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Original Research Article

Assessment of Physicochemical Parameters of Underground Water (Well Water) in Ijora - Badia Area of Lagos- State, Southwestern-Nigeria

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Physicochemical,
Anthropogenic,
Groundwater,
Environment,
Significant.

ABSTRACT
This study presents reports on the Assessment of Physicochemical Parameters of Undergroundwater (wellwater) in Ijora - Badia Area of Lagos- State, Southwestern- Nigeria. Ten wellwater samples were randomly collected from ten locations, four times per month, between August 2024 and January 2025. Samples were obtained with pre-washed, labelled plastic bottles, digested, and analyzed using standard procedures to measure physicochemical parameters such as pH, temperature, electrical conductivity (EC), acidity, alkalinity, turbidity, total suspended solids (TSS), and total dissolved solids (TDS). Results of Physicochemical parameters shows: pH (5.44 -7.05), temperature (29.3 - 29.8°C), EC (1417.5 - 2312.5 µS/cm), acidity (35.0 - 202.7 mg CaCO3/L), alkalinity (103.5 - 384.7 mg CaCO3/L), turbidity (7.8 - 337.5 NTU), TSS (30.5 -51.5 mg/L), and TDS (0.799 - 2.4123 mg/L). Principal Component Analysis identified three factors -PC1, PC2, and PC3 - which accounted for 70.25% of the total variance indicating predominantly anthropogenic sources from industrial, municipal, and domestic waste, dissolved and suspended solids, industrial effluents, and surface runoff, contributing to salinity and mineral-related pollution, thermal pollution, mineral dissolution, chemical weathering and natural geochemical processes. Correlation analyses ($p > 0.5$) further supports the high pollution levels. Physicochemical parameters varied significantly, except temperature.The physicochemical parameters values exceeded Nigeria Industrial Standards (NIS) and World Health Organization (WHO) limits, indicating that groundwater in the area is significantly polluted and unsuitable for domestic use.

CITATION
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INTRODUCTION

The failure of Federal, State, and Local Governments particularly the Lagos State Water Corporation (LWC) to adequately supply potable water has forced residents of Ijora - Badia, Lagos State, to depend largely on groundwater sources such as wells (Abraham et al., 2021).

Water is a clear, odourless, colourless inorganic substance that is indispensable to life and socio-economic development, covering about 70.9% of the Earth's surface (Scott et al., 2019; Indri et al., 2023). It occurs primarily as groundwater and surface water, where groundwater includes wells, springs, and boreholes, and surface water comprises streams, wetlands, creeks, and reservoirs (Emenike et al., 2019). In regions with inadequate water supply infrastructure particularly in developing countries and underserved communities like Ijora-Badia groundwater serves as a vital resource for domestic consumption, agriculture, and livestock production, underscoring the importance of continuous monitoring and sustainable management (UNICEF & WHO, 2021; Rahman et al., 2020).

Physicochemical parameters are the physical and chemical water quality indicators used to assess its safety and suitability for drinking. These include pH (acidity/alkalinity), temperature, turbidity, electrical conductivity (EC), total dissolved solids (TDS), total suspended solids (TSS), hardness, and dissolved oxygen (DO), which influence solubility, ion content, and clarity of water (Smith et al., 2021). pH affects metal solubility and biological processes, EC and TDS indicate dissolved ions, and turbidity shows suspended particles (Punde & Kulkarni, 2025). Monitoring these ensures compliance with WHO standards and detects contamination from natural or human sources, guiding water treatment and public health protection (Tongu et al., 2024; Punde & Kulkarni, 2025). Deviations from WHO standards suggest pollution or environmental imbalance(WHO, 2022). For example, abnormal pH levels may signal acidic or alkaline contamination, while high EC and TDS indicates an excess of dissolved salts or pollutants (García-Ávila, 2025). High levels of BOD and COD points out to organic or chemical contamination that could threaten aquatic life and public health (Tchounwou et al.,2012). Physicochemical parameters may reflect natural geology and anthropogenic influences (industrial discharge, agricultural runoff, sanitation failures) on groundwater quality (Islam et al., 2025; Dione et al., 2024). The Importance of Physicochemical Parameters provides a quantitative means of evaluating water quality and identifying potential contaminants. These values often determine whether water is safe for human consumption, agriculture, or industrial processes (García - Ávila, 2025). The WHO's Guidelines for Drinking-Water Quality offer internationally recognized benchmarks for many physicochemical water quality parameters (WHO, 2022).

Ijora - Badia, situated on the Lagos Mainland in southwestern Nigeria, is a densely populated settlement positioned close to major Nigeria railway corridors, where many residents live in congested and substandard conditions. The community faces severe infrastructural deficits, including unstable electricity, scarce potable water, and failing septic systems. Its land use is diverse, combining residential zones with small industries, warehouses, informal markets, and light manufacturing activities. Rapid urban growth has worsened issues such as poor drainage, inadequate waste management, seasonal flooding, and occasional oil spills from nearby tank farms, all of which heighten environmental pressure and increase the likelihood of water contamination. Most residents depend on groundwater from hand-dug wells and boreholes for drinking and domestic needs, making water quality a major concern.

Although, there are enormous studies on the Physicochemical parameters of wellwater in Nigeria and in the world (Dione et al., 2024; Lebbie & Kanneh, 2025; Mohana Priya, 2025; Danjari & Istifanus, 2025; Onoyima et al., 2025; Tonju et al., 2024; Mshelia & Mbaya, 2025) few literature(s) exist in Lagos (Kayode - Isola et al., 2025; Ogunware et al., 2020; Oritsedere et al., 2022) but little or no literature(s) in Ijora- Badia, Lagos-state (Okimiji et al., 2021). The objectives of this study are to evaluate whether well water in Ijora -Badia meets WHO and SON standards for drinking water and to determine its suitability for human consumption. The study also aims to generate baseline data to guide policy development and water-resource management, identify potential contamination sources, and recommend sustainable strategies for improving and maintaining well-water safety in the area.

