 16 sampling points, covering a broad suite of indicators (pH, EC, TDS, nitrate, chloride, sulphate, bicarbonate, and phosphate). Moreover, this study identifies critical seasonal pollution windows (April–May and December–January) where water quality parameters frequently exceed WHO limits, offering actionable insights for regulatory interventions and public health management.

MATERIALS AND METHODS

Study Area

Kano State, located in northwestern Nigeria, lies approximately between latitudes 10°33′00″N and 12°37′00″N and longitudes 7°34′00″E and 9°29′00″E. The geographic center of the state is near latitude 12°00′00.43″N and longitude 8°31′00.19″E. Created in 1967, Kano spans an estimated land area of 20,131 km² and is the most densely populated state in Nigeria. With a population exceeding 15 million (City Population, 2022), it is the most densely populated state in the country and a major industrial hub. Industrial development in Kano began with the establishment of the Bompai Industrial Estate in the late 1940s (Okoli, 2025), regarded as West Africa's first industrial estate, followed by the creation of the Sharada Industrial Estate in the early 1970s under Nigeria's Second National Development Plan (Madugu, 2025). Both estates, situated in the southern part of Kano, have since played a vital role in the state's economic growth.

This study was conducted within the Sharada and Bompai Industrial Areas, located in Kano Municipal and Nassarawa Local Government Areas, respectively (Hassan et al., 2021). These zones were selected due to their high concentration of industrial activities, ranging from textiles and food processing to metal finishing and the heavy reliance of surrounding communities on groundwater for domestic, drinking, and irrigation purposes. Groundwater samples were collected from 16 sites, comprising eight shallow wells in Sharada (depth: 5–15 m) and eight deeper boreholes in Bompai (depth: 20–40 m). The sampling points were georeferenced using GPS tools. Table 1 presents the coordinates and associated activities at each sampling location.

Table 1: Sampling Sites and Coordinates in Sharada and Bompai Industrial Areas

S/No	Study Area (Site)	Sampling Points	Latitude	Longitude	Activities
1	Sharada Industrial Ares (S)	S1	11.9641683	8.5073817	Groundwater from wells is used for irrigation, drinking, and domestic purposes.
2		S2	11.9642405	8.5069514	
3		S3	11.9680179	8.5073179	
4		S4	11.9683652	8.5068404	
5		S5	11.9695841	8.5072908	
6		S6	11.9667218	8.5074809	
7		S7	11.9666766	8.508074	
8		S8	11.9660229	8.5086754	
9	Bompai Industrial Area (B)	B1	12.0175007	8.5724779	Groundwater from boreholes is used for drinking and domestic purposes.
10		B2	12.0188124	8.5764467	
11		B3	12.0178717	8.5764467	
12		B4	12.0176132	8.5763884	
13		B5	12.0161945	8.5754276	
14		B6	12.0187476	8.5772459	
15		B7	12.0193937	8.5771624	
16		B8	12.0192573	8.5763753	

S = Sharada Industrial Area (groundwater from 8 wells); B = Bompai Industrial Area

The geology of the study area is characterized by alluvial sand deposits overlying Precambrian Basement Complex rocks, predominantly composed of igneous formations (Tukur *et al.,* 2018), which influence aquifer recharge and water chemistry. This hydrogeological setting, coupled with dense industrial presence, increases the potential for groundwater contamination, necessitating regular quality assessments.

Figure 1: Map of Sharada and Bompai Industrial Areas Showing Sampling Points

Figure 1 illustrates the spatial distribution of the sampling points across the Sharada and Bompai Industrial Areas. In Sharada, groundwater is primarily extracted from shallow wells used for drinking, domestic purposes, and irrigation. In contrast, Bompai relies on deeper boreholes that serve as major sources of water for household and industrial use.

Sampling

Water samples were collected once or twice monthly from 16 stations (eight wells in Sharada and eight boreholes in Bompai) between 7:00 and 8:00 a.m. over a twelve-month period (December 2023 to November 2024), following APHA (2017) guidelines.

