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Evaluation of Well Water Using Water Quality Index in Settlements near Confluence University of Science and Technology Osara, Kogi State, Nigeria

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Abstract

Regular quality checks are necessary to ensure that well water is suitable for consumption as it is an essential ecological resource for farming, industry and drinking. In this study, the water quality index and a number of physicochemical characteristics of well water were investigated between July and September 2024 in Osaragada, Osara and Abobo, which are nearby settlements of Confluence University of Science and Technology, Osara, Kogi State, Nigeria. The weighted arithmetic water quality index (WAWQI) technique was employed to estimate the water quality index for each station after physicochemical parameters were evaluated using accepted standard procedures. The findings revealed average values of pH (7.29 ± 0.42), total dissolved solids (224.88 ± 50.74 mg/L), salinity (0.031 ± 0.00 ppt), biochemical oxygen demand (0.013 ± 0.012 mg/L), electrical conductivity (168.44 ± 36.18 µS/cm), nitrates (5.18 ± 1.28 mg/L), turbidity (0.43 ± 0.18 NTU), chloride (36.92 ± 10.74 mg/L), dissolved oxygen (7.07 ± 3.44 mg/L) and total suspended solids (0.61 ± 0.30 mg/L), all of which complied with the WHO drinking water standards. The water quality indices for Osaragada (12.82), Osara (10.26) and Abobo (10.41) shows good water quality appropriate for industrial, agricultural and drinking purposes. One-way analysis of variance (ANOVA) was used to analyse the data and a p-value (<0.05) was accepted as statistically significant. The only physicochemical measure that showed significant differences between the sites was total dissolved solids (P-value = 0.037). The study recommends more research to evaluate heavy metals and bacteriological factors

Keywords: *Salinity, Osara, Water quality index, Turbidity, Chloride*

Introduction

One of the biggest problems in many developing nations is getting enough safe water for consumption (Salehi, 2022). Healthcare, food safety, economic growth and poverty alleviation all depend on a steady supply of clean water, which enhances regional well-being (Mohamed *et al.*, 2021). Groundwater is a valuable resource due to its natural filtration process which often removes harmful organisms and typically requires minimal treatment (Al-Hashimi *et al.*, 2021). It usually has consistent chemical properties and lacks color and turbidity. However, groundwater is vulnerable to contamination from past or present human activities (Sultana and Sultana, 2024) .

Humans need water to survive and its importance for human health is undeniable (Meride and Ayenew, 2016) . However, water can also transmit diseases, significantly impacting human and animal health (Ramírez-Castillo *et al.*, 2015). Global guidelines for safe drinking water, particularly for physicochemical properties standards, are often based on WHO recommendations, though specific regulations may vary (Mosi *et al.*, 2019). Standards for recreational water are usually less strict than those for consumption. The right to potable water is impeded in rural and economically disadvantaged areas by poor infrastructure and budgetary constraints (Omarova *et al.*, 2019). The majority of Nigeria cities have access to purified piped water however, the supply is erratic and frequently insufficient. According to Idowu *et al.* (2011), a large number of people in urban and semi-urban areas depend on wells to meet their water demands.

Well water in rural areas poses a serious public health risk due to frequent contamination with harmful substances and pathogens (Obikpo *et al.*, 2022). Waterborne illnesses may result from the presence of harmful microbes and toxic metals in well water if testing and monitoring are not conducted on a regular basis (Nwinyi *et al.*, 2020). Pollution is often worsened by nearby industrial and agricultural activities, further compromising water safety (Li *et al.*, 2024). Public health hazards in rural areas are increased by the enormous effect that this lack of access to clean drinking water has on susceptible groups, such as infants, the aged and people with compromised immune structures (Miller *et al.*, 2021).

Based on a number of factors, a Water Quality Index (WQI) is a definite figure that represents the general state of the water at a given place and time (Kumar and Dua, 2009; Ogbodo *et al*., 2020). WQI are currently adopted extensively throughout the world to evaluate the quality of groundwater as well as surface waters, giving a clear picture of the state of the water (Bora and Goswami, 2017, Ogbodo *et al.*, 2020). To make complex data on water quality easier to understand, several organizations have created indices such as the Weighted Arithmetic Water Quality Index (WAWQI) (Tyagi *et al.*, 2020).

The nearby communities of Abobo, Osara, and Osaragada have seen a notable increase in population as a result of the institution of Confluence University of Science and Technology in Osara village. Residents used to get their water from hand-dug wells and streams, but many now buy it from suppliers or private borehole vendors. Those who cannot use these alternatives, however, continue to obtain their drinking water from hand-dug wells. Due to the high-water table, most wells in the area are shallow (Kifelew and Mesalie, 2022). Despite the growing population, recent studies on water quality in these areas are lacking. In order to establish whether well water is suitable for a variety of uses, this study intends to evaluate the overall pollution trend in well water using the Weighted Arithmetic Water Quality Index (WAWQI) approach, which is a variation of Horton's formula created by Brown *et al.* (1970) as adopted in recent research works (Krishan *et al.*, 2016; Bora and Goswami, 2017; Ogbodo *et al*., 2020)

Materials and Methods

Study Area

Three communities in Kogi State, in the North Central region of Nigeria, namely Osaragada, Osara and Abobo have hand-dug wells from which water samples were taken for this research. Kogi State uniquely borders ten other states, including Ekiti, Kwara, and Benue and features a wet and dry seasons with a mean annual temperature of 29.88°C. The region is within the Savanna zone and its elevation is approximately 174.96 meters above sea level, with an average annual rainfall ranging from 1524 to 1916 mm in May to October 18, 2025 (Ifatimenhi *et al.*, 2021). Abobo, situated in Okehi Local Government Area, lies adjacent to the National Iron Ore Manufacturing Company. Osara, hosting Confluence University of Science and Technology and Osaragada are both located in Adavi Local Government Area along the Okene-Lokoja highway. The study area is bounded between Latitudes 7° 39’ and 7° 42’ North of equator and Longitudes 6° 18’ and 6° 27’ East of the Prime Meridian (Figure 1). The geology of the area is composed of granodiorite gneiss that is heavily foliated and has bands that alternate between being light (quartzo-feldspathic) and dark (biotitic and/or hornblendic). Additionally, the region has a variety of rock units, such as migmatite, mica gneiss, quartzite and granite gneiss (Kolawole *et al.*, 2016). The predominant occupation of the people is farming and they produce crops such as cassava, yam, cocoyam, maize, rice and cowpea. These communities are significant due to their proximity to the university.

