ANALYSIS OF PHYSICOCHEMICAL AND BACTERIOLOGICAL QUALITY OF WELLS IN OJU L.G.A. OF BENUE STATE

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ABSTRACT

Water is one of the most important renewable resources to living organisms. Water pollution remains a serious global contemporary environmental issue that affects every living thing. This study was undertaken to analyze the physicochemical and bacteriological quality of well water in Oju LGA. It also looked at the seasonal variations of these parameters and compared their values with that of the World Health Organization (WHO) and National Standard for Drinking Water Quality (NSDWQ) standards. A total of 40 well water were sampled randomly from five different locations and collected into clean plastics and sterile bottles. These samples were immediately transported to the laboratory for analysis. Standard methods were used in carrying out the physicochemical parameters, while bacteriological analysis was carried out using pour plate method. Data were analyzed statistically using one-way ANOVA, Descriptive and T-test at $p < 0.05$ significant level. Results from this study shows that physicochemical properties of water samples varied across locations (A-E) with significant differences observed for pH ($p = 0.001$), TDS ($P < 0.05$), temperature ($p = 0.05$), EC ($p = 0.027$). The bacteriological analysis revealed a higher concentration of Enterobacteria spp., Shigella spp and Bacillus spp during the rainy season (1.20 ± 0.84, 0.60 ± 0.89 and 2.20 ± 0.450) as compared to the dry season (0.80 ± 0.84, 0.40 ± 0.55 and 1.80 ± 0.84) respectively. Seasonal variation in TVC and TCC were significantly different ($P < 0.001$). In a whole, location C was highly contaminated as compared to other locations. In conclusion, contamination of well water is traceable to poor sanitation practice and incessant use of agrochemical. This study recommends that further studies should be conducted to compare the quality of boreholes with well water to ascertain its quality for human consumption.

Keywords: Physicochemical, Bacteriological, Analysis, Quality, Wells.

1. INTRODUCTION

Water is one of the most important renewable natural resources to living organisms. The importance of water to living organisms as a whole cannot be overemphasized as water plays vital roles in every life processes. About 60% (42L) of the total body mass of an average man weighing 70kg comprises of water (Tobias *et al.*, 2022). Over 71% of earth's surface is filled with water (USGS, 2019c). Although greater percent of the earth surface is covered with water, accessing safe and quality water is still a global challenge. Over 2 billion of the world population

lived in water stressed environment; billions of people in the world suffer from severe health hazards due to inability to access safe and quality water (WHO, 2022).

Water pollution remains a serious global contemporary environmental issue that affects every living thing most especially human health. Several anthropogenic activities such as agricultural practices, mining, industrial activities (industrial waste), domestic waste, and leakage from oil pipelines have contributed immensely to the pollution of water. Groundwater quality is mostly threatened by urbanization; agricultural practices, industrial activities, and climate change (Li *et al.*, 2021). Accessing potable water is the basic problem of the developing countries, most especially the rural and the sub-rural areas. About 80% of human diseases and 50% of child mortality worldwide are associated to poor water quality (Lin *et al.*, 2022). Groundwater contamination could be caused by natural activities such as weathering, volcanic eruption or anthropogenic activities such as mining, industrialization, urbanization, agriculture, poor sanitation.

Well water is mostly the common source of water for both drinking and domestic activities in the developing countries as it is more affordable. Well water bacteriological contamination mostly comes from pit latrine that of close proximity to well point. The major problem of well water safety is linked to poor siting and construction (US EPA 2024). Groundwater contamination control is highly significant. Unlike surface water, groundwater once contaminated, remediation is challenging and costly, because groundwater is located in subsurface geological strata and residence times are long (Wang *et al.*, 2020). In the developing countries, providing water and sanitation to low income earners is a key sustainable developmental challenge (Olayinka *et al.,* 2014). The world Health Organization had proposed an approach called water safety plan (WSP) so as to address the issue of sustainable sanitation and safe water source. According to world health organization (2023a) report "half of the world's population still does not have adequate access to safe drinking water, sanitation and hygiene (WASH) which could have prevented at least 1.4 million deaths and 74 million disabilities." Unsafe water, poor sanitation and poor hygiene are the leading cause of mortality and morbidity in developing countries. Transmission of diseases such as cholera, dysentery, hepatitis A, typhoid and polio are traceable to contaminated water and poor sanitation (WHO, 2023b).