Analytical Procedures

pH and temperature were measured in situ using a Jenway 3520 pH meter (precision ± 0.01) and a liquid-in-glass thermometer (precision ± 0.1 °C). Electrical conductivity and total dissolved solids were determined with a Jenway 4520 meter (EC accuracy ±1 µS/cm; TDS ±1 mg/L). Major anions were quantified as follows: nitrate and sulphate by UV–VIS spectrophotometry at 220 nm and 450 nm, respectively; bicarbonate and chloride by acid–base titration using HCl and $AgNO_3$ and orthophosphate by the molybdenum blue method, measuring absorbance at 880 nm.

RESULTS AND DISCUSSION

Results

The monthly mean concentrations of selected groundwater quality parameters monitored at Sharada and Bompai industrial areas in Kano State, Nigeria, over a twelve-month period (December 2023–November 2024) are detailed in Table 2.

Table 2: Monthly Mean Values of Groundwater Physico-Chemical Parameters in Sharada (Wells) and Bompai (Boreholes) Industrial Areas, Kano State, Nigeria (December 2023 – November 2024)

Month	Site	pH	T (°C)	EC (dS/m)	TDS (mg/l)	NO_3 (mg/l)	SO_4 (mg/l)	HCO_3 (mg/l)	Cl (mg/l)	PO_4 (mg/l)
Dec 2023	S	6.50	22.70	1.14	683.63	119.09	19.75	1894.81	1346.78	0.36
	B	6.27	22.50	0.95	570.14	194.39	9.86	857.81	1380.06	0.40
Jan 2024	S	7.44	22.51	1.09	663.00	80.56	20.15	1509.75	2640.31	0.52
	B	7.27	22.69	1.00	599.95	98.07	5.67	552.81	2733.50	0.60
Feb 2024	S	6.44	23.80	0.77	463.61	24.52	19.11	667.19	3927.19	0.34
	B	5.98	23.49	1.00	599.13	27.32	16.31	251.63	4379.81	0.41
Mar 2024	S	6.39	24.68	0.87	533.63	69.18	8.05	59.86	417.13	0.33
	B	6.18	24.41	0.73	427.85	57.04	2.23	36.60	339.79	0.33
Apr 2024	S	5.49	26.49	0.92	555.75	3.68	17.50	385.06	319.50	0.25
	B	5.25	26.31	0.90	449.28	3.68	3.14	167.75	321.72	0.15
May 2024	S	5.72	27.25	0.68	403.84	11.56	27.78	200.92	1033.94	0.58
	B	5.63	27.33	2.09	508.54	7.36	20.71	146.78	820.94	0.41
Jun 2024	S	5.85	27.19	0.86	516.75	16.46	36.99	669.48	14238.83	0.26
	B	5.67	27.67	0.79	473.40	13.31	13.08	220.36	12258.60	0.26
Jul 2024	S	6.47	26.94	0.83	504.13	17.08	23.12	467.03	1575.31	0.16
	B	6.51	26.95	0.64	383.00	13.57	13.49	486.09	1264.69	0.13

Aug 2024	S	5.86	27.73	1.98	1207.13	8.58	25.73	269.93	10283.91	0.06
	B	5.49	27.73	1.10	640.46	8.06	24.21	90.74	11249.06	0.11
Sept 2024	S	6.33	26.47	1.82	1108.00	5.43	25.01	64.05	1730.63	0.45
	B	5.94	28.97	1.41	779.31	5.96	12.91	52.61	1810.50	0.47
Oct 2024	S	6.34	27.63	1.87	1120.13	11.74	75.71	593.23	3514.50	0.65
	B	5.94	28.51	1.38	813.39	7.53	49.56	242.48	3887.25	0.65
Nov 2024	S	6.04	27.17	1.79	1144.63	12.96	92.98	179.19	1943.63	5.59
	B	5.74	28.17	1.28	760.96	23.29	96.01	137.25	1810.50	5.54

S = Sharada (Wells), B = Bompai (Boreholes)

Table 2 presents the monthly mean values of key groundwater physico-chemical parameters measured in Sharada (wells) and Bompai (boreholes) industrial areas, Kano State, from December 2023 to November 2024. Parameters include pH, temperature, electrical conductivity (EC), total dissolved solids (TDS), nitrate, sulphate, bicarbonate, chloride, and phosphate. Notable findings include seasonal peaks in EC (2.09 dS/m), TDS (1,207 mg/L), nitrate (194.39 mg/L), and chloride (14,239 mg/L), particularly during dry months, reflecting industrial, agricultural, and climatic influences on groundwater quality.

