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SEASONAL GEOCHEMICAL INFLUENCE ON FOUNTAIN UNIVERSITY, OSOGBO, GROUNDWATER QUALITY

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ABSTRACT

The United Nations' campaigns to ensure clean and safe water, good health and well-being, sustainable cities and communities (Sustainable Development Goals 3, 6, and 11, respectively) are interwoven. The study adopted these three SDGs to seasonally assess the available groundwater samples within the Fountain University, Osogbo, Osun State. The study sampled six locations in the dry (February 2024) and wet (May 2024) seasons in triplicate; analysed them at the Osun State Water Commission Laboratory, Ede Office, using standard procedures and methods; and subjected the obtained data to descriptive and inferential statistics, and compared their mean values with WHO (2011), NIS554 (2015), and institution-water-sampled research. The results showed that the pH (5.20 to 7.00 < 6.98 to 7.91), dissolved oxygen (2.40 to 2.80 < 4.30 to 6.50 mg/ L), alkalinity (18 to 170 < 24 to 142 mg/ L)/ total hardness (28 to 138 < 42 to 174 mg/ L)/ Ca hardness (20 to 114 < 14 to 50 mg/ L) (except at Yusufi Ali hostel), Ca (4.56 to 11.20 < 5.60 to 20 mg/ L), Sulphate (BDL to 37 < 34 to 51 mg/ L), residual-Cl (BDL < BDL to 0.21) and F (BDL < BDL to 1.45 mg/ L) were lower in the dry than wet season; carbonate (18 to 138 mg/ L) **<** bicarbonate (73 to 646.60 mg/ L) in the dry season; carbonate (138) and bicarbonate (646.60) were higher than the limit (100 mg/ L) at Yusuf Ali hostel in the dry season; water pH was lower than the limit, making the water sample slightly acidic at main canteen (5.20), Sambisa hotel (5.20) and Mountain (5.40) in the dry season; Fe (BDL to 1.90 mg/ L) content was higher than the limit (0.30 mg/ L) in dry season; Phosphate was BDL at Mountain, Yusuf Ali hostel, and Masjid in both seasons; turbidity (0.67 to 8.79 mg/ L) was lower than the limit (5.00 mg/ L) except at the main canteen in the wet season; K- and Cr-contents were higher than the limit (0.01 mg/ L) in both seasons; and lastly, there was possible seasonal influence on the water parameters' variations. Having found that K- and Cr-contents were higher than the limits in both seasons, the study recommends measures to prevent possible human health risks from high levels of K and Cr in the school's groundwater.

Keywords: SDG 6, SDG 14, health risks, water quality

INTRODUCTION

Groundwater is a dependent natural resource that sustains life and supports various human activities worldwide. Its benefits are not limited to serving as the best primary source of drinking water for millions of people and contributing to agricultural irrigation, industrial processes, and ecosystem functioning (Foster *et al;.,* 2019). In Nigeria, groundwater is particularly significant, especially in regions with limited or unreliable surface water availability. However, groundwater quality (GwQ) is subject to various natural and anthropogenic influences, which can have profound implications for human health, environmental sustainability, and socio-economic development. The community of Fountain University Osogbo, situated in Osun State, Nigeria, relies heavily on groundwater to meet its water needs. As urbanisation and population growth intensify in the region, there is increasing pressure on groundwater resources, raising concerns about water quality and availability (Olanrewaju et al, 2017). Understanding GwQ within this community is essential for ensuring access to safe and reliable drinking water (SDG 6), protecting public health, and promoting sustainable development.

Given the assertiveness of groundwater as a primary source of drinking water in Nigeria, there is a pressing need to assess and monitor GwQ to ensure its safety and sustainability; this is particularly relevant in the context of Fountain University, Osogbo, and its surrounding community, where reliance on groundwater is significant, and potential sources of contamination exist. Results can then identify and prioritise areas for intervention to promote sustainable water management practices and implement targeted remediation measures if GwQ is assessed (Adelabu *et al;.* 2019). So, the background of this study underscored the critical importance of determining GwQ within the Fountain University Osogbo community. By understanding the geochemical factors influencing GwQ and identifying potential sources of contamination, the research can contribute to informed decision-making, promote public health, and support sustainable development goals (3: good health and well-being, 6: clean and safe water, and 11: sustainable cities and communities) in the region. The scope of the study encompassed several key aspects related to the evaluation of GwQ and associated factors within the study area. The geographic area of the study included the surrounding community to account for its influence on the sampling locations within the university, which represent different potential sources of groundwater contamination. The study assessed various parameters to provide insights into the overall GwQ and suitability for use. Based on the assessment findings, the study proposes recommendations for management strategies, including regulatory measures, infrastructure improvements, and community-based interventions, to safeguard GwQ and protect public health (Adefemi *et al;.,* 2017; Fadare *et al;.,* 2020) within the Fountain University Osogbo community.