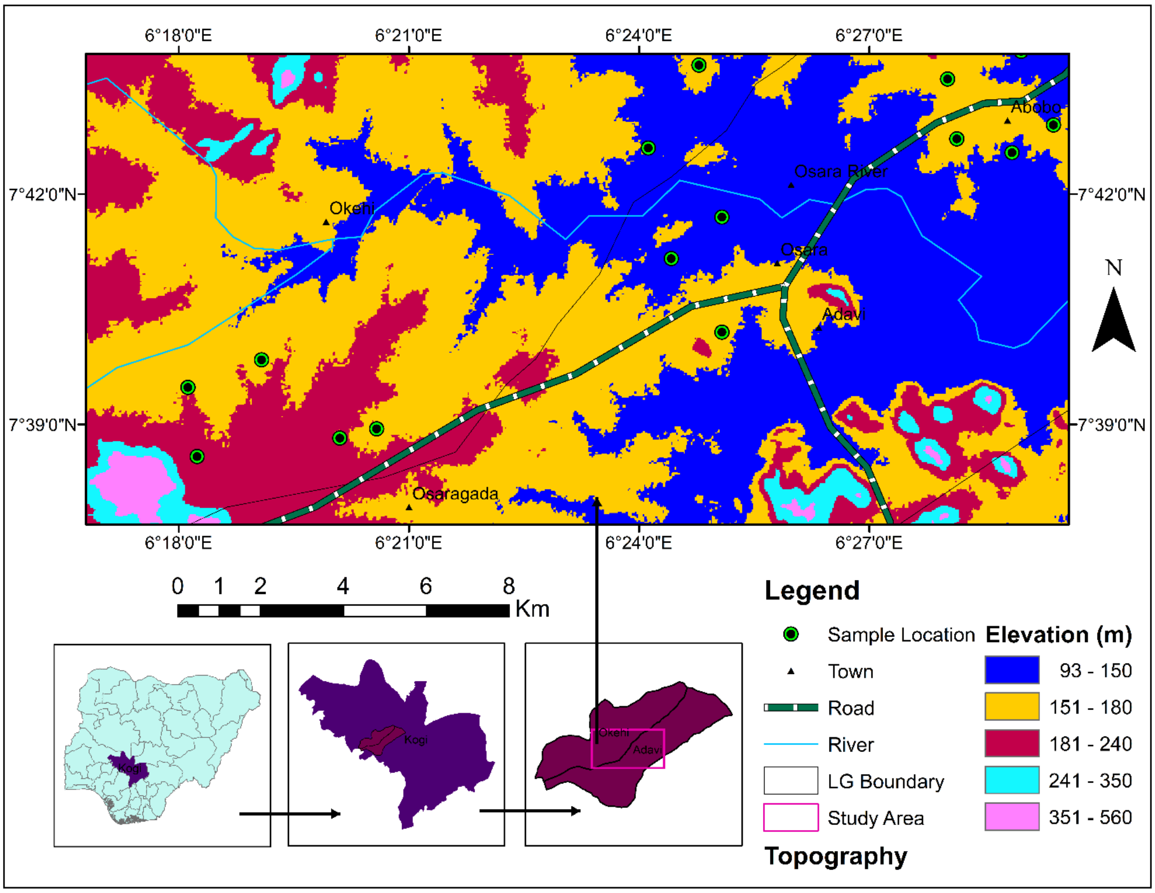

Figure 1: Map of Nigeria showing Kogi state and the various stations studied

Sampling

Three stations were used to gather water samples: Abobo (Station A), Osara (Station B) and Osaragada (Station C). Five wells that were manually dug were chosen from each location using random sampling. Sterilized plastic bottles were used for collecting water samples for physicochemical analysis while BOD bottles were used to collect water samples for BOD analysis. The water samples from each station were mixed to form a composite sample, which was then analyzed in triplicate. Water samples were stored at 4 °C in the laboratory refrigerator and analyzed within 24 hours (Oyem *et al.*, 2014). In all, 45 samples were obtained over the three months period (July – September, 2024). This sampling period represents the phase of water yield in most wells in the area.

Sample Analysis

The analysis followed standard laboratory methods of APHA (2005) and Trivedy and Goel (1986) adopted by Awoyemi *et al.*, 2014 and Bora and Goswami, 2017. Physicochemical parameters determined include pH, Electrical conductivity (EC), Total dissolved solids (TDS), Dissolved oxygen (DO), Salinity, Turbidity (using a Multiparameter meter – Hanna H19829), Total suspended solids (TSS) (using the gravimetric method), Chloride and Nitrate (using calorimetric analysis). Water sample was incubated at 20°C for 5 days and the oxygen consumed is measured. The difference between the dissolved oxygen obtained on day 5 and day 1 represents the BOD level. The Water Quality Index (WQI) was computed following the 'weighted arithmetic index method' (Krishan *et al.*, 2016; Bora and Goswami, 2017; Ogbodo *et al.*, 2020), using the equation:

$$WQI = \sum \boldsymbol{Qiwi} / \sum Wi \quad \text{--} (1)$$

The water quality rating scale (Qi) for each parameter is calculated by using the expression:

$$Qi = 100\,[(Vi - Vo) / (Si - Vo)] \quad \text{--} (2)$$

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Vi = is estimated level for each parameter
Vo = ideal level for each parameter (With the exception of pH = 7.0 and DO = 14.6 mg/L, most parameters are 0)
Si = the parameter standard value

Wi = K/Si (parameter unit weight), K = Proportionality constant ($\frac{1}{\sum\frac{1}{Si}}$)

The water quality rating scale (Table 1) was then used to categorize the computed WQI values.

Table 1: Water Quality Rating Table

WQI Range	Grade	Possible Usage	Water Quality Status
0 – 25	A	Ideal for irrigation, industrial and drinking	Excellent
26 – 50	B	Ideal for irrigation, industrial and Drinking	Good
51 – 75	C	Ideal for industrial and irrigation use	Poor
76 – 100	D	Ideal for Irrigation	Very Poor
> 100	E	Requires treatment before use	Unsuitable

Data Analysis

The data obtained were subjected to mean, standard error, standard deviation and analysis of variance (ANOVA) using SPSS Version 26 software. Tukey HSD test was used to describe significant differences at $P < 0.05$.

Results

Physicochemical properties of well water from sampling stations

The physicochemical analysis results (pH, electrical conductivity, turbidity, salinity, chloride, BOD, DO, nitrate, TDS and TSS) are summarized in Table 1. The pH levels varied from 7.19 (Osaragada) to 7.36 (Osara) (Figure 2), with an average value of 7.29±0.42. Osara had the lowest electrical conductivity (153.70 µs/cm), while Osaragada had the highest (194.43 µs/cm) (Figure 3). The average conductivity across all stations was 168.44±36.18 µs/cm. According to the study, Osaragada had the highest TDS level (276.33 mg/L), whereas Osara had the lowest (181.67 mg/L) (Figure 4). The average TDS for all locations was 224.88±50.74 mg/L.

