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PHYSICO-CHEMICAL AND BACTERIOLOGICAL CHARACTERISTICS OF WELL WATER IN SOME SELECTED RESIDENTIAL AREAS WITHIN THE AJAOKUTA HOUSING ESTATE, KOGI STATE, NIGERIA

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ABSTRACT
This study assesses the physico-chemical and bacteriological characteristics of well water within some selected residential areas of the Ajaokuta Housing Estate (A- Racca-Foam, B- Borno, C-Kwara, D – Lagos, and E – Abuja Estates). Water samples (six samples per estate) were collected from thirty wells in the study area, and were analyzed for physicochemical and bacteriological properties using standard techniques, and the results compared with the World Health Organization (WHO) standards. The results indicated that some physico-chemical parameters were outside the WHO acceptable limits. Notably, iron and manganese and magnesium contents exceeded the WHO in the five selected area where samples were collected, with the highest concentration at 0.54, 1.0 and 60.0 mg/L, respectively. Total hardness and total alkalinity were also above the permissible limit of 100 mg/L in all samples. Bacteriological analysis showed elevated TVC (0 to 3.0 × 10^3 CFU/mL) and TCC (0 to 1,200 per 100mL) especially with samples in areas B, D and E, suggesting potential faecal contamination or inadequate well maintenance. The presence of pathogenic bacteria such as *Salmonella* sp., *Staphylococcus aureus*, and *Escherichia coli*, further re-emphasises the public health risks posed by the water samples. Statistical analysis showed no significant discrepancies in water quality across the different wells sampled. These findings suggest that well water in the study area may not be totally safe for consumption without adequate treatment. Hence, a regular and proper thermal or chemical treatment of well water in the study area is recommended to ensure safe drinking water for the community/environs and prevent waterborne diseases.

Keywords: Well water, water quality, bacteriological contamination, physico-chemical characteristics, water safety compliance.

INTRODUCTION
The impact of human and industrial waste materials has been a source of worry for environmentalists and policymakers, globally (Hakeem *et al.,* 2020; Lemessa *et al*., 2023). Although, industries all over the world play critical in the development of a country's economy, poorly managed wastes from these industries pose potential risks to the environment through the contamination of surface and ultimately underground water (Siddiqua *et al.,* 2022). Underground water bodies, which function as a vital source of drinking water, irrigation, and other domestic uses, are particularly prone to contamination by pollutants generated from nearby industrial processes during and after production (Akhtar *et al.,* 2021). Water pollution has become a major challenge in recent times (Kundu *et al.,* 2024).

Water is one of the basic and critical resources utilized by man for normal physiological functions, as well as for industrial productions and agricultural activities (Bhagwat, 2019; Misra and Paunikar, 2023). Water comes from different sources, namely surface water from rivers and lakes, as well as underground sources from aquifers and wells (Lachassagne, 2020). Well water, a typical type of underground water, is a common source of domestic water supply in most Nigerian communities (Ogunbode *et al.,* 2023). The quality and safety of hand-dug well water is increasingly compromised due to anthropogenic activities within their vicinities, thereby posing serious risk to public health (Okafor *et al*., 2023). The demand for clean and safe drinking water is essential to the general well-being and survival of humans and biodiversity. Recent studies have shown that underground water is not only becoming scarce but are also impacted by anthropogenic activities and industrialization **(**Zacchaeus *et al.,* 2020; Akhtar *et al.,* 2021; Mishra *et al.,* 2021; Chandnani *et al.,* 2022).

Globally, one of such industries with high propensity to impact on the quality of underground water is the steel/metallurgy production sector (Hobson *et al*., 2018; Sun *et al.,* 2019; Nui *et al.,* 2023). Ajaokuta Steel Company, established in the late 1970s at Ajaokuta, Kogi State, has long symbolized Nigerians ambition for economic diversification and industrialization (Ibrahim *et al.,* 2022). It was established with the hope of producing local steels and related products for infrastructural development and fabrications (Adamu *et al*., 2022). The steel manufacturing sector has been known over the years to generate a considerable amount of wastewater, solid waste, slag, sludge, dust, scrap residues, and heavy metals (Kumar *et al.,* 2020; Mensah *et al.,* 2022; Toouzi and Horchani-Naifer, 2023). If not well managed, these pollutants can readily accumulate in soil and eventually leach into and contaminate underground water supply (Das and Poater, 2021).

Moreover, the large volume of wastewater resulting from water applications to cool, clean and operate the steel production processes is another direct source of environmental contamination (Chalaris *et al.,* 2023). Additionally, the wastewater generated can create hotspots and spread waterborne pathogen (Chahai *et al.,* 2016). This poses microbial health risks to the local communities residing with the steel production company. Although, Ajaokuta

Steel Company has remained moribund over forty (40) years after its establishment in 1979, the environmental impact from earlier steel production operations can persist for years, or even decades, particularly due to inadequate waste management. Some chemical pollutants are recalcitrant and can resist natural, chemical and biological transformation for years (Aziz *et al.,* 2023). Hence, the need for efficient waste management strategies (Ferronato and Torretta, 2019) to prevent contaminations from heavy metals and other pollutants can cause a wide range of health disorders and toxicities to skin, gastrointestinal, and deep organ-system (Tchounwou *et al.,* 2014).