Academic and Scientific Contribution: The study contributed to the body of knowledge on GwQ assessment, particularly in the context of urban environments in Nigeria. By employing rigorous scientific methods and interdisciplinary approaches, the study sought to generate new insights into the factors influencing GwQ and the effectiveness of management interventions (Adeniji *et al;.,* 2019). The study's findings can inform future research endeavours, policy development, and practical interventions to improve GwQ and

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resources for sustainability.

Policy and Decision-making Implications: The study results exemplified practical implications for policymakers, water resource managers, and local stakeholders involved in GwQ management and environmental protection. By providing evidence-based data and recommendations, the study supported informed decision-making processes, facilitated the implementation of targeted interventions to address water quality challenges, informed the development of policies, regulations, and monitoring frameworks to enhance GwQ protection and management at local, regional, and national levels (Aribisala *et al;.,* 2017).

Public Health Concerns: Access to safe and clean drinking water is indispensable to maintaining public health and preventing waterborne diseases (Howard *et al;.,* 2016). Given the reliance on groundwater as a primary source of drinking water in the community surrounding the Fountain University, Osogbo, it is imperative to assess the GwQ to ensure its safety for human consumption. Identifying potential sources of contamination and evaluating health risks associated with groundwater consumption would mitigate public health risk and protect the residents' well-being.

Environmental Sustainability: Groundwater resources are finite and vulnerable to contamination from various anthropogenic and natural sources (Foster *et al;.,* 2019). As urbanisation and industrialisation continue to intensify in the study area, there is a growing risk of groundwater pollution, which can adversely affect ecosystems and environmental sustainability. By conducting a GwQ assessment, this study aimed at identifying major contaminating parameters and proposing management strategies to preserve the GwQ integrity/ resources and promote environmental sustainability.

The importance of assessing GwQ to identify potential sources of contamination, evaluate health risks, and develop appropriate management strategies has been acknowledged. In Nigeria, GwQ issues are exacerbated by various factors, including industrial activities, agricultural runoff, inadequate sanitation practices, and geological conditions (Obeta, 2018). Pollution from such factors introduces contaminants, including heavy metals and organic compounds, into groundwater, posing risks to human health and ecosystem integrity. One or two studies had been conducted in different parts of Nigeria to report instances of groundwater contamination and associated health risks. For example, Olanrewaju *et al;.* (2017) conducted a GwQ and vulnerability assessment in the Ogbomoso area of southwestern Nigeria, revealing the presence of contaminants: nitrate, sulfate, and chloride in groundwater samples. Similarly, Obeta (2018) discussed Nigeria's groundwater challenges and management issues, highlighting the need for improved regulatory frameworks and sustainable groundwater management practices.

However, none of the above studies examined the seasonal influence, which is the focus of the research gap in the current study. Thus, the study objectives were to assess seasonal geochemical influence on the FUO Community water quality and identify the possible threatening parameters.

MATERIALS AND METHODS

Study Area

The study area (Fountain University, Osogbo, Osun State) is in Osogbo, the capital city of Osun State (Table 1). Osogbo is located in the Nigerian Southwestern region, characterised by its rich cultural heritage, bustling markets, and diverse population. Fountain University, a private institution established in 2007, is located in the city and serves as a focal point for educational and social activities in the community. The community surrounding Fountain University, Osogbo, is predominantly municipal, with a mix of residential, institutional, and commercial land uses. The diverse population comprises various ethnic, cultural, and socioeconomic backgrounds. The area experiences rapid urbanisation and population growth, driven by migration, economic opportunities, and educational pursuits. The hydrogeological setting of the study area is characterised by the presence of shallow aquifers, which are susceptible to contamination from surface activities and anthropogenic sources. The geology primarily consists of sedimentary formations, including sandstones, shales, and clayey deposits, which influence the groundwater flow patterns and aquifer characteristics.