MATERIALS AND METHODS

Study Area/Sampling Location

This study was conducted at Ijora - Badia (N6°27'58.6692", E3°21'25.62012"- N6°28'16.66812", E3°21'40.3632"-) area of Lagos - State, Southwestern - Nigeria namely; Gaskiya college road (GCR), Amusu street Adefila (ASA), Fadaini street badia (FSB), Idowu street, ijora badia (ISIB), Matiminu street (MS), 14, Bale street (14BS), 5, Bale street (5BS), Church street (CS), Guva street (GS), Sunday street (SS). (Figure 1).

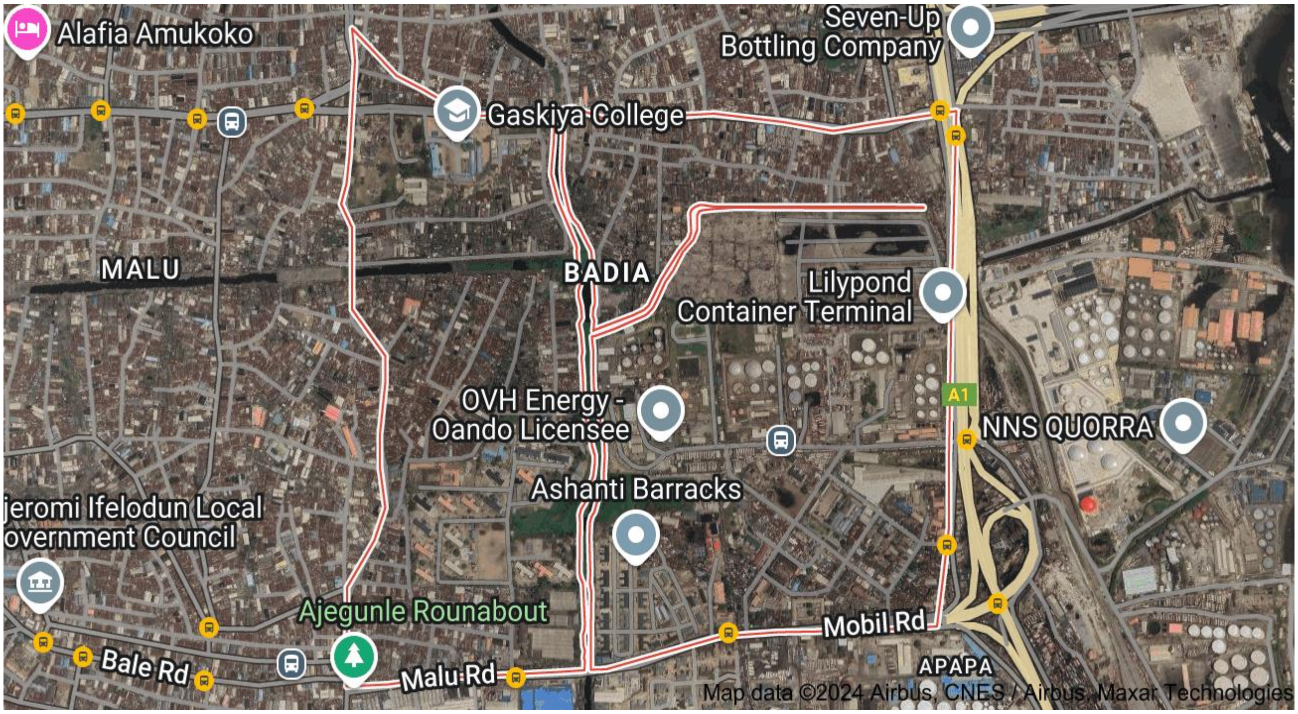

Figure 1: Map of Ijora – Badia

Selection of Sampling Sites/ Locations

Ten (10) Sampling sites were carefully chosen based on Accessibility to groundwater (Well water), natural and anthropogenic activities that may impact on the water quality in the Study area. A Global Positioning System (GPS) device was used to record the coordinates for each sampling site (GPS 76S Garmin) (Table 1).

Table 1: Sampling Sites, Characteristics and Coordinates of the Study Area

S/N	Location	Sample Code	Coordinates	
			Latitude	Longitude
1	Gaskiya college road	GCR	N6°27'58.6692"	E3°21'40.3632"
2	Amusu street Adefila	ASA	N6°28'3.1368"	E3°21'35.7588"
3	Fadaini street badia	FSB	N6°28'7.8024"	E3°21'33.4152"
4	Idowu street, ijora badia	ISIB	N6°28'6.7368"	E3°21'36.6696"
5	Matiminu street	MS	N6°28'0.9912"	E3°21'39.2508"
6	14, Bale street	14BS	N6°28'9.93958"	E3°21'36.612"
7	5, Bale street	5BS	N6°28'12.9"	E3°21'35.63388"
8	Church street	CS	N6°28'16.66812"	E3°21'34.24212"
9	Guva street	GS	N6°28'12.13212"	E3°21'33.138"
10	Sunday street	SS	N6°28'15.91212"	E3°21'25.62012"

Sampling and Sample Collection

Ten wellwater samples were collected from the Ijora - Badia area of Lagos State, Southwestern Nigeria, for six months (August 2024 - January 2025), four times per month. Sampling was done using pre-washed plastic bottles, rinsed with distilled water and air-dried. Each container was rinsed three times with the water sample before collection, tightly sealed, and labeled with identification codes. Samples were transported in an ice chest to the laboratory for analysis. The study measured potentially toxic metals - Lead (Pb), Cadmium (Cd), Mercury (Hg), Arsenic (As), and Chromium (Cr) - alongside physicochemical parameters, including Total Dissolved Solids (TDS), Total Suspended Solids (TSS), Electrical Conductivity (EC), Turbidity, Temperature, pH, Acidity, and Alkalinity.