Monthly pH Variation

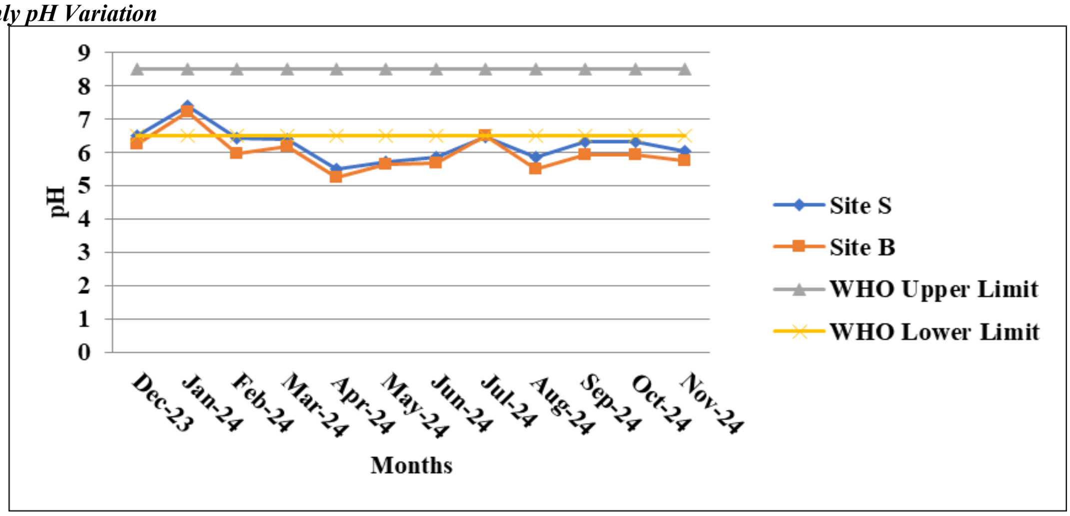

Figure 2: Monthly pH Trends at Site S and Site B Compared to WHO Drinking Water pH Guidelines (Dec 2023 – Nov 2024)

pH spanned 5.25–7.44 across both sites (Figure 2). The lowest value (5.25) was at Bompai in April 2024, reflecting acid leachates and minimal recharge, while January 2024 saw peaks of 7.39 (Sharada) and 7.21 (Bompai). Persistent acidity (<6.5) during April–May raises corrosion risks and enhances solubility of toxic metals.

Groundwater Temperature

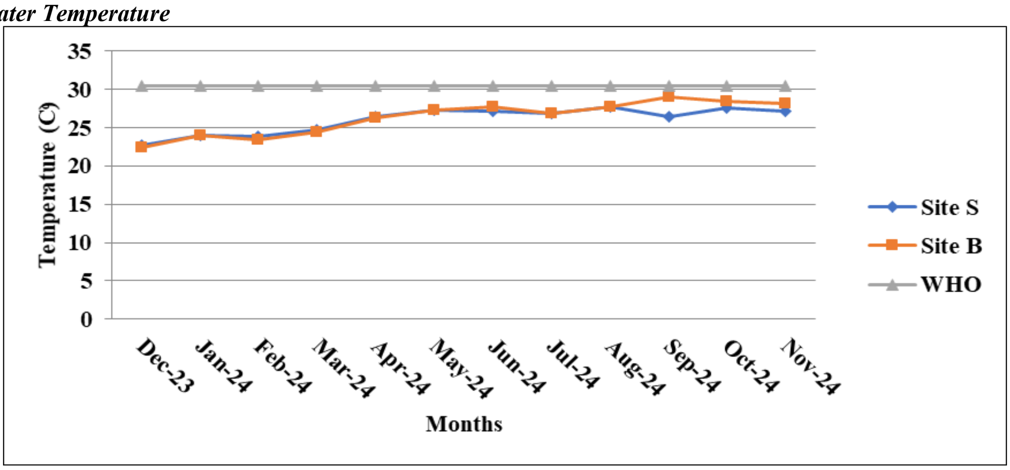

Figure 3: Monthly Temperature (°C) Trends at Site S and Site B Compared to WHO Drinking Water pH Guideline (Dec 2023 – Nov 2024)