Table 2: Summary of the physicochemical properties of well water

Parameter	pH	TDS	Salinity	BOD	EC	Nitrate	Turbidity	Chloride	DO	TSS
Unit		mg/l	Ppt	mg/l	**µs/cm**	mg/l	NTU	mg/l	mg/l	mg/l
Mean ± Std. Error	7.29 ±0.14	224.88 ±16.91	0.031 ±0.001	0.01 ±0.003	168.44 ±12.06	5.18 ±0.42	0.43 ± 0.05	36.92 ± 3.57	7.07 ± 1.14	0.61 ±0.10
SD	0.42	50.74	0	0.01	36.18	1.28	0.18	10.74	3.44	0.30
Min	7.17	181.67	0.032	0.01	153.7	4.32	0.3	30.25	6.23	0.54
Max	7.36	276.33	0.032	0.02	194.43	5.88	0.57	41.12	8.27	0.67
WHO Guidelines	6.5-8.5	500	500	5	1000	50	5	250	5	500

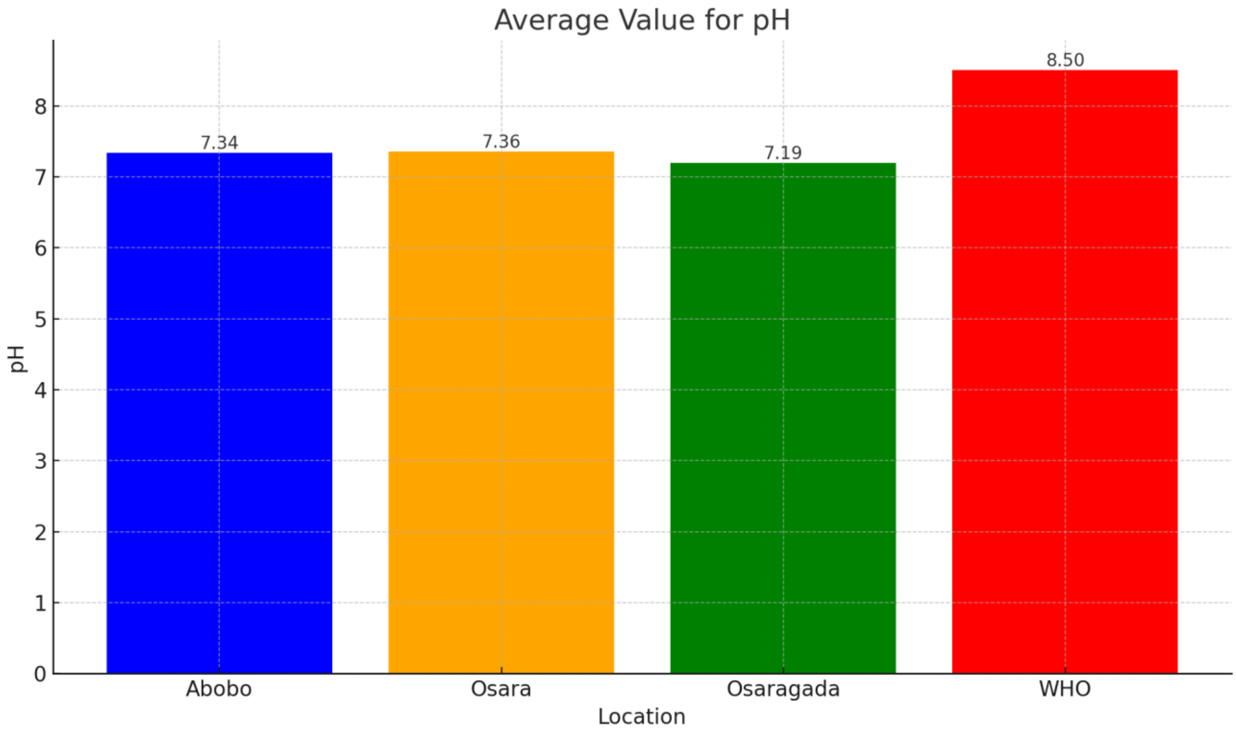

Figure 2: pH values at Sampling sites

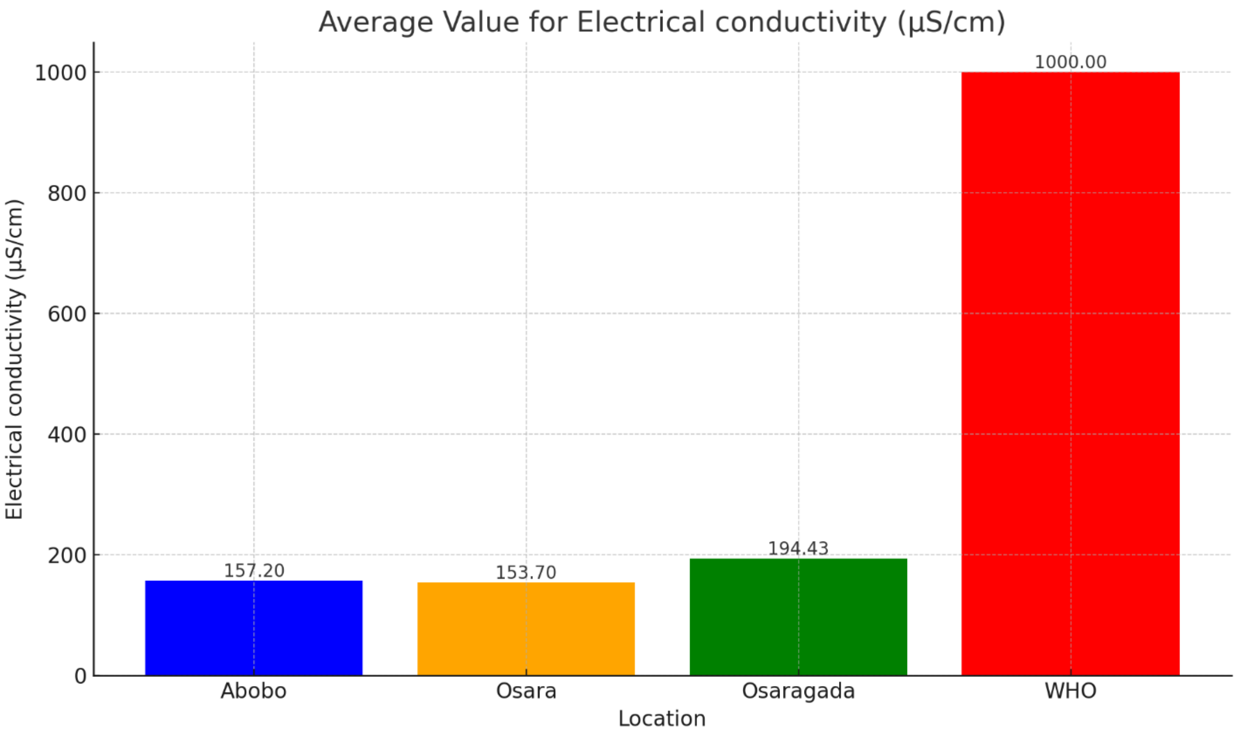

Figure 3: Ec values values at Sampling sites

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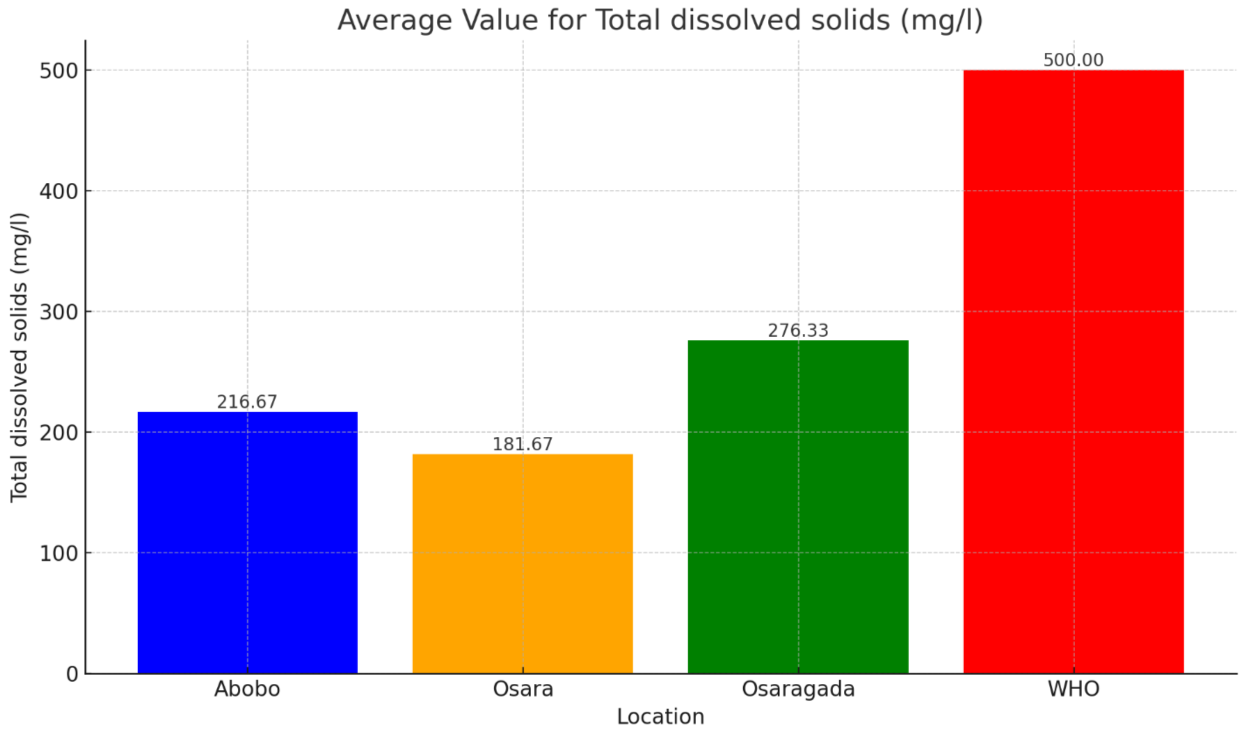