Laboratory Analysis

All chemicals and reagents (Tetraoxosulphate(vi) acid (H_2SO_4), Trioxonitrate (v) acid (HNO_3), Hydrochloric acid (HCl), Mercuric sulphate (HgSO4), Potassium dichromate ($K_2Cr_2O_7$), Distilled water, Ferroin indicator, Ferrous ammonium sulphate (0.25 M FAS), Ethanol, Hydrogen peroxide) used for the laboratory analysis were of analytical grade and purchased from Lazco Scientific in Lagos, Lagos - State. Nigeria. Laboratory analysis were conducted at the Analytical Chemistry Laboratory of the College Central Research Laboratory, Yaba College of Technology, Yaba - Lagos, Nigeria.

Analysis of Physicochemical Parameters

Procedure for the Measurement of Temperatute, pH and Electrical Conductivity (EC)

The temperature, pH and electrical conductivity of the water samples were determined by collecting 50 ml of each sample into a 100 ml beaker. The instrument used was Adwa (AD 8000) pH /Conductivity / Temperature meter. It was inserted into the beaker and readings were recorded. Electrical Conductivity was expressed in μS/cm according to the manual instruction of the machine. The meter was standardized using deionised water by inserting the electrodes into it. The water samples were analysed for their conductivity by immersing the probe in the beaker containing each sample and the readings were taken (APHA, 2017; AOAC, 2000; WHO, 2022; Baird et al., 2017; Perpetual et al., 2022).

Procedure for the Measurement of Dissolved (DO) and Biological Oxygen Demand (BOD)

The collected borehole water samples were tied in a black nylon immediately after collection to prevent light from penetrating into it and it was transported to the laboratory. Then, the initial dissolved oxygen (i.e. day zero (0) was measured using a portable dissolved oxygen meter (DO METER) and the values were recorded. Thereafter, the samples were incubated for five days in a dark cupboard, and date and time of incubation were noted. After incubation, the final dissolved oxygen (i.e. the quantity of oxygen used by the microbes within the five days) was measured using the same dissolved oxygen meter (DO METER) and the values were recorded.(APHA, 2017; AOAC, 2000; WHO, 2022; Aliyu et al., 2018).

The Biological Oxygen Demand (BOD) were calculated thus: BOD (Mg/L) for day 5 = Final DO5 - Initial DO_1

Procedure for the Measurement of Chemical Oxygen Demand (COD)

Chemical Oxygen Demand were determined using open reflux. 50.0 ml of each borehole water samples and distilled water (blank) were measured and transferred in a round bottom flask. 1g of Mecuric sulphate ($HgSO_4$) and 25.0 mL $K_2Cr_2O_7$ - (0.00417M) were added and mixed. This was followed by slow addition of 75 ml of Concentrated Tetraoxosulphate (vi) acid to the mixture. It was then heated at reflux for 2 hours and allowed to cool. The cooled solution was diluted with 350 ml distilled water and then cooled to room temperature. Then the excess Potassium dichromate ($K_2Cr_2O_7$) in it was determined by titrating with 0.25 M Ferrous ammonium sulfate (FAS) using Ferroin indicator. A blank determination as above was done using 50ml of distilled water. (APHA, 2017; AOAC, 2000; WHO, 2022 ; Sawyer et al., 2003; Ovonkimwen, 2020).

The Chemical Oxygen Demand (COD) were calculated thus:

$$\text{COD (mg/L)} = \frac{(A-B) \times M \times 8000}{\text{Volume of the sample (ml)}} \quad (1)$$

Where: A = mL of Ferrous ammonium sulphate (FAS) used for the blank; B = mL of FAS used for the sample; M = Molarity of the FAS. :

Procedure for the Determination of Total Suspended Solids (TSS)

Total Suspended Solid (TSS) were obtained gravimetrically by filtration. An aliquot (100ml) of the water sample was filtered through dried pre - weighed 0.45 filter paper placed in a Buchner funnel. After wards, the filter paper was over dried at 105^0c for one hour. Then the filter paper was cooled and weighed. The difference in filter paper weight before and after was used to calculate the total suspended solid. (APHA, 2017; AOAC, 2000; WHO, 2022; Sawyer et al., 2003; Arafat et al., 2021).

The Total Suspended Solids (TSS) were thus: TSS (mg/L) = (final wt - initial wt) × 1000 / amount of the sample taken.

Procedure for the Determination of Total Dissolved Solids (TDS)

Total Solids (TS) and Total Suspended Solids (TSS) were determined before calculating Total Dissolved Solids (TDS). A 100 mL borehole water sample was evaporated in a dish over a water bath. The residue was dried at 106 °C in an oven, cooled, and weighed. This process was repeated twice to achieve a constant weight. The difference in weight before and after drying gave the TS value. TDS was calculated by subtracting TSS from TS. (APHA, 2017; AOAC, 2000; WHO, 2022).

The Total Dissolved Solids (TDS) were calculated thus: TDS (mg/L) = Total Solids (TS) - Total Suspended Solids (TSS):

Statistical Analysis

Mean values and standard deviations were calculated, and data were analyzed using ANOVA and Pearson's correlation. Duncan's Multiple Range Test (DMRT) was used to determine significant differences among sites, with superscripts (a - f) Table 2 denoting group variations. DMRT showed significant differences ($p < 0.001$) across all sites. pH ranged from slightly acidic to near neutral (5.44-7.05), whereas temperature remained fairly constant (~29 °C) and showed no significant variation (Table 3). Electrical conductivity varied markedly, being highest at ISIB and lowest at GS. Other parameters exhibited significant spatial variability, with electrical conductivity accounting for the greatest variation (79%).