The Ajaokuta Housing Estate is still occupied by the families of the Ajaokuta Steel Company Staff and others, and due to the scarcity of potable water sources, the residents depend on the available water from different sources (boreholes, shallow wells, and water vendors) daily for drinking, cooking, and general sanitation, which raises serious questions about whether this water is still safe for use. Previous reports revealed that toxic metals and microorganisms are harboured in wastewater from steel/metallurgy production, globally (Jozi *et al.,* 2014; Tchounwou *et al.,* 2014; Freitas *et al*., 2008; Shinde *et al*., 2018; Vardhan *et al.,* 2019; Kolbl *et al.,* 2022). Hence, the need to constantly monitor the quality of well water used by Ajaokuta Steel Company Territory, in order to identify the extent of contamination and propose measures to ensure the safety of water for domestic uses by the local community. Therefore, the study was carried out to assess the physicochemical and bacteriological characteristics of well water within the vicinity of Ajaokuta Steel Company, Kogi State.

MATERIALS AND METHODS

Description of the study area

The study area comprises of some selected residential areas (A- Racca-Foam, B- Borno, C- Kwara, D – Lagos, and E – Abuja Estates), in the Ajaokuta Steel Company Territory residential area situated within Ajaokuta town, Ajaokuta Local Government Area, Kogi State, Nigeria (Figure 1). Geographically, Ajaokuta is located between latitudes 7°24'N - 7°39'N, and longitudes 6°36'E - 6°42'E. The Ajaokuta integrated steel complex, initiated in 1979, was designed as a Metallurgical Process Plant and Engineering Complex, intended to stimulate significant upstream and downstream industrial and economic activities (Aderemi, 2019). Its establishment was a key part of Nigeria's industrialization strategy, earning it the nickname "Bedrock of Nigeria's industrialization" (Aderemi, 2019).

Ajaokuta Steel Company territory encompasses a vast expanse of land acquired and designated by the Federal Government, with the Ajaokuta Steel Industry and Steel Housing Estates as part of the development. The steel plant itself occupies about 800 hectares within this territory, while the Steel Housing Estates consist of over 4,500 housing units in low, medium, and high-density categories. These estates were developed by the Federal Government to accommodate steel workers and other government employees. The territory, covering 24,000 hectares of green-field land, includes both developed and undeveloped areas. The undeveloped portions of the territory are set aside for future phases of steel and industrial development. Currently, much of this land is under arable cultivation by indigenous settlers and migrants.

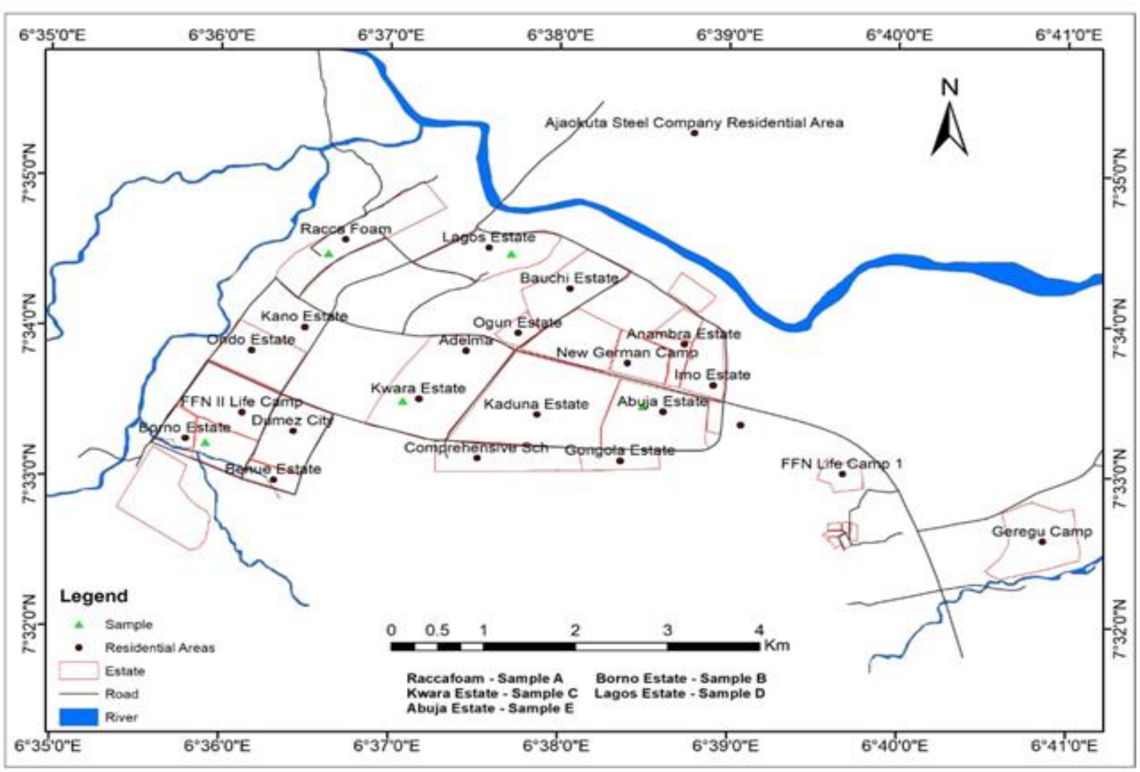

Figure1: Showing the Study Area (Source: GIS Lab, FULokoja)