Table 1: Coordinates of the sampling locations

S/ N	Locations	Latitude	Longitude
1	Main canteen	07.7444° N	004.5472° E
2	Senate building	07.7438° N	004.5470° E
3	Sambisa hostel	07.7440° N	004.5431° E
4	Mountain	07.7438° N	004.5435° E
5	Yusuf Ali	07.7429° N	004.5443° E
6	Masjid	07.7446° N	004.5442° E

Sample Collection

The sampling involved random sampling to ensure coverage of groundwater sources within the Fountain University, Osogbo, Osun State. The sampling locations were the main canteen, the Senate building, the Sambisa hostel, the Mountain, the Yusuf Ali hostel, and the Masjid. Direct water from boreholes into the reservoirs was considered the sampling point to determine the actual GwQ. Sampling was done three times each season.

Sample Collection Procedure

Groundwater samples were collected using a pre-washed 2.5-litre keg with a removable inner cock before the main cover to prevent contamination. The samples were collected at six locations following standard protocols to ensure consistency and accuracy (https://www.scribbr.com/methodology/sampling-methods/ accessed on 16-10-2024). A calibrated handheld water kit measured four *in-situ* parameters: pH, temperature, conductivity, and turbidity at each sampling time. The samples for laboratory analysis were preserved and stored in an ice chest/ cooler to maintain the samples' integrity during transportation.

Laboratory Analysis

The six groundwater samples were taken twice (February for the dry season and May for the wet season) and analysed at the Osun State Water Central Laboratory, Ede Office, for physicochemical parameters, including pH, turbidity, conductivity, total dissolved solids (TDS), hardness, and concentrations of major ions (e.g., chloride, sulfate, nitrate).

Data Presentation
The gathered data were compiled in a Microsoft Excel Spreadsheet for descriptive and inferential (Duncan Multiple Range Test, Posthoc set at $p \leq 0.05$) statistical analyses. The descriptive results were tabularized for easy comparisons across the six sampling locations and with the National Industrial Standards for Drinking Water Quality (NIS554, 2015). Inferential results were indicated by superscripts (a, b, c, d, e, etc.) attached to the tabularized mean values.

RESULTS
The quality results of available water samples taken within the Fountain University Osogbo community during the dry season (February 2024) and wet season (May 2024) are presented in Tables 2 to 4. The pH values were generally lower in the dry season than in the wet season; all but three locations in the dry season were below the stipulated standard (NIS554, 2015) and were acidic (5.20 and 5.40) in the main canteen, Sambisa hostel, and Mountain. Values of the assessed turbidity were higher (30 at Senate building to 68 mg/ L main canteen) in the dry than (0.63 at Sambisa hostel/ Mountain to 8.79 mg/ L main canteen) in the wet season across the sampled locations; all but that of the main canteen was lower (8.79 mg/ L) than the compared standard (NIS554, 2015) in the wet season. The quantity of determined dissolved oxygen (DO) was generally lower (2.40 mg/L at Masjid to 2.80 mg/L at Mountain/Yusuf Ali hostel) in the dry season than (4.30 mg/L at Masjid to 6.50 mg/L at Mountain, Yusuf Ali hostel, and Sambisa hostel) in the wet season. The DO values generally conformed to the stipulated standard: a minimum of 0.40 mg/ L. The temperature values were higher in the dry season than in the wet season; none was lower than the stipulated ambient temperature of 27.00 °C. There were indications that the water samples' conductivity was higher (120 at Masjid to 681.30 µS/ cm at Mountain) in the dry season than (242.80 at Masjid to 526.60 µS/ cm at Yusuf Ali hostel) wet season across the six locations except in the Masjid; the water samples' conductivity generally conformed to the stipulated limit of 1000 µS/ cm.

The alkalinity values were lower in the dry than wet season except at the Senate building (26 and 24 mg/ L, respectively) and Yusuf Ali hostel (170 and 142 mg/ L, respectively); all the determined alkalinity values across the six water samples were lower than the compared NIS554 (2015) value of 200 mg/ L. The total hardness values were lower in the dry (28 at Masjid and main canteen to 138 mg/ L at Yusuf Ali hostel) than wet season (42 at Sambisa hostel to 174 mg/ L at Mountain) except at Yusuf Ali hostel; the NIS554 (2015) limit of 100 mg/ L was exceeded at Yusuf Ali hostel (138 mg L) in the dry season and at the Mountain (174 mg/ L) in the wet season. The determined high levels of total hardness were observed to be more influenced by Ca-hardness than Mg hardness, except during the wet season when the order was Mountain > Masjid > Yusuf Ali hostel, with Ca: Mg ratios of 124: 50, 52: 30, and 36: 14, respectively. Levels of K were generally higher than the stipulated 0.01 mg/L of the NIS554 (2015) across the areas where they were determined; and below the detection limit of the instrument (BDL) across the Senate building, Mountain, and Masjid in the dry season, but at Yusuf Ali hostel in the wet season. However, the K-contents were higher in the dry season than in the wet season at the time of determination. Levels of the Al were mostly BDL except at the main canteen (0.05 mg/L) and Sambisa hostel (0.01 mg/L), where they were lower than the stipulated 0.1 mg/L of the NIS554 (2015).