Bacteriological contamination of water is the leading cause of illness in the developing countries. Bacteria, such as *E. coli* or fecal *Streptococci* are known as indicators of sewage pollution in drinking and bathing water (Some *et al.,* 2021). Safe water is undoubtedly paramount to the health of human. In 2019, the outbreak of COVID-19 epidemic which consumed millions of lives; hand washing was one of the recommended preventive measure by CDC. Thus, access to potable water for drinking and other domestic uses can go a long way in preventing mortality and morbidity in human.

Physicochemical parameters of water are vital and principal determinants to test the quality of water before it is used for domestic, agricultural, drinking and industrial purposes (Vipul *et al.,* 2021). Physicochemical parameters of water are the reflection of water quality. Most physicochemical parameters may not have direct health impacts on human but they are important indicators of water contamination.

2. MATERIALS AND METHODS

Study Area

This study was conducted in Oju Local Government Area of Benue State. Five different communities in Oju Local Government Area of Benue State were selected randomly for this study and they include: Ukpila-Anina Ikachi, Onyike, Ega, Anyuwogbu and Oju-Umoda.

Oju Local Government is located on the southern edge of Benue State and is bounded by Obi Local Government Area in the northwest, Konshisha Local Government in northeast, Cross River State by the east, Enugu State by the south and Ado Local Government in the west (Ogbu, 2020). Oju Local Government Area lies at latitude 6°53'26.55"N and longitude 8°21'9.56"E. It covers a land scale of 1,283 square kilometers and ranges from 200m to over 500m above sea level. Oju Local Government Area has a tropical savanna climate . Over the course of the year, the temperature usually varies from 63 °F to 89 °F and is seldom below 57 °F or above 93 °F (Ogbu, 2020).
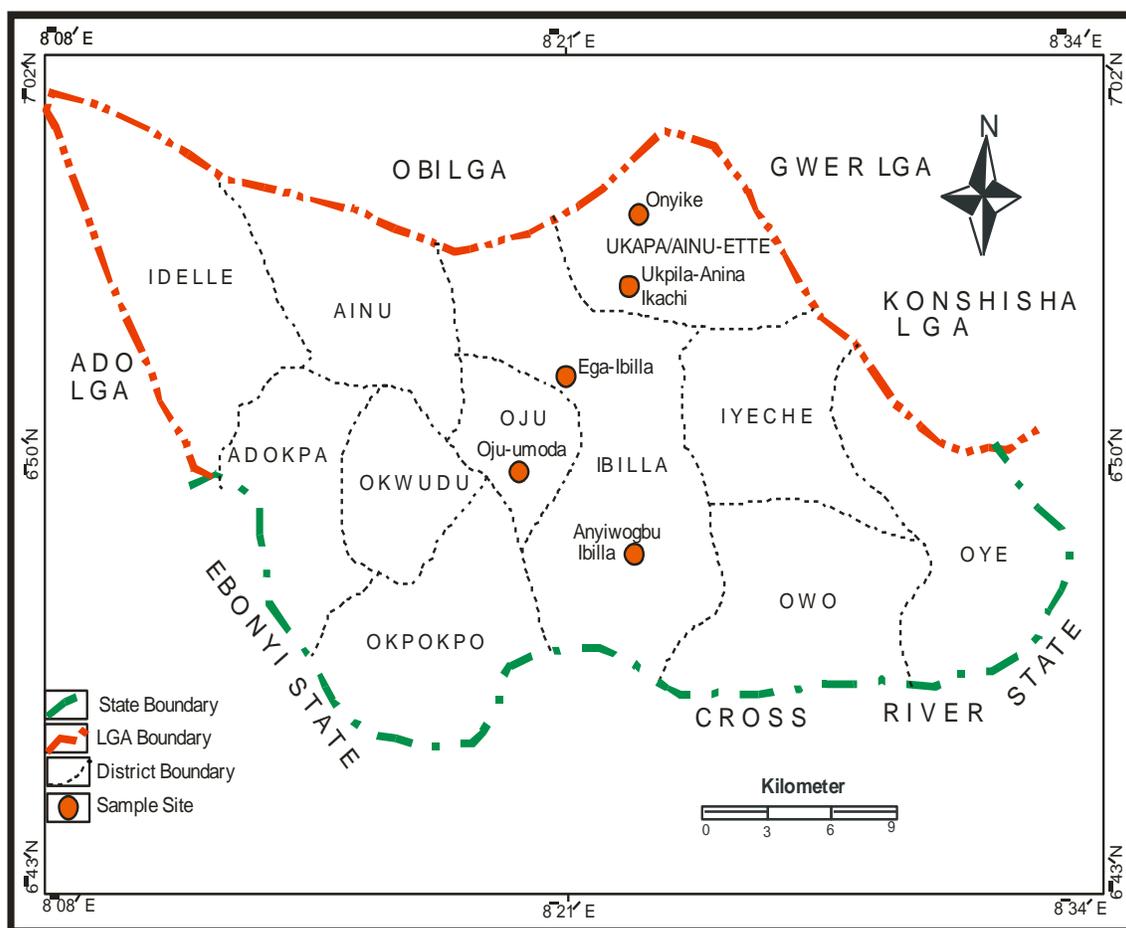