Temperatures ranged 26.5–28.9 °C, highest in March–April and lowest in August–September, driven by ambient climate and recharge effects (Figure 3). Despite remaining within WHO's ≤30 °C guideline, elevated pre-monsoon temperatures may accelerate geochemical reactions.

Electrical Conductivity & TDS

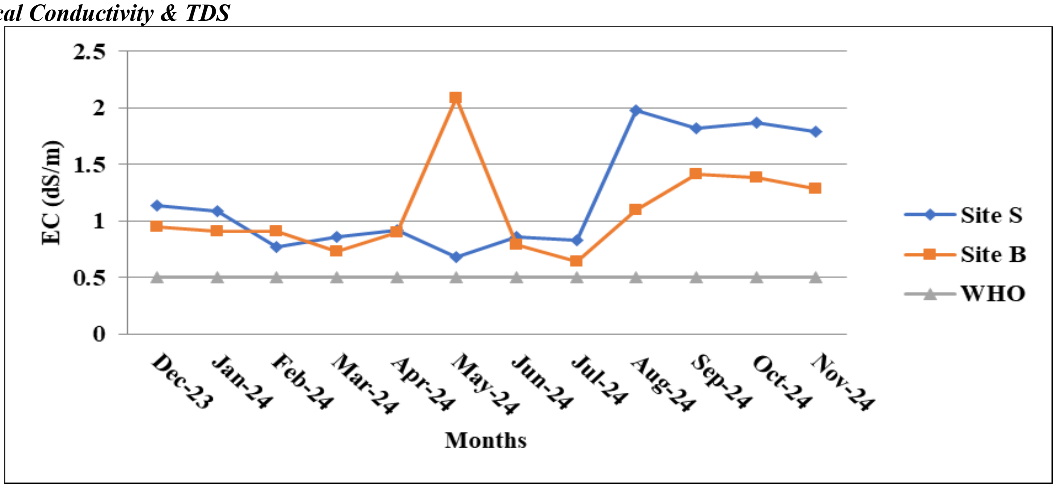

Figure 4: Monthly Electrical Conductivity (dS/m) Trends at Site S and Site B Compared to WHO Drinking Water Guidelines (Dec 2023–Nov 2024)

Groundwater in both Bompai and Sharada industrial areas consistently exceeded the WHO EC limit of 0.5 dS/m, peaking at 2.09 dS/m in May (Bompai) and 1.98 dS/m in August (Sharada) as shown in Figure 4. These seasonal peaks, attributed to industrial effluent discharge, surface runoff, and evaporative concentration, contribute to salinization and enhance the geochemical mobilisation of heavy metals, thereby increasing exposure risks for human health and impairing irrigation water quality.