Table 2: Mean ± Standard Deviation of levels of Physicochemical Parameters

Sites/ Location	pH	Temp (°C)	Ec (µS)	Acidity ($mgCaCO_3/L$)	Alkalinity ($mgCaCO_3/L$)	Turbidity (NTU)	TSS (mg/L)	TDS (mg/L)	%
GSR	7.05 ±0.02^{a}	29.35 ± 0.19^{a}	1417.50 ± 1.87^{i}	35.00 ± 2.37^{i}	223.00 ± 2.37^{c}	64.75 ± 0.19^{d}	30.50 ± 1.87^{f}	2.41 ± 0.000^{a}	7.8
ASA	6.54 ± 0.03^{c}	29.58 ± 0.26^{a}	1865.17 ± 2.32^{g}	74.67 ± 2.16^{f}	103.50 ± 2.43^{g}	27.98 ± 0.53^{f}	37.50 ± 1.87^{d}	1.54 ± 0.002^{c}	9.2
FSB	6.23 ± 0.02^{f}	29.47 ± 0.22^{a}	2163.33 ± 2.16^{b}	65.17 ± 2.64^{g}	183.50 ± 3.08^{e}	22.25 ± 0.19^{g}	51.50 ± 1.87^{a}	1.484 ± 0.003^{d}	10.8
ISIB	6.44 ± 0.02^{e}	29.82 ± 0.69^{a}	2312.50 ± 1.87^{a}	202.67 ± 2.16^{a}	223.67 ± 2.81^{c}	206.05 ± 1.31^{b}	38.50 ± 1.87^{d}	1.139 ± 0.002^{g}	13.0
MS	6.47 ± 0.03^{d}	29.40 ± 0.26^{a}	1949.83 ± 2.32^{e}	104.50 ± 1.87^{d}	363.33 ± 2.16^{b}	109.08 ± 1.35^{c}	46.50 ± 1.87^{v}	1.303 ± 0.002^{e}	11.2
14BS	6.25 ± 0.03^{f}	29.28 ± 0.23^{a}	1986.83 ± 2.64^{d}	161.17 ± 2.64^{b}	203.17 ± 2.64^{d}	60.35 ± 0.11^{e}	51.33 ± 1.86^{a}	1.255 ± 0.002^{f}	10.7
5BS	5.64 ± 0.02^{h}	29.48 ± 0.23^{a}	1994.17 ± 3.06^{c}	62.83 ± 2.32^{g}	222.50 ± 1.87^{c}	15.75 ± 0.19^{h}	45.50 ± 1.87^{bc}	1.579 ± 0.002^{b}	10.2
CS	5.44 ± 0.03^{i}	29.37 ± 0.22^{a}	1432.00 ± 2.90^{h}	79.50 ± 2.74^{e}	384.67 ± 3.33^{a}	347.53 ± 0.70^{a}	31.83 ± 2.32^{ef}	0.955 ± 0.003^{i}	9.9
GS	6.77 ± 0.03^{b}	29.27 ± 0.16^{a}	1354.17 ± 2.64^{j}	55.67 ± 2.81^{h}	122.50 ± 1.87^{f}	13.85 ± 0.19^{i}	43.33 ± 2.81^{c}	0.799 ± 0.002^{j}	7.0
SS	5.97 ± 0.02^{g}	29.37 ± 0.22^{a}	1929.00 ± 2.90^{f}	151.00 ± 2.37^{c}	203.17 ± 2.64^{d}	7.75 ± 0.19^{j}	33.67 ± 3.56^{e}	0.971 ± 0.002^{h}	10.1
F-Statistics (p)	2393.519 (<0.001)	1.731 (0.106)	103973.126 (<0.001)	3037.378 (<0.001)	7381.162 (<0.001)	160077.272 (<0.001)	71.413 (<0.001)	258517.281 (<0.001)	
%	0.3	1.3	79.0	4.3	9.6	3.8	1.8	0.1	

Table 3: Statistical Analysis of Physicochemical Parameters

Physicochemical Parameter	Range (mean ± SD)	Duncan grouping (highest = "a")	Statistical significance	Interpretation
pH	5.44 - 7.05	GSR (7.05 ± 0.02^{a}) highest, CS (5.44 ± 0.03^{i}) lowest	F = 2393.519, p < 0.001	pH values differ significantly. GSR is slightly alkaline, while CS, 5BS, and SS are acidic, indicating site-specific influences (possibly industrial discharge or organic matter decomposition).
Temperature (°C)	29.27-29.82	No significant difference (all "a")	F = 1.731, p = 0.106	All sites have similar temperature, suggesting a uniform thermal condition across sampling points—likely due to similar climatic and environmental exposure.
Electrical Conductivity (EC, µS/cm)	1354.17 - 2312.50	ISIB (2312.50 ± 1.87^{a}) highest, GS (1354.17 ± 2.64^{j}) lowest	F = 103,973.126, p < 0.001	Highly significant differences. ISIB shows strongest ionic concentration, indicating elevated dissolved salts and potential pollution; GS shows lowest mineralization.
Acidity (mg$CaCO_3$/L)	35.00 - 202.67	ISIB (202.67 ± 2.16^{a}) highest, GSR (35.00 ± 2.37^{i}) lowest	F = 3037.378, p < 0.001	Significant variation in acidity. ISIB's high acidity suggests industrial effluent influence; GSR and GS are least acidic.
Alkalinity (mg$CaCO_3$/L)	103.5-384.67	CS (384.67 ± 3.33^{a}) highest, ASA (103.50 ± 2.43^{g}) lowest	F = 7381.162, p < 0.001	Significant variation. CS's high alkalinity may be due to carbonate-rich discharges or buffering capacity, while ASA has low alkalinity, indicating poor buffering against acidification.
Turbidity (NTU)	7.75 - 347.53	CS (347.53 ± 0.70^{a}) highest, SS (7.75 ± 0.19^{j}) lowest	F = 160,077.272, p < 0.001	Large, significant differences. High turbidity at CS and ISIB indicates suspended particles and pollution load, while SS shows clear water conditions.
Total Suspended Solids (TSS, mg/L)	30.50-51.50	FSB (51.50 ± 1.87^{a}) highest, GSR (30.50 ± 1.87^{f}) lowest	F = 71.413, p < 0.001	Significant differences. FSB and 14BS have high TSS, likely due to particulate discharge or runoff. GSR shows lowest suspended solids.
Total Dissolved Solids (TDS, mg/L)	0.799-2.41	GSR (2.41 ± 0.000^{a}) highest, GS (0.799 ± 0.002^{j}) lowest	F = 258,517.281, p < 0.001	Significant variation. GSR's high TDS suggests elevated ionic pollution; GS again shows least contamination.