Table 2: Physicochemical Parameters of the FUO Community Water Quality

	Main canteen	Senate	Sambisa hostel	Mountain	Yusuf Ali	Masjid	NIS 554 (2015)
	Dry Sampling Periods (February 2024)						
pH	5.20^{a}	6.80	5.20	5.40	6.80	7.00^{d}	5.6-8.5
Turbidity	68.00^{e}	30.00^{a}	64.00	50.00	40.00	40.00	5.00
Dissolved oxygen	2.50	2.60	2.60	2.80^{d}	2.80	2.40^{a}	0.40
Temperature	31.50^{a}	31.80	31.60	31.50	31.60	31.60	27.00
Conductivity	531.00	461.90	606.20	681.30^{e}	630.70	120.00^{a}	1000
	Wet Sampling Periods (May 2024)						
pH	7.46	7.48	7.91^{c}	7.11	6.98^{a}	7.56	5.6-8.5
Turbidity	8.79^{d}	0.67	0.63	0.63^{a}	2.26	0.67	5.00
Dissolved oxygen	6.30	6.40	6.50	6.50^{b}	6.50	4.30^{a}	0.40
Temperature	30.00	30.00	30.00	30.00	30.00	30.10^{a}	27.00
Conductivity	335.50	225.60	333.10	280.40	526.60^{d}	242.80^{a}	1000

	Main canteen	Senate	Sambisa hostel	Mountain	Yusuf Ali	Masjid	NIS 554 (2015)
	Dry Sampling Periods (February 2024)						
Alkalinity	22.00	26.00	22.00	22.00	170.00^{d}	18.00^{a}	200
Total hardness	28.00^{a}	30.00	32.00	38.00	138.00^{e}	28.00	100

Ca hardness	22.00	28.00	20.00[a]	30.00	114.00[e]	20.00	
Mg hardness	6.00	2.00[a]	12.00	8.00	24.00[e]	8.00	
Potassium	2.80[d]	BDL	2.50	BDL	2.30[b]	BDL	0.01
Aluminum	0.05	BDL	0.01	BDL	BDL	BDL	0.10
	Wet Sampling Periods (May 2024)						
Alkalinity	40.00	24.00[a]	34.00	34.00	142.00[d]	36.00	200
Total hardness	88.00	68.00	42.00[a]	174.00[e]	50.00	82.00	100
Ca hardness	50.00[d]	36.00	36.00	50.00	14.00[a]	30.00	
Mg hardness	38.00	32.00	6.00[a]	124.00[e]	36.00	52.00	
Potassium	0.70[c]	0.50	0.40	0.40[b]	BDL	0.40	0.01
Aluminum	BDL	BDL	BDL	BDL	BDL	BDL	0.10

The results were presented as mean values with different superscripts (a, b, c, d, e, etc.) along the row indicating a significant difference at the $p < 0.05$ statistical level

Table 3 showed that the quantity of Ca-ions was generally lower in the dry season (4.56 at Yusuf Ali hostel to 11.20 mg/ L at the Senate building) than in the wet season (5.60 at Yusuf Ali hostel to 20.00 mg/ L at the main canteen) across the water samples, with no limit for its comparison. The Fe-contents were higher during the dry season (and exceeded the limit of 0.30 mg/L) than the wet season, except at the Masjid, where it was BDL in both seasons. The Mn-contents were higher during the dry season (and below the limit of 0.05 mg/L) than the wet season, except at the Mountain and Masjid, where it was BDL in both seasons. The Cu-contents were determined to be highest at the main canteen (1.06 mg/L), exceeding the set limit of NIS554 (2015): 1.00 mg/L, while BDL at the Masjid across the six locations during the dry season. The Cu-contents were determined below the detection limit (BDL) and lower than the set limit of NIS554 (2015): 1.00 mg/L, except at the Senate building (0.02 mg/L) during the wet season. The Cr-content was higher in the dry season (0.06 at Masjid to 2.65 mg/L at the main canteen) than in the wet season (0.04 at the Mountain to 0.22 mg/L at the Sambisa hotel), exceeding the set limit of 0.01 mg/L (NIS554, 2015). The Zn-content was higher in the dry season (0.03 at the Masjid to 0.68 mg/L at the main canteen) compared to the wet season, when it was determined to be BDL except at the Senate building, where it was 0.04 mg/L. However, none exceeded the NIS554's (2015) limit of 5.00 mg/ L. There were traces of more N-nitrate in the dry (0.058 mg/ L) than wet (0.01 mg/ L) season in the main canteen's water samples, broadly lower than the NIS554 (2015) limit of 10.00 mg/ L, while BDL in the Senate building and Yusuf Ali hostel water samples. The N-nitrite contents were BDL in the Mountain and Masjid water samples during the dry season, while they were determined across the water samples in the wet seasons. However, the N-nitrite contents in the two seasons were below the compared limit of 0.01 mg/ L (NIS554, 2015).