Figure 1: Map of Oju Local Government Area Showing Sample Sites

Source: Ministry of Lands, Survey and Solid Minerals, Makurdi

Collection of Water Samples

Collection of water samples for dry and raining season was conducted in February 2023 and July 2024 respectively. A total of forty (40) well water samples were collected from 5 different study locations within Oju Local Government Area randomly. Prior to collection of samples, the plastic bottles were washed with detergent and rinsed with clean water and distil water properly. At the point of collection, the sample containers (plastic bottles and sterile bottles) were first rinsed three times in the field using water sample collected from the well to be sampled. A clean plastic container was then tired to a long rope which was let down to the well gently to collect water. The fetched water sample was poured immediately into plastic bottle and the sterile bottles respectively. All the collected samples were properly covered and labeled immediately at the point of collection. The collected water samples across the study areas were transported immediately to Joseph Sarwuan Tarka University laboratory at Makurdi, Benue State for analysis. The collected water samples were analyzed in the laboratory for physicochemical and bacteriological quality.

Analysis of Physicochemical Parameters

The following physicochemical parameter were analyzed from the water samples collected, pH, total hardness, temperature, turbidity, electrical conductivity, dissolve oxygen (DO), total dissolve solids (TDS), biochemical oxygen demand (BOD), nitrate and ammonia. Physicochemical parameters such as pH, temperature, electrical conductivity and dissolved oxygen were analyzed in-situ. Samples were analyzed in situ and in the laboratory using standard methods (APHA, 1992).

Determination of total coliform count (TCC)

One milliliter of properly mixed well water sample was added into a sterile petri dish using a micropipette and mixed with 100ml of sterile MacConkey agar.. The petri dishes were swung in a figure 8 movement to achieve thorough mixing and left horizontally until it solidified. The culture plates were then inverted and incubated at 20°C-37°C for 44 to 48h. The visible coliforms were counted. The plate was divided into four to avoid error in counting. The total bacterial count was then scaled up for 100ml of sample.