Figure 4: TDS values at Sampling sites

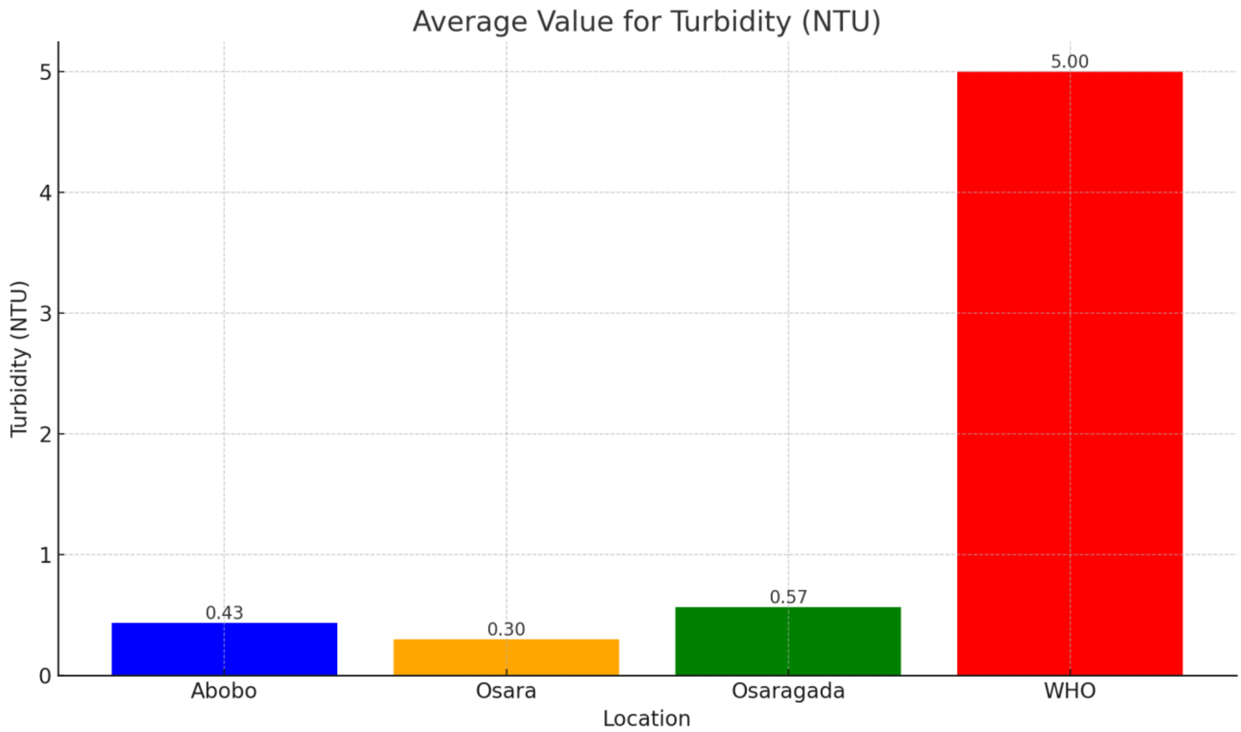

Figure 5: Turbidity values at Sampling sites

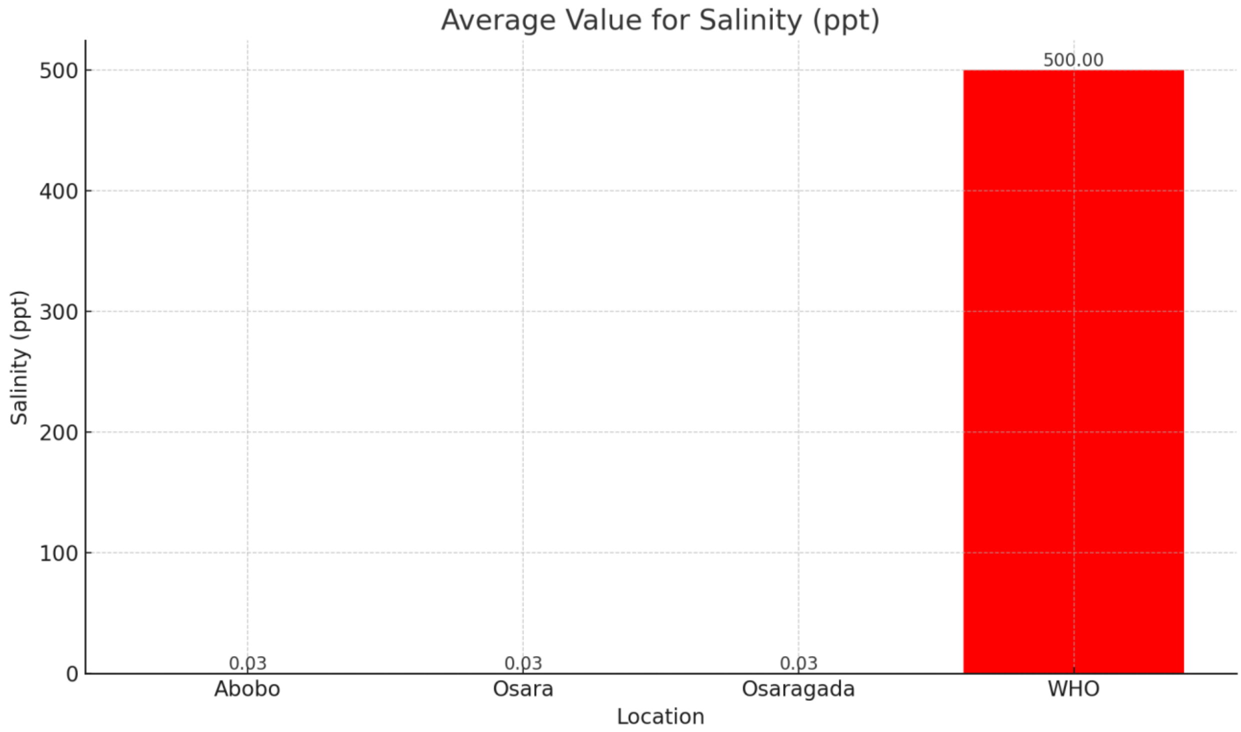