The residual-Cl content was BDL across the dry season, ranging from BDL at the main canteen to 0.21 mg/L at the masjid water samples in the wet season, but below the limit of 0.30 mg/L. The Chloride Contents were higher in the dry season than in the wet season, except for the Mountain water sample, where all contents were lower than the compared limit of 100 mg/L (NIS554, 2015).
Table 4 indicates that the sulphate contents were lower in the dry (BDL at Masjid to 37 mg/ L at main canteen) than in the wet season (34 mg/L at Yusuf Ali hostel to 51 mg/ L at Masjid); all the determined contents were lower than the NIS554 (2015) limit of 100 mg/ L. The phosphate contents were BDL in the dry season except at the main canteen: 17.80 mg/L and Sambisa hotel: 22.40 mg/L, while BDL in the wet season across the six sampled locations. However, there is no limit for comparison. The levels of carbonates were higher in the dry season than in the wet season, except at the Masjid, while bicarbonate contents were consistently higher throughout the dry season. The carbonate levels (138 mg/L) and bicarbonate contents (646.60 mg/L) were higher in both seasons in the Yusuf Ali hostel water samples than the compared limit of 100 and 250 mg/L, respectively. The bicarbonate content was also higher (317.2 mg/L) at Sambisa hostel than the limit of 250 mg/L in the dry season. The F-content was BDL across the dry season water samples, but ranged from the BDL at the Yusuf Ali hostel to 0.15 mg/L at the Masjid in the wet season, thereby conforming to the NIS554 (2015) limit of 0.15 mg/L. The sulphide contents were determined to be 0.08 and 0.04 at the main canteen and Sambisa hostel, respectively, while other locations had BDL in the dry season. The level of Sulphide was BDL across the six sampled locations in the wet season, with a limit specified for comparison from the NIS554 (2015).

Table 3: Results of the Heavy Metals and N-sources across the FUO Community Water Quality

	Main canteen	Senate	Sambisa hostel	Mountain	Yusuf Ali	Masjid	NIS 554 (2015)
	Dry Sampling Periods (February 2024)						
Ca	8.80	11.20	8.00	12.00[c]	4.56[a]	8.00	
Fe	1.90[e]	1.40	1.30	0.55[b]	0.80	BDL	0.30
Mn	0.005[b]	0.002	0.003	BDL	0.001	BDL	0.05
Cu	1.06[e]	0.80	0.74	0.34[b]	0.46	BDL	1.00
Cr	2.65[e]	0.95	1.90	1.55	1.55	0.06[a]	0.01
Zn	0.68[e]	0.12	0.49	0.30	0.30	0.03[a]	5.00
Nitrate-N	0.058	BDL	0.04[b]	BDL	BDL	BDL	10.00
Nitrite-N	0.069[c]	0.023[b]	0.047	BDL	0.039	BDL	0.10
	Wet Sampling Periods (May 2024)						
Ca	20.00[d]	14.40	14.40	20.00	5.60[a]	12.00	
Fe	BDL	BDL	BDL	BDL	BDL	BDL	0.30
Mn	BDL	BDL	BDL	BDL	BDL	BDL	0.05
Cu	BDL	0.02a	BDL	BDL	BDL	BDL	1.00
Cr	0.096[c]	0.21	0.22	0.04[a]	0.06	0.06	0.01
Zn	BDL	0.04[a]	BDL	BDL	BDL	BDL	5.00
Nitrate-N	0.10	BDL	BDL	0.32[c]	BDL	0.14	10.00
Nitrite-N	0.001	0.002	0.004	0.001	0.005[a]	0.003	0.10

The results were presented as mean values with different superscripts (a, b, c, d, e, etc.) along the row indicating a significant difference at the $p < 0.05$ statistical level.