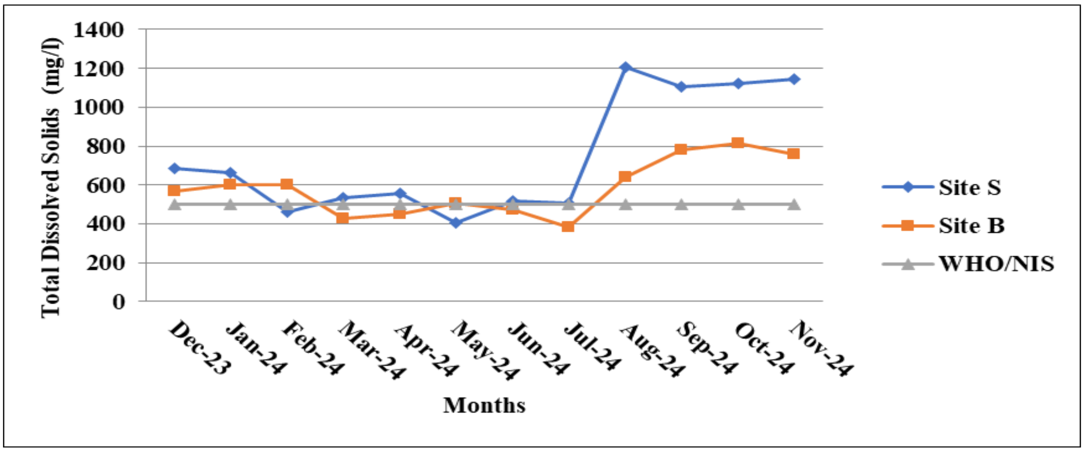

Figure 5: Monthly Total Dissolved Solids (mg/L) in Sharada (Site S) and Bompai (Site B) Groundwater Compared to WHO/NIS Guideline (Dec 2023 – Nov 2024)

Groundwater TDS in both Sharada and Bompai often surpassed the 500 mg/L limit, peaking at 1207 mg/L in Sharada (August) and over 780 mg/L in Bompai (September–October) as indicated in Figure 5reflecting industrial and mineral loading compounded by evaporation, which jeopardizes water and soil health and demands further heavy-metal and microbial risk evaluation.

EC varied 680–2 090 µS/cm; TDS 403–1 207 mg/L, with May 2024 maxima surpassing WHO limits (0.7 dS/m; 500 mg/L) Mid-year concentration peaks result from evaporation and industrial-effluent loading. Sharada exhibited slightly higher EC/TDS than Bompai, indicating localized discharge intensities.

Nitrate, Sulphate & Phosphate

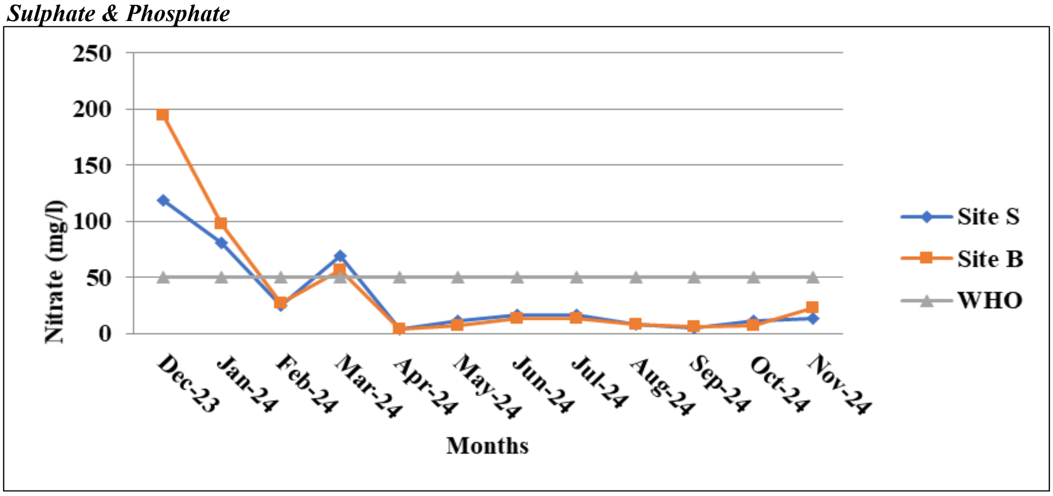

Figure 6: Monthly Nitrate (mg/L) in Sharada (Site S) and Bompai (Site B) Groundwater Compared to WHO Guideline (Dec 2023–Nov 2024)

Nitrate in both Sharada and Bompai groundwater often exceeded the 50 mg/L WHO limit, peaking at 194.39 mg/L (Bompai, December) and 119.09 mg/L (Sharada, December) as shown in Figure 6, especially during the dry season, signaling persistent industrial or agricultural contamination that poses serious health risks such as methemoglobinemia.