Figure 6: Salinity values at Sampling sites

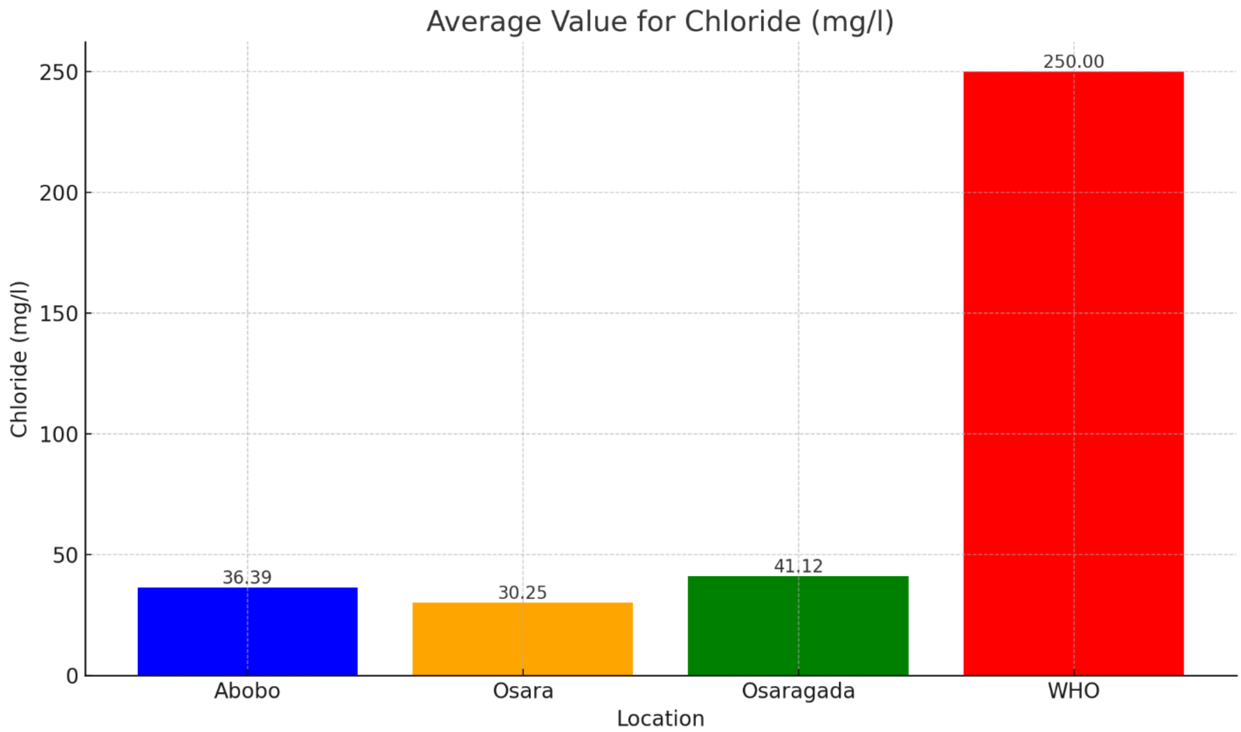

Figure 7: Chloride values at Sampling sites

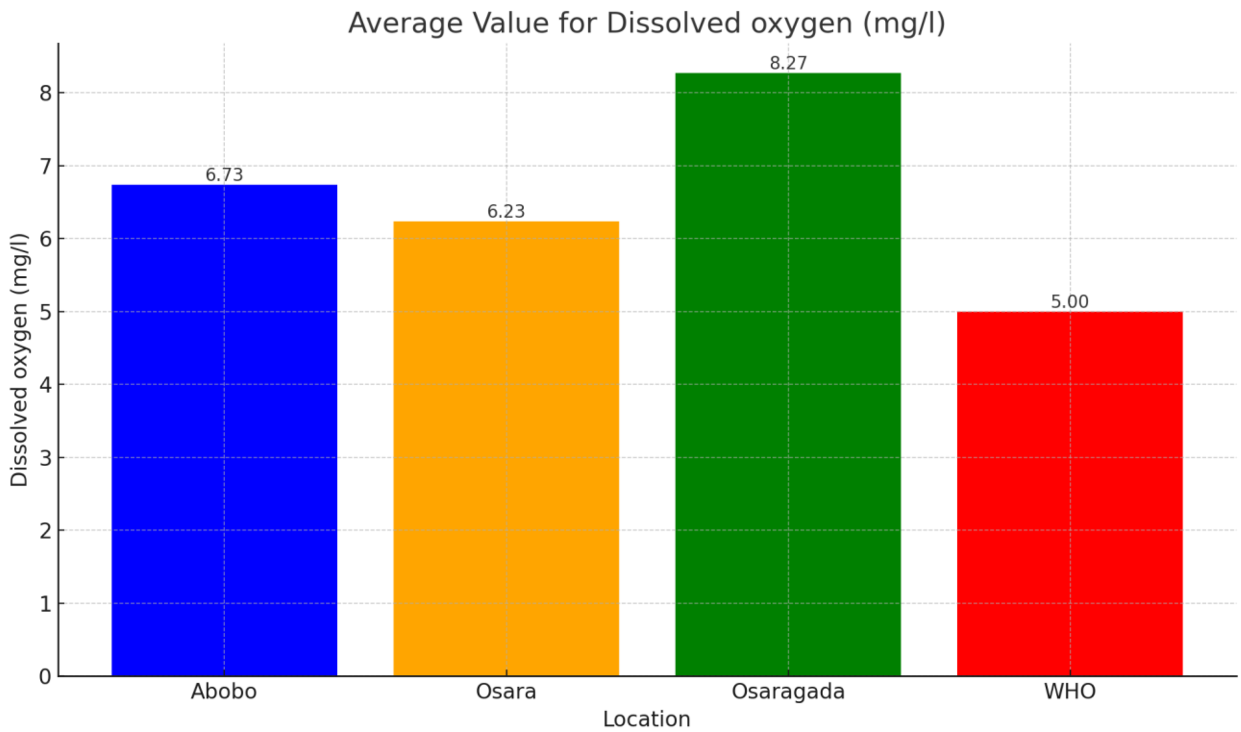

Figure 8: DO values at Sampling sites