RESULTS AND DISCUSSION

Physicochemical Parameters in Wellwater Sample

Tables 4. shows the average values of Physicochemical Parameters. It presents site - specific averages, and percentage contributions of each Physicochemical Parameters to the total contamination load while Figure 2 shows selected photos of wells in the study areas.

(a) (b) (c)

(d)

(e)

Figure 2: Photos of wells in the study area: a - Sunday Street ; b - Amusu Street, Adefila; c- Gaskiya, College Road; d- Fadaini Street, Badia; e - Guva Street

Physicochemical Parameters of Wellwater Samples

Tables 4 and Figures 3a - h. shows the values of Physicochemical Parameters of wellwater samples across ten sampling locations. Wellwater temperatures in the study area ranged from 29.3°C to 29.8°C, with an average of 29.46°C. Idowu Street (ISIB) recorded the highest value, while 14 Bale Street (14BS) and Guva Street (GS) showed the lowest (Table 4). Although, these variations fall within acceptable limits, temperature can influence groundwater quality. Higher temperatures will accelerate chemical reactions, promote rock weathering, and increase the release of contaminants. They also reduce dissolved oxygen, affecting aquatic ecosystems. Generally, temperature shapes chemical processes, biological activity, and the solubility of gases and minerals, with high values generally lowering oxygen availability and impacting groundwater quality (Gebresilasie et al., 2021; Dodds & Whiles, 2020).

The pH of well water across the ten sampled locations ranged from 5.44 to 7.05, with an average of 6.28. Gaskiya College Road (GCR) recorded the highest pH (7.05), while Church Street (CS) showed the lowest value (5.44), reflecting strong acidity (Table 4). Most samples fell below WHO (2011) recommended range of 6.8 - 8.5, indicating acidic conditions that may pose health concerns. Such acidity is often influenced by atmospheric pollutants, acid rain, industrial emissions, and local soil composition (Opaluwa et al., 2020; Ogunware et al., 2020; Ikeagwuan et al., 2024; Adamu & Yusuf, 2025). Prolonged intake of acidic water can affect mineral balance, emphasizing the need for ongoing monitoring and remediation.

Electrical conductivity (EC) is a key parameter for assessing water quality for drinking and irrigation, as it reflects the concentration of dissolved ions and is influenced by temperature, with higher temperatures enhancing conductivity. In this study, EC values ranged from 1354.2 to 2312.5 µS/cm, averaging 1840.45 µS/cm. The highest value was recorded at Idowu Street (ISIB) (2312.5 µS/cm), while the lowest occurred at Guva Street (GS) (1354.2 µS/cm) (Tables 4). All samples exceeded WHO (2011) and NIS (2007) limits of 1000 µS/cm, indicating high dissolved ion content (Lebbie et al., 2025; Kayode-Isola et al,.2025). High EC value suggests increased water hardness and salinity, posing potential health risks such as kidney disorders and hypertension, therefore, there is need for monitoring and treatment Ijora-Badia wellwater.

Total Suspended Solids (TSS) are key indicators of water quality, affecting clarity, microbial activity, and suitability for domestic use. In this study, TSS levels ranged from 30.5 to 51.5 mg/L, averaging 41.01 mg/L (Table 4) (Awang et al., 2025). The highest concentrations occurred at Fadaini Street (FSB) and 14 Bale Street (14BS), while Gaskiya College Road (GCR) showed the lowest. All results were below the WHO (2011) and NIS (2007) limit of 100 mg/L (Onoyima et al., 2025; Tongu et al., 2024). Although, high TSS values affects water quality, increase bacterial growth, and heighten risks of gastrointestinal and other health problems (Hassan, 2016).

Total Dissolved Solids (TDS) serve as an important measure of drinking water quality, influencing taste, salinity, hardness, and possible health effects. TDS levels in well water ranged from 0.799 to 2.4123 mg/L, with an average of 1.3404 mg/L. Gaskiya College Road (GCR) had the highest value, while Guva Street (GS) recorded the lowest (Table 4). All measurements were far below the WHO (2015) and NIS (2007) guideline of 500 mg/L, indicating good water quality (Onoyima et al., 2025; Tongu et al., 2024)). However, High TDS indicates mineral contamination or wastewater influence, which can increase salinity, hardness, and long-term health risks such as kidney problems (Baloguru & Senthi, 2013; Yusuf et al., 2018).

Acidity indicates water's capacity to neutralize bases and is determined by hydrogen ion concentration. Acidity values ranged from 35.0 to 202 mg$CaCO_3$/L, with an average of 99.23 mg$CaCO_3$/L, showing that all locations were acidic relative to the WHO recommended pH range of 6.5 - 8.5 (Opaluwa et al., 2020) (Tables 4). Idowu Street (ISIB) recorded the highest acidity, while Gaskiya College

Road (GCR) had the lowest. Increased acidity often results from industrial effluents, mining activities, or decomposing organic matter, which can intensify metal leaching, elevate groundwater toxicity, and create health hazards. Continuous monitoring and pollution control remain vital (Hassan, 2016; Caerio et al., 2005; Ajiwe and Eboagu, 2021).

Alkalinity measures water's capacity to neutralize acids and is mainly influenced by salts of weak acids, bicarbonates, carbonates, and hydroxides (Elinge *et al.*, 2018). Alkalinity ranged from 103.5 to 384.7 mgCaCO$_3$/L, averaging 223.55 mgCaCO$_3$/L (Tables 4). The highest level was at Church Street (CS) (384.7 mgCaCO$_3$/L), while the lowest was at Amusu Street (ASA) (103.5 mgCaCO$_3$/L). All values were within WHO (2011) and NIS (2017) acceptable limits(Onoyima et al., 2025). Higher alkalinity, as seen at CS, enhances the water's ability to neutralize acidic contamination, reducing the risk of metal leaching, corrosion, and associated groundwater quality issues.