Total viable counts (TVC)

1 ml of properly mixed well water sample was added into a sterile petri dish using a micropipette and mixed with 100ml of sterile nutrient agar.. The petri dishes were swung in a figure 8 direction to achieve thorough mixing and left horizontally until it solidified. The culture plates were then inverted and incubated at 20°C-37°C for 44 to 48h. The visible coliforms were counted. The plate was divided into four to avoid error in counting. The total bacterial count was then scaled up for 100ml of sample (Gershom *et al.*, 2020).

Identification of bacteria
Biochemical test

The following biochemical tests were carried out on the pure cultures colony to identify the various bacteria in the water samples. They include; catalase, citrate, urease, indole, motility test, gram staining and oxidase. The method of Cheesbrough, 2016 was adapted.

Statistical Analysis

Data collected were statistically analyzed using the most appropriate statistical packages such as descriptive statistic, t-test and one-way ANOVA ($p>0.05$). Results obtained were tabulated.

4. RESULTS

Table 1: Physicochemical Parameters of Sampled Well Water between Dry and Rainy Season

Parameter	Dry	Rain	WHO	NSDWQ
pH	6.88 ± 0.34	7.16 ± 0.25	6.5-8.5	6.5-8.5
TDS (mg/l)	260 ± 193.34	223.65 ± 72.21	NS	500
DO (mg/l)	2.67 ± 0.44	4.08 ± 0.55	NS	NS
Temp (^{0}C)	27.3 ± 0.7	25.61 ± 0.58	Ambient	Ambient
EC (µs/cm)	517.95 ± 388.49	446.85 ± 144.53	NS	1000
Turbidity (NTU)	14.47 ± 17.65	4.93 ± 4.98	NS	5
BOD (mg/l)	0.26 ± 0.43	0.18 ± 0.31	NS	NS
Nitrate (mg/l)	0.01 ± 0.03	0.11 ± 0.34	50	50
Ammonia (mg/l)	1.46 ± 3.80	0.06 ± 0.13	NS	NS
Hardness (mg/l)	1.71 ± 3.89	1.67 ± 3.75	NS	150

Keys: TDS=total dissolved solid; DO=dissolved oxygen; EC=Electrical conductivity; BOD=Biochemical Oxygen Demand; pH= Hydrogen ion concentration; NTU = Nephelometric turbidity unit; Mg/l = Milligram per liter; µs/cm =Microsiemens per centimeter

Table 2: Prevalence of Bacteria Species in Sampled Well Water

Parameters	Dry	Rain	WHO	NSDWQ
Klebsiella spp.(CFU/ml)	1.80 ± 1.30	1.80 ± 1.30	0	0
Enterobacter spp. (CFU/ml)	0.80 ± 0.84	1.20 ± 0.84	0	0
Proteus spp.(CFU/ml)	1.00 ± 0.71	0.80 ± 0.84	0	0
Shigella spp.(CFU/ml)	0.40 ± 0.55	0.60 ± 0.89	0	0
E. coli spp.(CFU/ml)	0.80 ± 0.84	0.60 ± 0.55	0	0
Bacillus spp.(CFU/ml)	1.80 ± 0.84	2.20 ± 0.45	0	0
Staphylococcus spp.(CFU/ml)	2.00 ± 0.71	0.80 ± 0.84	0	0

Keys: *E. coli=Eschericheria coli;* spp=species; CFU/ml= coliform forming unit per milliliter; NSDWQ= National Standard for Drinking Water Quality

Table3: Physicochemical, Heavy metals and Bacteriological Water Quality Parameters