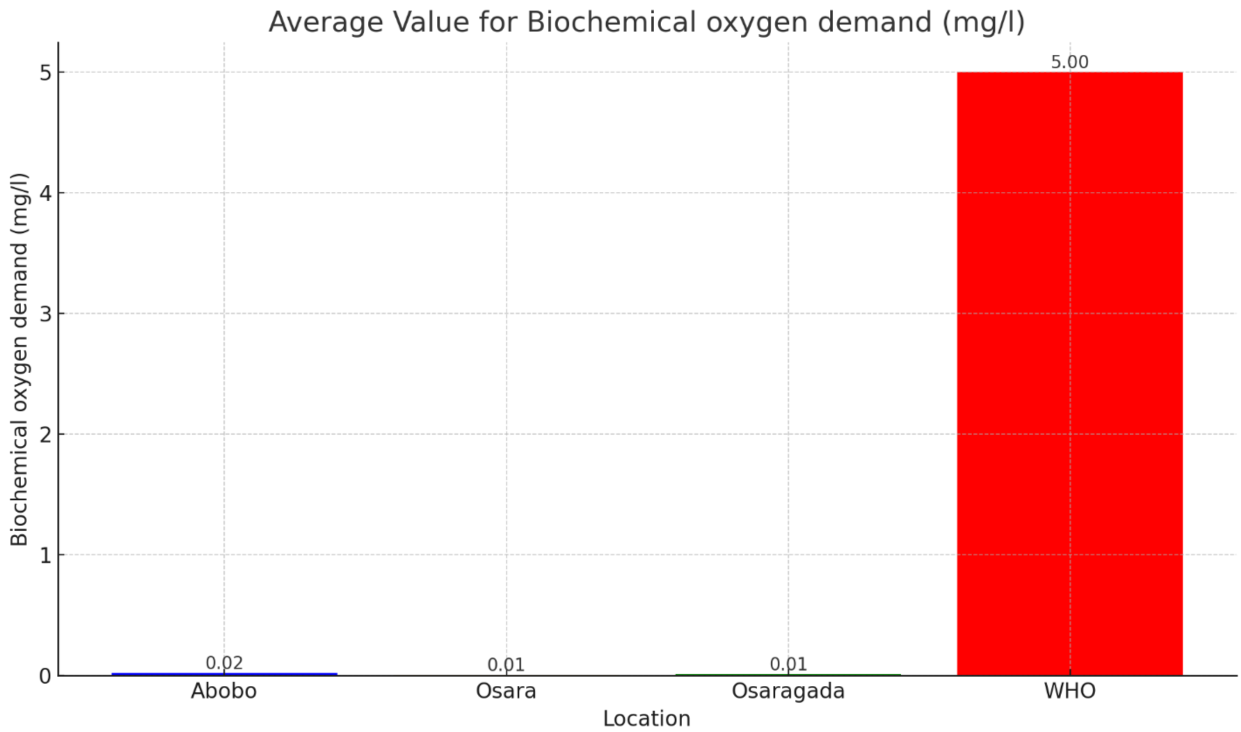

Figure 9: BOD values at Sampling sites

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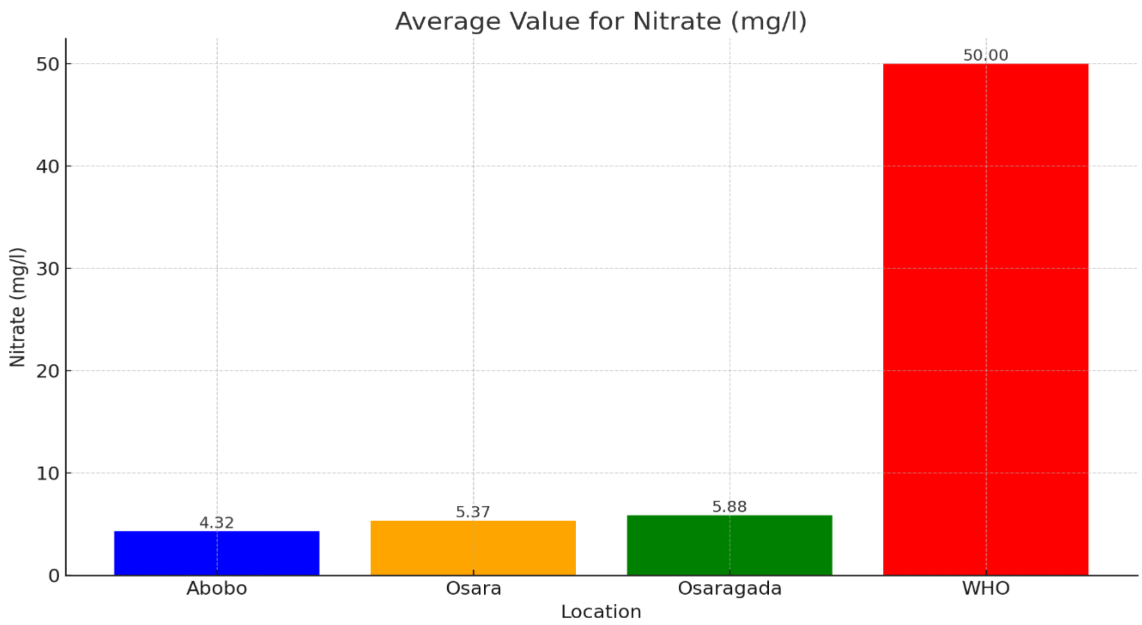