Turbidity refers to the cloudiness of water caused by suspended particles like sediments, microorganisms, and organic matter, reduces clarity. In this study, turbidity ranged from 7.8 to 337.5 NTU, averaging 86.86 NTU (Indri et al., 2023). Church Street recorded the highest (337.5 NTU), while Sunday Street had the lowest (7.8 NTU) (Tables 4). All values exceeded the WHO and NIS limit of 0.5 - 5 NTU, indicating contamination from microbial activity, industrial discharge, and waste (Adamu & Yusuf, 2025; Kayode-Isola et al., 2025). High turbidity increases waterborne disease risk and affects ecosystems, highlighting the need for effective treatment such as filtration and coagulation.

Table 4: Average Values of Physicochemical Parameters

S/N	Sample Code	pH	Temp (°C)	EC (µS)	Acidity mgCaCO$_3$/l	Alkalinity mgCaCO$_3$/l	Turbidity (NTU)	TSS (mg/l)	TDS (mg/l)
1	GCR	7.05	29.4	1417.5	35.0	222.7	64.8	30.5	2.4123
2	ASA	6.54	29.6	1865.2	74.7	103.5	27.9	37.5	1.535
3	FSB	6.23	29.5	2163.3	65.2	183.5	22.3	51.5	1.484
4	ISIB	6.44	29.8	2312.5	202.7	223.7	206.1	38.5	1.139
5	MS	6.47	29.4	1949.8	104.5	363.3	109.1	46.5	1.303
6	14BS	6.25	29.3	1986.8	161.2	203.2	60.4	51.3	1.255
7	5BS	5.64	29.5	1994.2	62.8	225.5	15.8	45.5	1.579
8	CS	5.44	29.4	1432.0	79.5	384.7	337.5	31.8	0.955
9	GS	6.77	29.3	1354.2	55.7	122.5	13.9	43.3	0.799
10	SS	5.97	29.4	1929.0	151.0	203.2	7.8	33.7	0.971
Total		62.8	294.6	18404.5	992.3	2235.5	865.6	410.1	13.432
Average		6.28	29.46	1840.45	99.23	223.55	86.56	41.01	1.3432
Percentage (%)		0.270	1.141	79.161	4.268	9.615	3.723	1.764	0.058
W.H.O (2015)		6.8-8.5	30-32°C	<1000		30-500	0.5-5	100	500
NIS (2007)		6.8-8.5	30-32°C	1000		30-500	5	100	500