Parameter	Mean	WHO	NSDWQ	t value	*p* value
pH	7.02	.NS	6.5-8.5	10.048	< 0.001
TDS (mg/l)	241.83	NS	500	-11.244	< 0.001
DO (mg/l)	3.37	NS	5.00	-11.877	< 0.001
Temp (^{0}C)	26.45	25	Ambient	8.6182	< 0.001
EC (μs/cm)	482.4	NS	1000	-11.228	< 0.001
Turbidity (NTU)	9.7005	NS	5	2.17	<0.036
BOD (mg/l)	0.2175	NS	NS	-234.31	< 0.001
Nitrate (mg/l)	0.06075	50	50	-1297.3	< 0.001
Ammonia (mg/l)	0.76825	NS	200	-458.06	< 0.001
Hardness (mg/l)	1.6875	NS	150	-248.85	< 0.001
TCC (CFU/ml)	92.75	10	10	10.11	< 0.001
TVC (CFU/ml)	148.7	0	0	10.80`	< 0.001

Keys:TDS=total dissolved solid; DO=dissolved oxygen;EC=Electrical conductivity; BOD=Biochemicsl Oxygen Demand; pH= Hydrogen ion concentration; NTU = Nephelometric turbidity unit; Mg/l = Milligram per liter; μs/cm =Microsiemens per centimeter; Cu= copper; Cr= Chromium; Cd= Cadmium; Pb= Lead; WHO= World Health Organization; NSDWQ=National Standard for Drinking Water Quality; mg/l=milligram per liter; TVC=Total Viable Count; TCC=Total Coliform Count; DF=degree of freedom; CL=Class interval.

Table 4: Physicochemical Qualities of Well Water between Seasons

Parameter	Dry	Rain	t-statistic	p value
pH	6.88 ± 0.08	7.16 ± 0.06	-2.21	0.09
TDS	260.00 ± 43.23	223.65 ± 16.15	0.61	0.58
DO	2.67 ± 0.10	4.08 ± 0.12	-6.04	0.00
Temp	27.30 ± 0.16	25.61 ± 0.13	6.86	0.00
EC	517.95 ± 86.87	446.85 ± 32.32	0.59	0.59
Turbidity	14.47 ± 3.95	4.93 ± 1.11	1.87	0.14
BOD	0.26 ± 0.10	0.18 ± 0.07	0.48	0.66
Nitrate	0.01 ± 0.01	0.11 ± 0.08	-1.41	0.23
Ammonia	1.48 ± 0.85	0.06 ± 0.03	1.22	0.29
Hardness	1.71 ± 0.87	1.67 ± 0.84	0.03	0.98

Table 5: Bacteriological Quality of Well Water between Seasons

Season	TVC	TCC	t-statistic	p value
Dry	203.40 ± 19.20	125.70 ± 10.66	12.06	0.00
Rain	94.00 ± 9.76	59.80 ± 6.85	5.48	0.01

5. DISCUSSION

The pH is an important indicator of water quality because it regulates both the chemical and biological processes of water. pH regulates the lives of bacteria and availability of other contaminants in water (Saalldong *et al.*,2022). pH is a significant parameter that regulates the solubility and bioavailability of nutrients, heavy metals, and other substances in water (Gunarathina *et* al., 2016). Low and high pH value of water can be harmful to aquatic because low pH can lead to the release of toxic metals from sediments while high pH can reduce the availability of dissolved oxygen, which is essential for aquatic organisms (Dewangan *et al.,* 2023a). The pH was slightly acidic to neutral across both seasons. The pH mean value during the rainy season (7.16 ± 0.25) was higher than the dry season with mean value (6.88 ± 0.34). This report corresponds to Olatunde and Ayandele (2017) and Nguyen and Huynh (2023) who recorded higher pH during rainy season. In contrast to this study, Giao et al. (2022) and Rahman *et al.*, (2021) recorded higher pH in the dry (7.37±0.14) than the rainy seasons (7.33±0.34). this increase could be caused by water runoff from agricultural practices; pH mean values of wells in the study areas were within the WHO and NSDWQ permissible limit of 6.5-8.5. pH< 6.5 can leach metals such as lead and copper from pipes into water causing harm to human, pH > than 8.5 could cause gastrointestinal problem (Dewangan *et al.,* 2023a).