Table 4: Results of the Chemical Components across the FUO Community Water Quality

	Main canteen	Senate	Sambisa hostel	Mountain	Yusuf Ali	Masjid	NIS 554 (2015)
	Dry Sampling Periods (February 2024)						
Residual Cl	BDL	BDL	BDL	BDL	BDL	BDL	0.30
Chloride	21.00	14.00	25.50[e]	17.00	20.00	12.50[a]	100
Sulphate	37.00[f]	16.00	29.00	10.00[b]	25.00	BDL	100
Phosphate	17.80	BDL	12.40[b]	BDL	BDL	BDL	
Carbonate	22.00	26.00	22.00	22.00	138.00[d]	18.00[a]	100
Bicarbonate	122.00	73.00[a]	317.20	97.60	646.60[f]	109.80	250
Fluoride	BDL	BDL	BDL	BDL	BDL	BDL	1.50
Sulphide	0.08[b]	BDL	0.04	BDL	BDL	BDL	
	Wet Sampling Periods (May 2024)						
Residual Cl	BDL	0.11	0.10[b]	0.14	0.11	0.21	0.30
Chloride	10.00	10.00[a]	15.00	25.00[c]	10.00	10.00	100
Sulphate	39.00	40.00	40.00	39.00	34.00[a]	51.00[c]	100
Phosphate	BDL	0.03	BDL	BDL	BDL	BDL	
Carbonate	21.96	14.21[a]	19.06	19.06	71.39[d]	20.03	100
Bicarbonate	18.04[c]	9.79[a]	14.94	14.94	70.61	15.97	250
Fluoride	1.43	1.45	1.50[c]	1.39	BDL	0.97[b]	1.50
Sulphide	BDL	BDL	BDL	BDL	BDL	BDL	

The results were presented as mean values with different superscripts (a, b, c, d, e, etc.) along the row indicating a significant difference at the $p < 0.05$ statistical level.

DISCUSSION

Sampling the water across the six locations within the school was randomly done to ensure a representative sample. Sampling over two seasons was to check the possible seasonal influence on the variations in the water parameters. Levels of these parameters were then compared with the National Industrial Standard (NIS554, 2015) for drinking water; any deviation from these limits indicated that the parameter was not within the specified wholesome range.

The study by Meride and Ayenew (2016) examined water quality and its potential effects on the residents of Wondo Genet Campus, Hawassa University, Ethiopia. The study was deemed necessary to recognise water as a vital, naturally occurring resource. It is a fundamental human need, essential for maintaining good health and protecting human rights. All the determined parameters were said to conform to the compared WHO (2011) limits, thereby posing no possible physicochemical, unlike microbial, threats to the residents' health. Owamah (2019) verified possible correlations among various parameters of the water sample around the University residential community, Oleh, Delta State, Nigeria. The study lastly suggested consistent groundwater monitoring around the study areas with provisional pipe-borne water to prevent humans from ill-health. Al-Maliki *et al. (2021) evaluated university students' awareness of sewage, agricultural, and industrial-influenced water pollution to identify possible reduction strategies at* Wasit University, Iraq, using nearly 400 students as respondents. The study, conducted due to community health and safety concerns, revealed a gap in practical education on water pollution awareness. It highlights the need for its integration into environmental education to provide hands-on experience.

Olatunde *et al;.* (2021) assessed groundwater quality within FUNAAB, Ogun State, Nigeria, by comparing the determined parameters with limits and classifying based on the water quality index. The study found that all ten samples had either good or fair quality for irrigation purposes, posing no threat to soil health. The survey by Arriaga-Medina and Piedra-Miranda (2021) aimed to determine the water consumption rate within the community of the National Autonomous University in the Mexico Valley. It also evaluated the open and public platform that typically provides real-time water quality information, considering its implications for the authority. Thus, the study discovered that nearly 75 % of the respondents consumed PET-bottled water because of the university water's unwholesome quality. The necessity for this university water quality study can be substantiated by the above, and previously conducted, copious research by Meride and Ayenew (2016), Al-Maliki *et al;.* (2021), Olatunde *et al;.* (2021), Owamah (2019), and Arriaga-Medina and Piedra-Miranda (2021) in Ethiopia, Iraq, Delta Nigeria, Ogun Nigeria, and Mexico, respectively. In comparing the current study's water parameters with those of other studies, the temperature range was higher than the value determined by Yogendra and Puttaiah (2008), Magaji and Chup (2012), Ezeribe *et al;.* (2012), and Meride and Ayenew (2016). However, all the temperature values were lower than the permissible limit of < 40 °C (WHO, 2004) for potable water. Temperature is one of the chief features controlling organisms' behavioural characteristics, as well as the solubility of gases and salts in the water body (Joanne *et al;.,* 2011).