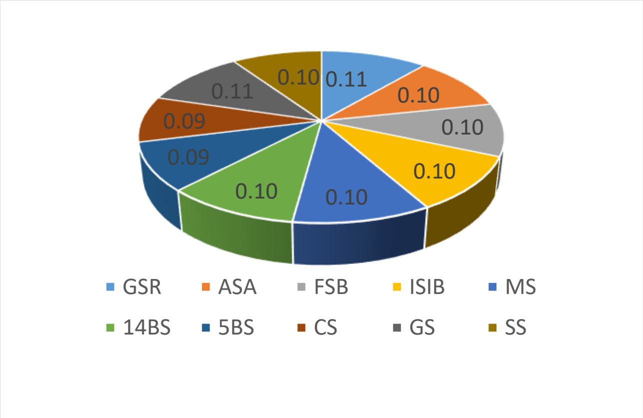

Figure 3a: Mean level of pH in the locations

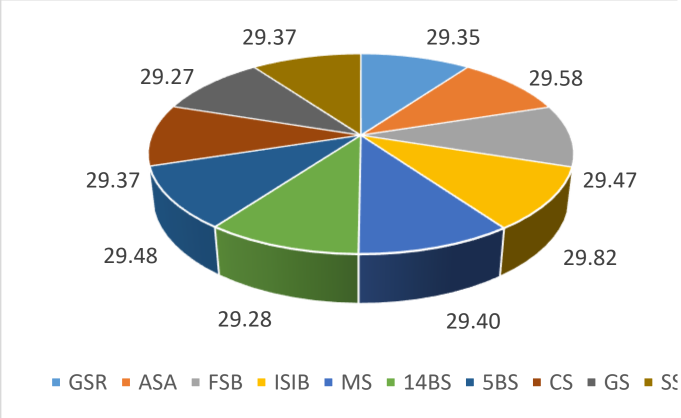

Figure 3b: Mean level of Temperature (°C) in the locations

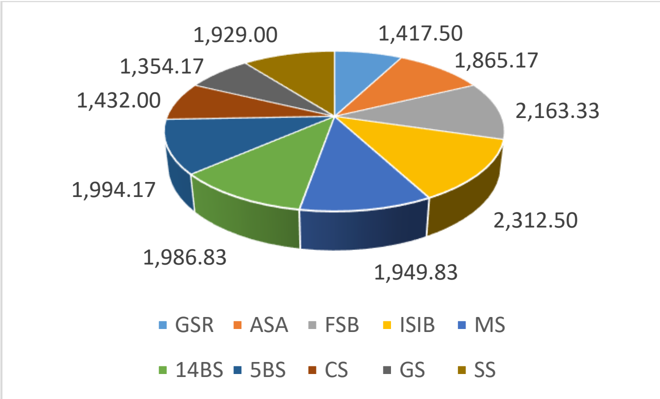

Figure 3c: Mean level of EC (μS) in the locations

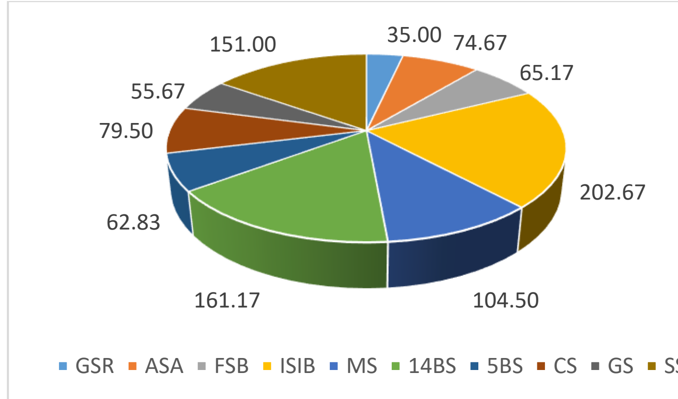

Figure 3d: Mean level of Acidity (mgCaCO3/L) in the locations

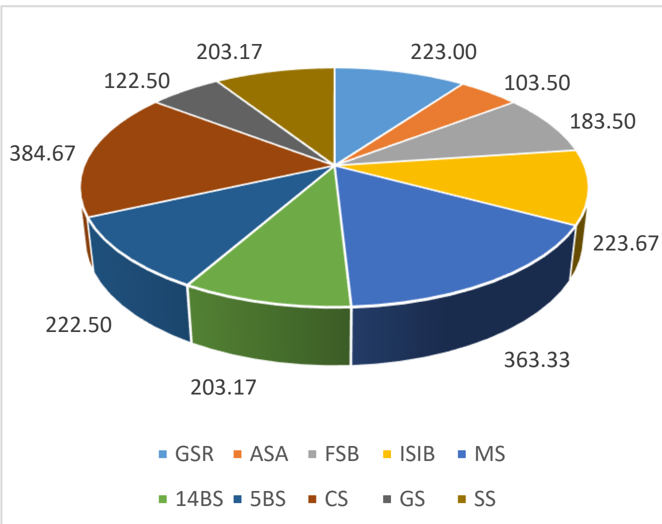

Figure 3e: Mean level of Alkalinity (mgCaCO3/L) in the locations

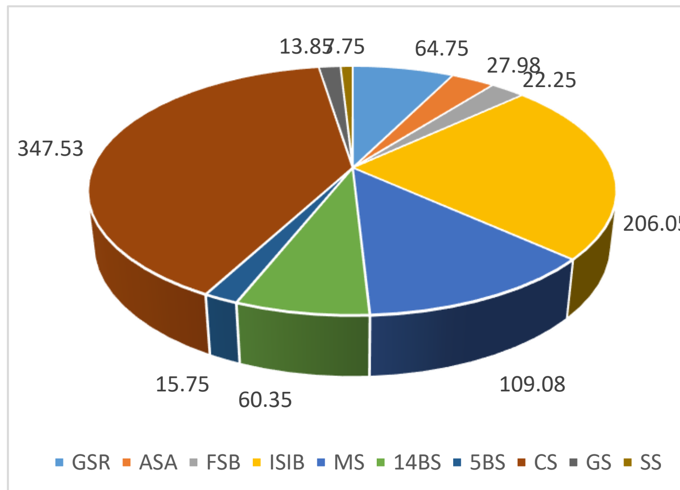

Figure 3f: Mean level of Turbidity (NTU) in the locations

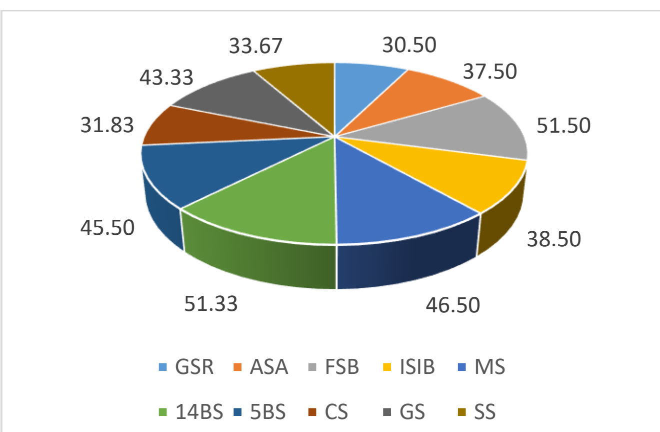

Figure 3g: Mean level of TSS (mg/L) in the locations

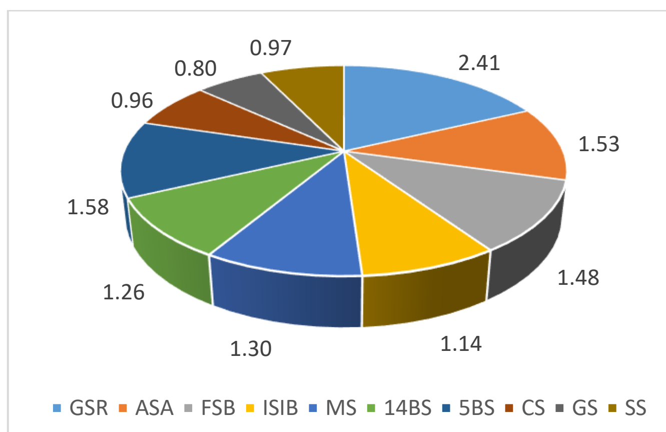

Figure 3h: Mean level of TDS (mg/L) in the locations

Using Principal Component Analysis (PCA) to Identify the Potential Sources of Physicochemical Parameters

Three major factors were identified as key contributors to the measured water quality parameters in the Ijora-Badia area (Figure 4). PCA grouped the Physicochemical Parameters dataset into three principal components -PC1, PC2, and PC3 - which accounted for 70.25% of the total variance (Table 5). PC1 accounted for 29.97% of the variance and was strongly associated with turbidity, alkalinity, and acidity, reflecting natural geochemical processes and inputs from industrial, municipal, and domestic waste. PC2 accounted for 26.36% of the variance, with high loadings from electrical conductivity (EC), total suspended solids (TSS), acidity, and temperature, indicating influences from dissolved and suspended solids, industrial effluents, and surface runoff, contributing to salinity and mineral-related pollution. PC3 contributed 13.93% of the variance, defined by temperature and total dissolved solids (TDS), pointing to thermal pollution, mineral dissolution, and chemical weathering as sources.