Figure 10: Nitrate values at sampling sites

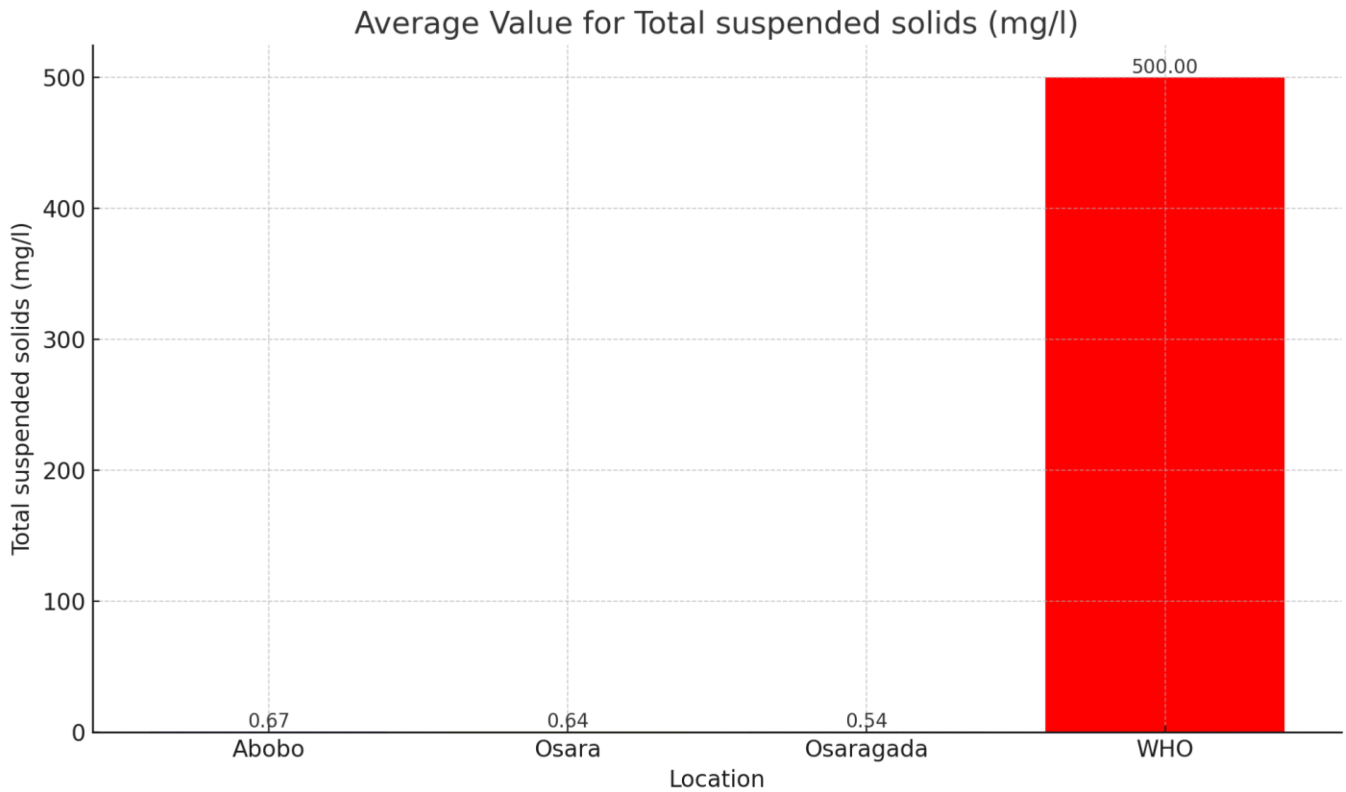

Figure 11: TSS values at sampling sites

The study found that Osara had the lowest turbidity value (0.30 NTU), while Osaragada had the highest (0.57 NTU) (Figure 5). The mean turbidity across all stations was 0.43 ± 0.18 NTU. Salinity levels at all stations were uniformly low (0.03 ppt) (Figure 6). Osaragada had the highest chloride content (41.12 mg/L) and Osara had the lowest (30.25 mg/L) (Figure 7). All stations had an average chloride level of 36.92 ± 10.74 mg/L. According to the study, Osaragada had highest dissolved oxygen (DO) level (8.27 mg/L), while Osara had the lowest (6.23 mg/L) (Figure 8). The mean DO level was 7.07 ± 3.44 mg/L. For Biochemical Oxygen Demand (BOD), Abobo had the highest value (0.02 mg/L), while Osara and Osaragada had

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the lowest (0.01 mg/L) (Figure 9). The mean BOD level was 0.013 ± 0.012 mg/L. The study found nitrate levels ranging from 4.32 mg/L (Abobo) to 5.88 mg/l (Osaragada) (Figure 10) and a mean value of 5.18 ± 1.28 mg/l. TSS ranges from 0.54 mg/L (Osaragada) to 0.67 mg/L (Abobo) (Figure 11), with an average of 0.61 ± 0.30 mg/L. Analysis of variance (ANOVA) showed that there is no significant difference in values of all physicochemical parameters between the locations except in total dissolved solids (P-value = 0.037).Well water in Abobo, Osara, and Osaragada had their respective Water Quality Index (WQI) values determined to be 10.43, 10.23 and 12.77.

Discussion

The physicochemical parameters assessed in well water from Abobo, Osara, and Osaragada communities in Kogi State, Nigeria, demonstrate overall high-quality groundwater with minimal contamination, as most values comply with WHO standards for drinking water. The pH range of 7.19–7.36 (mean 7.29 ± 0.42) indicates neutral to slightly alkaline conditions, which supports biological processes (Dewangan *et al.,* 2023). Similar result was obtained in most groundwater samples around Obajana community in Kogi State (Jacob *et al*., 2022). Olubunmi (2018) however, found low pH values in wells in Idah metropolis, Kogi State, which they attributed to human activity and agricultural runoff. pH values below 6.5 are deemed too acidic for human intake and can result in health issues like acidosis, which can negatively impact the lymphatic and digestive systems (Jacob *et al.*, 2022).