The wet season range of turbidity values was higher than that of the dry season, aligning with the WHO (2011) stipulated value and the range determined by Meride and Ayenew (2016). Four out of the six pH values obtained were lower than those reported by Meride and Ayenew (2016) in the dry season. In contrast, during the wet season, their values exceeded but conformed to the ranges specified by the WHO (2011) and Olatunde et al. (2021). The current study's water samples' range of pH values was within the wholesome range; the pH is a determinant of dissolved CO_2 and the carbonic acid it forms in the water (Aremu *et al;.,* 2011; Edimeh *et al;.,* 2011). The higher the dissolved oxygen in the water samples, the lower the biochemical oxygen demand, and the better the water is free of pollution; the study by Tekenah et al. substantiates this. (2014), which mentioned that high dissolved oxygen water samples can optimally have low biochemical oxygen demand as a strong indication of unpolluted water.

Aside from the EC range of values determined in the current study's Masjid water samples in both seasons, the values of other samples exceeded those determined by Meride and Ayenew (2016). However, the EC of the water samples determined at Masjid and Mountain in the dry season was lower and higher than the lowest and highest range of EC determined by Olatunde *et al;.* (2021), respectively. The determined EC across other locations' water samples conformed to Olatunde *et al;.* (2021) 's range of determined values but exceeded the WHO (2011) value of 400 µS/cm in the dry season, while only that of Yusuf Ali hostel (526.60 µS/cm) exceeded in the wet season. The water samples, whose EC values exceeded the limit, may not be substantially ionised, which could influence their ionic activity levels due to the presence of slight dissolved solids. The study observed that the water samples were slightly complex in the dry and wet seasons at Yusuf Ali hostel and Mountain, and accounted for higher levels of Ca than Mg, conforming to the study of Olatunde *et al;.* (2021). The wet season water samples were more complex than the dry season water samples. However, the Mg-value deviated significantly from the 20 mg/L concentration expected for wholesome water samples in the wet season (except at Sambisa hostel: 6 mg/L), more so than in the dry season (except at Yusuf Ali hostel: 24 mg/L). Water samples obtained their Mg-contents from the dissolution of basal rocks, which triggers water hardness (Saha *et al;.*, 2019). This is not a health risk issue, except for individuals who cannot tolerate high levels of Ca and Mg consumption (Sengupta, 2013).

The alkalinity values determined in the study by Olatunde *et al;* (2021) included those found in this study, except for the Yusuf Ali hostel water samples, which had higher values than the dry season water samples. The K-contents in the water samples during the wet season were generally lower than the values determined by Olatunde *et al;. (2021), unlike in the dry season, where they conformed to the expected levels*. The K-contents in the water samples analysed by Meride and Ayenew (2016) obtained a range of 20.83 to 27.51 mg/ L. However, the WHO (2011) stipulated its potable water K-content limit at 12 mg/ L, whose exceedance (deviation) may trigger depression, weakness of muscle, and disorderliness in the heart function (or rhythm), while conformity is essential to human bodily functions to protect the heart; regulate blood pressure, dissolution of protein, contraction of muscle, and stimulation of nerves. The residual-Cl levels were BDL in the dry season water samples and were determined in the wet season (below the limit of 0.30 mg/L) except at the main canteen, where they were also BDL. The determined range of residual-Cl in the study of Meride and Ayenew (2016) and Olatunde *et al;.* (2021) was 3.00 to 4.40 mg/L and 17.00 to 146 mg/L, respectively. The residual-Cl, which should be at least 0.30 mg/L, indicates that the water samples have been sufficiently chlorinated to restrain microbial loads and prevent pathogenic infections for consumers. On that note, the current study's residual Cl content indicated the water samples' susceptibility to microbial loads. Though the dry season water samples had more chlorides than the wet season water samples except at the Mountain, no value reached one-fourth of the NIS554 (2015) limit of 100 mg/ L; this indicated that water samples were free from pollution as corroborated by the WHO (2004) that it is water with high chloride ions' levels that damages irrigated plants and contributes unpleasant taste to the potable water.