This study recorded a high DO during the rainy season compared to dry season as seen in table 1. This report corresponds to Olatunde and Ayandele (2017) and Rahman *et al.*, (2021) recorded an increase in DO during the rainy season as compared to dry season. Dissolved oxygen is an essential component of life. Every living thing needs oxygen to survive. Thus, healthy water should contain certain amount of dissolved oxygen. Low level of dissolved oxygen in water is an indicator of contamination and it is also a vital determinant of water quality, pollution control and treatment process (Omid *et al.,* 2021). Seasonal variation between the dry and rainy season were statistically significant. The recommended DO concentration are 6 mg/L for drinking water, 4-5 mg/L for entertainment, 4-6 mg/L for fish and domesticated animals, and 5 mg/L for industrial applications (WHO, 2017b).

Water temperature is a measure of the kinetic energy of water and is expressed in degrees Fahrenheit (F) or Celsius (C). Temperature regulates the degree of water contamination as it controls bacterial growth and regulates the rate at which heavy metals are released. High water temperature can increase the growth of microorganisms and can increase problems associated to taste, odour, colour and corrosion (WHO, 2022). The water temperature controls the rate of all chemical reactions (Onwughara *et al.,* 2013). This study recorded higher temperature during the dry season than the rainy season. This study corresponds with Onyegeme-Okerenta (2016) who observed higher temperature in the dry season compared to rainy season. Contrarily, Rahman *et al.*, 2021 recorded higher temperature during the rainy season compared to the dry season. High water temperature can increase the growth of microorganisms and can increase problems associated to taste, odour, colour and corrosion (WHO, 2022). High temperature can enhance the growth of microorganisms, facilitate the rate of heavy metals pollution of water, and regulates conductivity and total dissolved solid.

The levels of electrical conductivity of the studied samples were moderate. The mean values of EC were less than the permissible limit of WHO and NSDWQ. EC was higher during the dry season (517.95 ± 388.49) than the rainy season (446.85 ± 144.53). The high value experienced during the dry season could be as a result of low level of water table which results from high

concentration of minerals and salts in the water. Similar to this study, Rahman *et al*., 2021 recorded higher EC in the dry season than in the rainy season.

TDS concentration increased during the dry season (260 ± 193.34) than the rainy season (223.65 ± 72.21). similarly to this study, Onyegeme-Okerenta (2016); Nguyen and Huynh (2023) and Rahman *et al*., (2021) recorded increase in TDS concentration during the dry season than the raining season in their study. The concentration of dissolved solid increases as the water level decreases. According to WHO (2017), drinking water supplies containing more than 500 mg L^{-1} TDS are considered undesirable.

Biological Oxygen Demand (BOD) remained low in both seasons, with slightly higher values in the dry season (0.26 ± 0.43 mg/L) than in the rainy season (0.18 ± 0.31 mg/L). Although there increase in the concentration of BOD between season it is not statistically significant. This study corresponds with Rahman *et al*., (2021) who recorded increase in TDS concentration in the dry season than rainy season.

The turbidity levels in most of the studied samples were higher than the recommended, guideline standard of 5 NTU. Turbidity was higher in the dry season (14.47 ± 17.65 NTU) compared to the rainy season (4.93 ± 4.98 NTU). This study corresponds with Olatunde and Ayandele (2017); Rahman *et al*., (2021) who recorded higher turbidity during the dry season than the raining season. High turbidity in waters harbours microbial pathogens which attached to particles and impair disinfection; high turbidity in filtered water indicates poor removal of pathogens (WHO, 2017). High turbidity observed during the dry season could be due to decrease in water level which has resulted to higher concentration of pollutants, suspended soil, sediment, carbon-based substances, inorganic materials, and other invisible living things in the water.