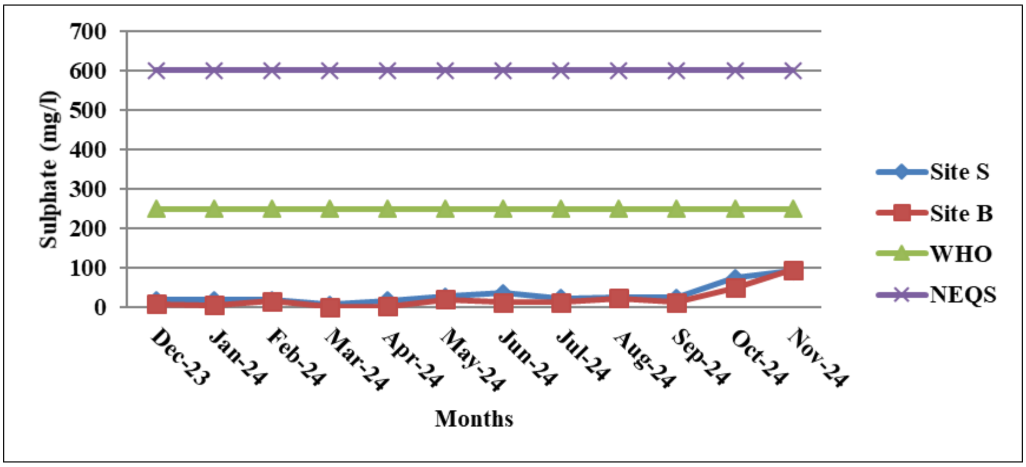

Figure 7: Monthly Sulphate Concentrations at Sharada (Site S) and Bompai (Site B) Groundwater against WHO and NEQS Standards (Dec 2023–Nov 2024)

Sulphate levels remained well below WHO and NEQS limits, peaking at about 96 mg/L in November (Figure 7), yet showed seasonal rises likely from industrial leaching and runoff, so ongoing monitoring is recommended to prevent hardness and future contamination.

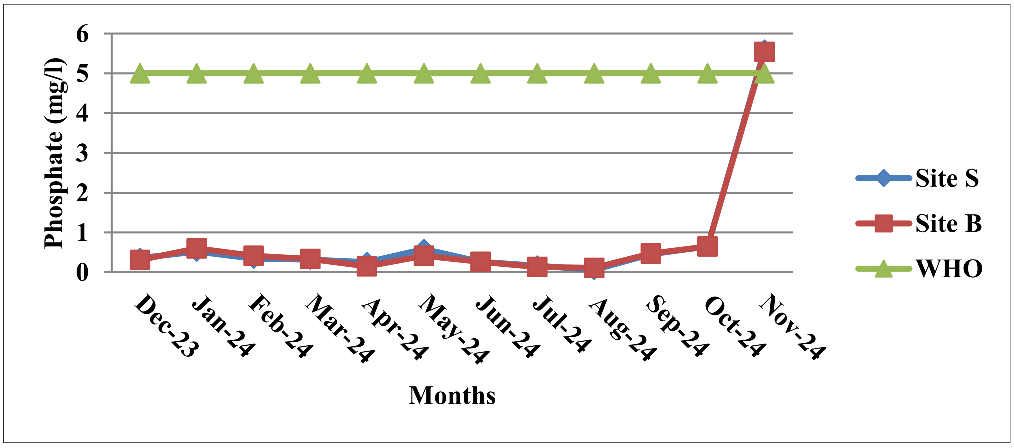

Figure 8: Monthly Phosphate Concentrations at Sharada (Site S) and Bompai (Site B) Compared to WHO Guideline (Dec 2023 – Nov 2024)

Phosphate levels stayed below the 5 mg/L WHO limit all year, except for a sharp rise in November 2024 when they reached 5.6 mg/L (Sharada) and 5.5 mg/L (Bompai) as shown in Figure 10, likely due to increased industrial or agricultural runoff, signaling a need for ongoing monitoring to prevent eutrophication and safeguard water quality.