Table 5: The Rotated Component Matrix for Data of Physicochemical Parameters

Physicochemical Parameters	Components		
	PC1	PC2	PC3
Turbidity (NTU)	.753	-.486	
pH	-.709		
Alkalinity (mgCaCO$_3$/L)	.680	-.460	
Acidity (mgCaCO$_3$/L)	.609	.538	
TDS (mg/L)	-.598		.541
EC (μS)		.822	
TSS (mg/L)		.703	
Temp (°C)		.407	.712
Eigenvalues	2.397	2.108	1.114
% of Variance	29.966	26.355	13.927
Cumulative %	29.966	56.322	70.248

Mean values and standard deviations were calculated, and data were analyzed using ANOVA and Pearson's correlation. Duncan's Multiple Range Test (DMRT) was applied in SPSS (IBM v27) to determine significant differences among sites, with superscripts (a–f) in Table 2 denoting group variations. DMRT revealed highly significant differences ($p < 0.001$) across all sites. pH ranged from slightly acidic to near neutral (5.44–7.05), whereas temperature remained fairly constant (~29 °C) and showed no significant variation (Table 3). Electrical conductivity varied markedly, being highest at ISIB and lowest at GS. Other parameters exhibited significant spatial variability, with electrical conductivity accounting for the greatest variation (79%).

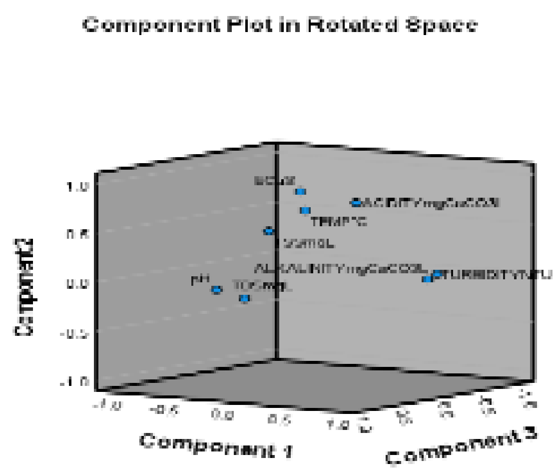

Figure 4: Bi - plot of the Physicochemical parameters

Correlation Analysis

Pearson's correlation analysis was used to examine statistical relationships between Physicochemical Parameters and their possible sources in well water. It measures the strength and direction of associations among Physicochemical Parameters. pH showed significant negative associations with EC, alkalinity, and turbidity, and a positive association with TDS, reflecting its influence on water quality. Temperature showed weak positive relationships with EC and acidity. EC showed a strong positive correlation with acidity and a moderate correlation with TSS, showing its contribution to ionic characteristics. Alkalinity was strongly and positively associated with turbidity, while acidity showed a significant negative relationship with TDS. Although, the Physicochemical Parameters are interrelated, most relationships are relatively weak (Table 6).

Table 6: Correlation Coefficient Analysis among Physicochemical Parameters in Well Water

	pH	Temp (°C)	EC (µS)	Acidity (mg$CaCO_3$/L)	Alkalinity (mg$CaCO_3$/L)	Turbidity (NTU)	TSS (mg/L)	TDS (mg/L)
pH	1.000	.031 (0.406)	-.184 (0.028)	-.148 (0.129)	-.450 (<0.001)	-.389 (0.001)	-.015 (0.456)	.420 (<0.001)
Temp (°C)		1.000	.323 (0.006)	.237 (0.034)	-.029 (0.413)	.114 (0.193)	.145 (0.135)	.028 (0.417)
EC (µS)			1.000	.633 (<0.001)	-.082 (0.266)	-.145 (0.135)	.478 (<0.001)	-.066 (0.308)
Acidity (mgCaCO3/L)				1.000	.093 (0.240)	.231 (0.038)	.099 (0.225)	-.450 (<0.001)
Alkalinity (mgCaCO3/L)					1.000	.727 (<0.001)	-.148 (0.130)	-.089 (0.248)
Turbidity (NTU)						1.000	-.376 (0.002)	-.255 (0.024)
TSS (mg/L)							1.000	-.149 (0.128)
TDS (mg/L)								1.000

CONCLUSION

The study assessed physicochemical quality of well water across ten locations and revealed several concerns. pH values indicated predominantly acidic conditions, with most physicochemical parameters exceeding the permissible limits set by the Nigeria Industrial Standards (NIS) and the World Health Organization (WHO). Electrical conductivity was high at all sites, exceeding recommended limits and suggesting high dissolved ions, salinity, and hardness. Although, TSS, TDS, and alkalinity were generally within permissible limits, Turbidity levels were extremely high, indicating contamination and possible increase in risk of waterborne diseases. The high turbidity and electrical conductivity (EC) indicates elevated pollution levels with significant contributions from both natural processes and human activities reflecting substantial contamination by dissolved and suspended solids, making the water unsuitable for drinking or domestic use.

PCA which accounted for 70.25% of the total variance, identified key pollution drivers such as industrial effluents, municipal and domestic waste, chemical weathering, mineral dissolution, and surface runoff. These observations shows the extent to which human activities have affected the groundwater in the study area. Furthermore, strong correlations among key parameters ($p > 0.5$) reinforce the interpretation that multiple pollutants originate from common contamination sources, especially industrial and urban inputs. Among all parameters assessed, temperature was the only one that did not vary significantly, suggesting uniform climatic influence but not necessarily better water quality.

In conclusion, groundwater in Ijora - Badia is significantly polluted and unfit for domestic purposes without proper treatment. Therefore, there is the urgent need for environmental management interventions, stricter pollution control policies, and community-level awareness campaigns to prevent further degradation of this vital water resource.

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