Nitrate level was generally low with 0.11 ± 0.34 mg/l in the rainy season and 0.01 ± 0.03 mg/l in the dry season. Nienie *et al.* (2017) also recorded high level of nitrate during rainy season than in dry season. The nitrate levels of all the studied samples were below the permissible limit of WHO and NSDWQ. Therefore, this water does not pose any health risk in respect to nitrate toxicity. Several studies have shown that exposure to high level of nitrate is the major cause of large number of diseases such as methemoglobinemia, gastric and intestinal cancer, Blue-baby Syndrome, vomiting, diarrhea, birth defects, hypertension and catharsis (Sharma, 2016).

Result from this study shows low level of ammonia in water samples across the two seasons. The WHO and NSDWQ has no set guideline value for ammonia. The concentration of ammonia was higher in the dry season (1.46 ± 3.80 mg/l) compare to the rainy season (0.06 ± 0.13 mg/l). This result corresponds with the result of Nguyen and Huynh (2023). This increase observed in the dry season could be due to decrease in the level of water which has resulted to increase in the concentration of ammonia.

Total hardness is the measure of water mineral content (magnesium or calcium). Water hardness is formed from infiltration of water through deposits of minerals (limestone, chalk or gypsum) which comprises of calcium and magnesium carbonates, bicarbonates and sulfates (National Groundwater Association, 2019; Akani *et al*., 2021). This study shows increase in total hardness during the dry season (1.71 ± 3.89 mg/l) than the rainy season 1.67 ± 3.75 mg/l). This agrees with the result of Nguyen and Huynh (2023); Ojekunle *et al*., (2020); Rahman *et al*., 2021 and Antony *et al*., (2020) who recorded increased in total hardness during the dry season. The consumption of water with high hardness can cause cardiovascular diseases and reduce the quality of detergent, soap, and cleaning products Aleem *et al., (*2018). This study recorded moderate value of total hardness across the season. The mean value of both the dry season (1.71

± 3.89 mg/l) and rainy season (1.67 ± 3.75 mg/l) were below the permissible limit of WHO and NSDWQ (150 mg/l). When water concentrations of calcium carbonate is below 60 mg/l it is considered as soft; from 60- 120 mg/l is moderately hard; 120-180 mg/l is hard; and more than 180 mg/l is very hard (Akram and Rehman, 2018).