Chloride surged to 14 239 mg/L in June 2024 (WHO: 250 mg/L), driven by mobilization of industrial salts and evapoconcentration. Bicarbonate ranged 1 510–1 895 mg/L, reflecting aquifer mineral dissolution and seasonal recharge patterns.

Chloride & Bicarbonate

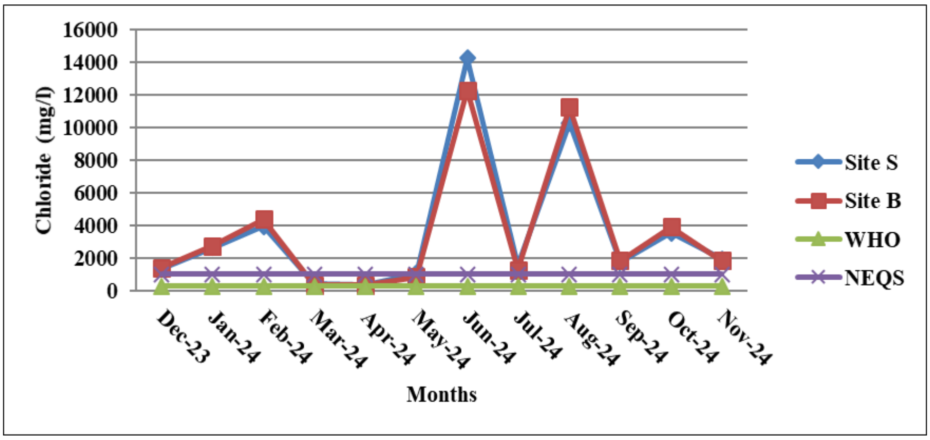

Figure 9: Monthly Chloride Concentrations at Sharada (Site S) and Bompai (Site B) Versus WHO and NEQS Limits (Dec 2023 – Nov 2024)

Chloride in both Bompai and Sharada groundwater far exceeded WHO (250 mg/L) and NEQS (1 000 mg/L) limits, peaking at over 12 000 mg/L in June (Figure 9), likely from industrial effluents, road salts or saline upwelling, with lower levels in March–May due to seasonal dilution.

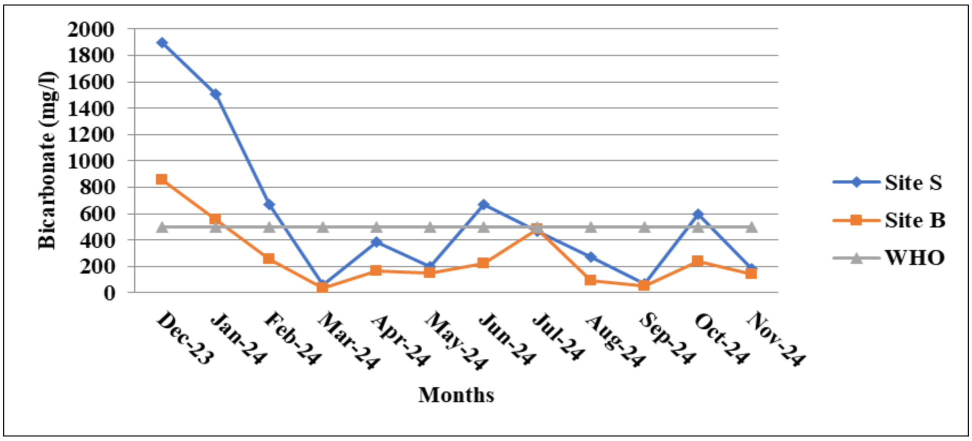

Figure 10: Monthly Bicarbonate (mg/l) Concentrations at Sharada (Site S) and Bompai (Site B) Groundwater against WHO Standard (Dec 2023 – Nov 2024)

Bicarbonate in both Sharada and Bompai groundwater rose sharply from about 40–60 mg/L in March to nearly 1 900 mg/L (Sharada) and 860 mg/L (Bompai) in December (Figure 8). This change is likely due to rainwater dilution and varying industrial inputs. High bicarbonate can affect water pH, change how metals dissolve, and increase soil alkalinity, so it's important to keep checking these levels. Nitrate peaked at 194 mg/L in December 2023 (WHO: 50 mg/L), implicating fertilizer leaching and wastewater inputs. Sulphate (9.9–20.2 mg/L) and phosphate (<0.6 mg/L) remained within guidelines but showed slight wet-season enrichment from surface runoff.