The capacity of water to transmit electricity at 25°C is measured by electrical conductivity, which indicates the existence of free ions. The conductivity range of 153.70 – 194.43 (mean 168.44±36.18 µs/cm) indicates the presence of ions like chlorides, nitrates, and calcium (Oyem *et al.*, 2014). All readings fell within the 1000 µs/cm WHO drinking water acceptable guideline. A study in Obajana Community in Kogi State found electrical conductivity (EC) values ranging from 6.21 to 339.67 µS/cm (Jacob *et al*., 2022), which is broader than the range found in Abobo, Osara, and Osaragada. This suggests that the water in Abobo, Osara, and Osaragada might be less mineralized.

In water, total dissolved solids (TDS) comprise both organic and inorganic materials in different forms (Wang *et al.*, 2021). According to the study, TDS range of 276.33 - 181.670 mg/L (mean 224.88±50.74 mg/L) do not exceed the 500 mg/L WHO drinking water permitted level. A similar result was recorded in the study of well water from Ajaokuta Housing Estate in Kogi State which was attributed to low levels of carbonate, bicarbonate, sulphate, chloride, nitrates and other substances (Folorunsho and Ogu, 2024). Generally speaking, water with TDS levels around 600 mg/L is acceptable, while those over 1000 mg/L can be distinctly distasteful (Faysal *et al.*, 2017).

The term "turbidity" describes the cloudy appearance of water produced by suspended particles (Deeba *et al.,* 2020). The study found turbidity range 0.30 - 0.57 NTU (mean 0.432 ± 0.059 NTU) which is below the WHO maximum allowable limit of 5 NTU, indicating clear water. A similar study in Majidun area of Ikorodu in Lagos State, Nigeria recorded a higher turbidity range of 0.37 – 21.60 NTU (Awoyemi *et al.*, 2014). High turbidity could be as a result of soil erosion, urban runoff, industrial wastes and organic matter (Kale, 2016). A low turbidity suggests a lower risk of disease-causing microorganisms (Allen *et al.,* 2008).

Salinity levels at all stations were uniformly low (0.03 ppt), well below the WHO recommended limit of 500 mg/L. Electrical conductivity is often used as proxy for salinity (Ojoma *et al.*, 2024). For drinking water, the World Health Organization (WHO) recommends EC <1,000 which is an indication of good salinity. Given the EC range of 153.70-194.43 µS/cm in this study, 6.21 – 339.67 µS/cm recorded for hand dug wells in Obajana community (Jacob *et al.,* 2022), 250 – 750 µS/cm in Ajaokuta Housing Estate (Folorunsho and Ogu, 2024), all in Kogi State, indicate the well water in this area is likely freshwater and suitable for drinking.

According to the study, chloride range 30.25 - 41.12 mg/L (mean 36.922 ± 3.579 mg/L) is within the 250 mg/L WHO tolerable range. Chloride had the highest concentration (14.1-180 mg/L) in hand dug well water samples collected in Okene Local Government Area of Kogi State (Aremu *et al*., 2014). One important measure of water quality is the presence of chloride ions, which can come from both natural and man-made sources (Anh *et al.*, 2023). The presence of chloride where it does not occur naturally indicate possible water pollution and could be hazardous to plants and wild life (Aremu *et al*., 2014).

According to the study, dissolved oxygen range 6.23 - 8.27 mg/L (mean 7.077 ± 1.146 mg/L) and the biochemical oxygen demand range 0.01 - 0.02 mg/L (mean 0.013 ± 0.003 mg/L) are within WHO standards value of 5 mg/L. The high DO levels and low BOD levels in relation to WHO standards suggest minimal organic matter decomposition by microorganisms (Isah *et al.*, 2023). This is in agreement with the work of Aremu *et al.* (2014) who recorded DO of 6 – 12 mg/L in water from hand dug wells in Okene, Kogi State.

Nitrate ions in drinking water can be toxic above 50 mg/L, as per WHO guidelines (Ward *et al.*, 2018). The study found nitrate levels ranging from 4.32-5.88 mg/l (mean 5.188 ± 0.426 mg/l), indicating safe consumption levels. A similar study in Zing Local Government Area of Taraba State, Nigeria produced a range of 2.33 – 75.10 mg/L (Moses and Ishaku, 2020). Nitrates in water can come from fertilizers, sewage, and natural deposits (Brindha *et al.*, 2017). According to Clemmensen *et al*. (2023), elevated nitrate levels may have negative effects on thyroid function and the neurological system in addition to causing health problems like Blue Baby Syndrome.

The term "total suspended solids" (TSS) describes particles of solids in water that can be eliminated by filtering (Huang and Fisher, 2019). With an average of 0.617 ± 0.101 mg/L, TSS levels were significantly below the WHO 500 mg/L limit. A range of 0.06 – 0.51 mg/L was detected in water from hand dug wells in Okene, Kogi State (Aremu *et al.*, 2014). Elevated TSS levels may be a sign of low water quality, which is frequently brought about by industrial processes, agriculture and construction (Weiss *et al.*, 2008; Agbaje *et al.*, 2024).

Total dissolved solid is the only parameter whose values showed significant difference among the three locations. This could be as a result of possible difference in aquifer characteristics and human activities such as agricultural practices and waste disposal pattern (Wali *et al*., 2025).

Water Quality Index (WQI) of well water from sampling stations

Well water in Abobo, Osara, and Osaragada had their respective Water Quality Index (WQI) values determined to be 10.427, 10.229 and 12.773 respectively. These results indicate that the water from all three sites is Grade A, meaning it can be used for industrial, agricultural and drinking purposes.

Regular monitoring is still required to make sure that extraneous factors do not degrade the quality of the water, even though all physicochemical measurements were within the WHO-recommended ranges.

Conclusion and Recommendation

Selected physicochemical characteristics of well water in Osaragada, Osara and Abobo communities in Kogi State, Nigeria, were evaluated between July and September 2024. The well water quality index (WQI) was also computed and analysed. The physicochemical properties that were measured were within WHO permissible limits. The physicochemical characteristics and the WQI ratings of the well water from Abobo, Osara, and Osaragada indicate that it is suitable for drinking, irrigation, and industrial use. The majority of the wells that were inspected had protective coverings, which decreased the possibility of contamination from runoff and human activities. For efficient well water management and conservation, routine monitoring and inspections are essential. Additional studies are advised to explore other factors, including bacteriological parameters and heavy metals.

Conflict of Interest: The authors declare that there are no competing interests or conflicts of interest related to this study.

Contributions by Author: Every author collaborated on the study, analyzed the results and approved the final draft of the publication.

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