The isolated coliform bacteria were *Shigella*, *E. coli*, *Enterobacter*, Proteus, *Klebsiella*, *Staphylococcus* and *Bacillus* which were all above the Nigeria and WHO standard for potable water (table 3). The wells were all highly contaminated with *Shigella* spp., *Escherichia coli* spp., *Enterobacteria* spp., *Proteus* spp., *Klebsiella* spp., *Staphylococcus* spp. and *Bacillus* spp. in both dry (0.40 ± 0.55, 0.80 ± 0.84, 0.80 ± 0.84, 1.00 ± 0.71, 1.80 ± 1.30, 2.00 ± 0.71 and 1.80 ± 0.84) and rainy season (0.60 ± 0.89, 0.60 ± 0.55, 1.20 ± 0.84, 0.80 ± 0.84, 1.80 ± 1.30, 0.80 ± 0.84, and 2.20 ± 0.45). Similarly, Akani *et al*., (2021) also isolated indicator bacteria such as *Escherichia coli*, *Enterobacter* spp*., Bacillus* spp., *Staphylococcus* spp., *Chromobactereium* spp., Samonella spp., Shigella spp.and *Vibrio* spp. above WHO permissible limit in the study wells. *Bacillus* spp. was the most prevalent coliform bacteria isolated in all the wells. *Bacillus* spp. is mostly harmless except few which are pathogenic to humans and animals (Akani *et al*., 2021). Bacillus cereus are the major causes of food poisoning (Akani *et al*., 2021). Pathogenic Bacillus spp. such *as B. anthracis* causes anthrax in animals and human, *B. cereus sensu lato* (*B. cereus sl*) causes food poisoning*, B. thuringiensis* or *B. cereus sensus stricto* (*B. cereus ss*) causes human infections such as septicaemia, endophthalmitis, periodontitis. *(*Akani et al., 2021; Brillard *et al., 2014*). Staphylococcus spp. is the second most prevalent indicator bacteria isolated from the wells. The mean value of the total coliform count (92.75 CFU/ml) and total viable count (148.7 CFU/ml) of all the wells were higher than WHO and NSDWQ permissible limit of 10 CFU in 100ml for TCC and 0 CFU in 100ml for TVC (table 4). Total coliforms are indicator organisms used to monitor water quality (Maheux *et al.* 2014). This study reveals that contamination of wells was higher in dry season than in rainy season. This study corresponds with Ayeta *et al*. 2023 who observed increase in total *coliform* and *E. coli* during the dry season in some of the studied sites. The elevated temperature during the dry season provides a warmer ground for several fecal coliforms to thrive (Gershom *et al.*, 2020). High numbers of coliform bacteria occur mostly in summer, due to high surface water temperatures (Reitta *et al.*, 2021). This was also observed by Salim *et al.*(2014) who observed increase in coliform counts in autumn compared to other seasons used in the work. Contrarily, Olatunde and Ayandele (2017) recorded increase in TCC during the rainy season than the dry season. The high contamination of the wells with indicator bacteria is likely caused by poor sanitation and hygiene, closeness to pit toilet or septic tank, topography of the land. Mostly, cases of waterborne diseases are usually higher during the dry season when there is water scarcity than rainy season. Increase observed in TCC and TVC could be caused by seepage from a close toilet, dump site or water runoff for improperly covered wells.

6. CONCLUSION AND RECOMMENDATIONS
Conclusion

This study revealed the contamination of the wells with total *coliform* bacteria, *Shigella*, *E. coli*, *Enterobacter*, *Klebsiella*, *Staphylococcus*, *Bacillus* above the Nigeria and WHO standard for potable water makes the water unsafe for drinking and other domestic purposes. Total coliform and Enteric bacteria are indicators of faecal contamination. This high bacteriological contamination of the water sources observed in Oju LGA may be the cause of most preventable

water borne diseases which has triggered the mortality and morbidity rate. Good hygiene, sanitation and adequate water treatment scheme is significant to ensure the safety of the water accessed by the people so as to reduce mortality and morbidity rate.

Recommendations

i. More research work is recommended on this area of study so as to compare the quality of boreholes with well water.

ii. Regular monitoring of water and treatments before use is highly recommended so as to reduce mortality and morbidity rate. The use of modern methods of water treatment such as nano-filtration, ultra-nanofiltration, and reverse osmosis of water treatment should be adopted for removal of heavy metals contamination.

iii. The government can setup a permanent monitoring committee that can investigate groundwater quality of the region with the aim of proffering solution and assisting the community in providing tap water.

iv. To enhance the quality of well water, proper disposal of waste and sitting of well far from sewage or dumpsite and the use of standard toilets facility could reduce the level of contamination.

ABBREVIATIONS

B. cereus sl: Bacillus cereus sensu lato
B. cereus ss: Bacillus cereus sensu strict
CFU: coliform forming unites
TVC: total viable count
TCC: total coliform count
TDS: total dissolved solid;
 DO: dissolved oxygen;
EC: Electrical conductivity;
 BOD: Biochemicsl Oxygen Demand;
 pH: Hydrogen ion concentration;
NTU : Nephelometric turbidity unit;
 Mg/l : Milligram per liter;
 µs/cm : Microsiemens per centimeter;
 Cu: copper;
 Cr: Chromium;
 Cd: Cadmium;
 Pb: Lead;
 WHO: World Health Organization;
NSDWQ: National Standard for Drinking Water Quality
 mg/l=milligram per liter

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CONFLICTING INTEREST

Authors have no conflicting interest

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