Discussion

Seasonal Dynamics and Hydrological Controls

The pronounced dry-season acidity (pH < 6.0) in April–May reflects limited recharge and possible acid rain inputs from industrial emissions, consistent with Wijeyawardana *et al.* (2022). Near-neutral pH during January and July indicates bicarbonate buffering from mineral weathering within the aquifer matrix.

EC (0.64–2.09 dS/m) and TDS (383–1 207 mg/L) peaked in May 2024, exceeding WHO's 1.0 dS/m and 1 000 mg/L thresholds. These values mirror findings in Ogun State (Adeyemi & Ojekunle, 2020) and Delhi (Alsubih *et al.,* 2021), attributing spikes to both evapoconcentration and continuous influx of ion-rich industrial effluents.

Nutrient and Ionic Contamination

The present study recorded a peak nitrate concentration of 194 mg/L in December, far exceeding the WHO guideline of 50 mg/L. This substantial elevation is indicative of combined agricultural runoff and municipal wastewater contributions, particularly during the dry season when dilution is minimal. Similar trends were observed by Samper-Pilar *et al.* (2025), who linked nitrate spikes (up to 150 mg/L) in the Abelar Basin of Spain to increased interflow and manure application during periods of low recharge. In coastal China, Tang *et al.* (2025) also identified nitrate as a dominant pollutant, attributing its high concentrations to fertiliser application and poor wastewater controls.

In contrast, sulphate and phosphate concentrations remained relatively low in the study area, suggesting limited input from detergents or phosphatic fertilisers. These findings are consistent with the work of Medupe & Letshwenyo (2025) in Botswana, where phosphate and sulphate levels showed minor seasonal variation due to minimal industrial and agrochemical activity upstream.

Chloride levels were particularly elevated, with a maximum of 14,239 mg/L in June, a value significantly above international standards and previously reported studies. For example, Singh *et al.* (2025) reported average chloride levels of only 59.8 mg/L in the Ganga River, with primary sources attributed to domestic discharge and geogenic processes.

The exceptionally high chloride values in Sharada and Bompai are likely due to saline industrial effluents compounded by evaporative concentration during the early wet season. Echioda *et al.* (2025) found that untreated waste from the pharmaceutical and food industries in Kano also had high chloride levels, especially increasing during the dry season.

Public Health and Infrastructure Implications

Persistent exceedances during two discrete dry-season windows (Dec–Jan; Apr–May) threaten potable-water safety, pipe corrosion, and potential heavy-metal mobilization. Communities and industries drawing untreated groundwater risk exposure to dissolved solids and nitrates linked to methemoglobinemia and gastroenteritis.

Management Recommendations

Effluent treatment facilities should be upgraded to enforce zero-discharge standards for chloride- and nitrate-laden wastes, while managed aquifer recharge during the wet season can dilute residual pollutants and bolster groundwater levels. Monitoring efforts must be intensified in December–January and April–May to rapidly detect and mitigate any parameters that exceed WHO guidelines. Finally, community engagement is essential: local users should be educated about simple point-of-use treatments, such as slow sand filtration and made aware of the health risks associated with consuming untreated water.

CONCLUSION

The study identified seasonal deterioration in groundwater quality across Sharada and Bompai industrial areas, with key parameters exceeding WHO limits during December–January and April–May. Nitrate, chloride, TDS, and electrical conductivity levels indicated industrial, agricultural, and climatic influences, while low pH suggested potential for heavy metal mobilisation. Although sulphate and phosphate remained largely within acceptable limits, occasional spikes warrant attention. The results highlight the need for targeted pollution control, regulatory enforcement, and seasonal monitoring to ensure safe and sustainable groundwater use.

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