The carbonate and bicarbonate contents determined in this study conformed to the previously determined ranges: carbonate contents: BDL to 6.00 mg/ L, and bicarbonate contents: 4.60 to 32.50 mg / L in the borehole water samples, while BDL to 0.10 mg/ L and 10.90 to 41.05 mg/ L in the well water samples Aribisala *et al;.* (2017), who also observed that water sampled acidic medium had tendencies of having bicarbonates and carbonic acid. Sulphate is naturally derived from water through the dissolution of sulfuric acid salts, resulting in concentrations of up to several hundred milligrams per litre (mg/L) with no significant negative impact on human health/according to the WHO (2011), which stipulates a limit of 250 mg/L for drinking water. The levels in this study's water samples were lower than those reported by NIS550 (2015): 100 mg/L, Meride and Ayenew (2016): 0.30 mg/L, and Olatunde *et al;.* (2021): 12.40 to 23.70 mg/L. The levels of phosphate in the main canteen and Sambisa hostel water samples during the dry season raised concerns, as they exceeded the levels reported by Olatunde *et al;* (2021). Its presence in any available water can result from sewerage or agricultural waste infiltration.

The determined F-contents conformed to the ranges of values reported by Agbo *et al;.* (2019). Higher values exceeding the limit may lead to dental fluorosis as a toxic effect; however, they also enrich bone development and prevent tooth decay (Kundu *et al;.,* 2001). The study observed that while some water parameters (e.g., pH, dissolved oxygen, alkalinity/ total hardness/ Ca (except at Yusufi Ali hostel), Ca, Cr, Zn, Sulphate, residual-Cl and F) were lower in the dry than wet season, others (such as the turbidity, temperature, conductivity (except at Masjid), K- and Al-contents (at the main canteen and Sambisa hotel), Fe, Mn, Cu, Nitrite-N, carbonate and bicarbonate (except at Masjid), chloride (except at Sambisa hostel) were higher in the dry than the wet season. The study observed that carbonate **<** bicarbonate contents in the dry season, while carbonate > bicarbonate contents in the wet season. The study found that Ca > Mg, with Ca accounting for the water hardness. The Mountain, Yusuf Ali hostel, and Masjid water samples were free of phosphate in both seasons. The water samples collected from the main canteen, Sambisa hotel, and Mountain during the dry season were slightly acidic, with pH values below the set limit of 6.50. The water samples had higher K- and Cr-contents than their respective set limit in both seasons, while higher Fe-content than the set limit in the dry season.

Conclusion

The results conclusively observed that the pH (5.20 to 7.00 < 6.98 to 7.91), dissolved oxygen (2.40 to 2.80 < 4.30 to 6.50 mg/ L), alkalinity (18 to 170 < 24 to 142 mg/ L)/ total hardness (28 to 138 < 42 to 174 mg/ L)/ Ca hardness (20 to 114 < 14 to 50 mg/ L) (except at Yusufi Ali hostel), Ca (4.56 to 11.20 < 5.60 to 20 mg/ L), Sulphate (BDL to 37 < 34 to 51 mg/ L), residual-Cl (BDL < BDL to 0.21) and F (BDL < BDL to 1.45 mg/ L) were lower in the dry than wet season; Carbonate (18 to 138 mg/ L) **<** bicarbonate (73 to 646.60 mg/ L)-contents in the dry season; Carbonate- (138) and bicarbonate- (646.60) contents were higher than the limit (100 mg/ L) at Yusuf Ali hostel in the dry season; Water pH was lower than the limit, thereby making the water sample slightly acidic at the main canteen (5.20), Sambisa hotel (5.20), and Mountain (5.40) in the dry season; Fe (BDL to 1.90 mg/ L) -content was higher than the limit (0.30 mg/ L) in the dry season; Phosphate was BDL at Mountain, Yusuf Ali hostel, and Masjid in both seasons; Turbidity (0.67 to 8.79 mg/ L) was lower than the limit (5.00 mg/ L) except at the main canteen in the wet season; K- and Cr-contents were higher than the limit (0.01 mg/ L) in both seasons; and Lastly, there was a possible seasonal influence on the water parameters' variations. Having found that K- and Cr-contents were higher than their respective limits in both seasons, the study recommends measures to conduct seasonal monitoring of the community groundwater, implement effective water management practices, prevent possible human health risks from their high levels in water, and lastly ensure clean and safe drinking water.

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Conflict(s) of Interests

The authors have no financial interests to disclose for any entity (e.g., employment, significant share ownership, patent rights, consultancy, research funding, etc.) to benefit from our publication. The authors have no details of any other potential competing interests (of a personal nature that readers or editors might consider relevant to our publication) to provide. The authors are openly and explicitly stating that potential conflicts do not exist.

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