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Collection of well water samples

Thirty (30) well water samples (six per residential area) were randomly collected from the five (5) selected residential areas within the study area (A- Racca-Foam, B- Borno, C- Kwara, D – Lagos, and E – Abuja Estates) using a sterile 250 mL glass (for the bacteriological analysis), and 500 mL plastic bottles (for physico-chemical analysis). The samples were collected between morning and afternoon period (8:00 - 14:00 pm) and appropriately labelled before they were transported in an ice-box to laboratory for analysis.

Physico-chemical analysis of well water samples

The water samples were analysed for appearance, turbidity, odour, colour, total dissolved solids, total suspended solids, pH, electrical conductivity, iron content, total hardness, nitrate content, total alkalinity, manganese hardness, and magnesium content using standard techniques (American Public Health Association, 2005). The appearance was estimated by visually inspecting the water sample under a bright condition for cloudiness, sediment, or discoloration. Odour was determined by gently smelling the sample for unusual or offensive scents. Colour was compared against standard colour charts to spot deviations from clear water. Turbidity was evaluated with a portable turbidimeter (H198703). Total dissolved solids (TDS) were assessed using a TDS meter. pH was determined with an automated pH meter. Electrical conductivity measured after standardization of the water sample with potassium chloride (KCl) solution before measuring with a conductivity EC meter. Iron content was determined using a spectrophotometer. Total hardness was determined through titration with EDTA, with a colour change signalling the endpoint. Total alkalinity was also measured via titration, using a strong acid to determine the water's capacity to neutralize acids (APHA, 2005).

Determination of bacteriological load of well water samples

The bacteriological loads namely total viable count (TVC), total coliform count (TCC) were carried after a tenfold serial dilution of the water samples using standard microbiological techniques (Cheesbrough, 2009). To do this, a millilitre (1 mL) of the water samples was added into a 9 mL normal physiological saline to obtain 10^{-1} dilution. The serial dilution process was continued until 10^{-6} was reached. From each of dilutions 10^{-2}, 10^{-4} and 10^{-6}, aliquot (0.1 ml) was withdrawn and aseptically spread plated on to the surface of sterile nutrient agar (Oxoid, UK) for TVC, MacConkey agar (Oxoid, UK) and Eosin methylene blue agar (Oxoid, UK) for TCC, *Salmonella-Shigella* agar (Oxoid, UK) for isolation of *Salmonella* and *Shigella*, and Mannitol salt agar (Oxoid, UK) for *Staphyolococcus aureus* (Cheesbrough, 2009). The plates were incubated at appropriate temperature (37°C for 24-48 h excluding coliform bacteria plates at 44.5 ± 2°C for 24 – 48 h). The plates were examined for bacterial colonies which were enumerated using a colony counting machine and the bacterial loads were represented as colony-forming-units (CFU) per 100 mL of water samples (Cheesebrough, 2009).

Isolation and phenotypic identification of bacterial colonies

The colonies were repeatedly sub-cultured onto fresh media to obtain pure cultures, which were stored and identified using a battery of phenotypical characterization. These included colonial appearance, Grams reactions, spore test catalase test, oxidase test, motility test, indole test, methyl red test, vogesproskauer test, urease test, citrate test, glucose test, fructose test, lactose test, sucrose and mannitol test (Cheesebrough, 2009). The probable identity of the characterised isolates was done using the Bergey's Manual of Determinative Bacteriology described by Holt *et al.* (2002)

Data analysis

The data obtained in this study were analyses using descriptive statistics and values were presented as mean ± standard deviation and represented in tabular forms. One-way ANOVA was used to compare data of different locations at p value of 0.05. Tukey's HSD was used to separate significant means.

RESULTS AND DISCUSSION

In this study, physico-chemical and bacteriological characteristics of the well water samples collected from some selected residential areas in the study area (the Ajaokuta Housing Estate, Ajaokuta, Kogi State, Nigeria). The results for physico-chemical characteristics of the well water samples are presented in Table 1. In general, some of the physico-chemical parameters did not meet WHO standards, suggesting a possible presence of organic and inorganic contaminants. With respect to the physical appearance, samples from wells 'A', 'D', and 'E' were clear, while 'B' and 'C' appeared cloudy.

The WHO standard requires that portable to be clear water. This suggests that samples 'B' and 'C' could have contained organic and inorganic contaminants which must have affected their physical appearances. Pourfadakari *et al.* (2022) reported that the presence of microbial, organic and inorganic pollutants changes the physical clarity of water. This physical appearance is connected to the turbidity and is important physical indices for water quality (Pourfadakari *et al.*, 2022). The values obtained for turbidity measurements revealed that all samples fell within the WHO limit of 5.0 NTU. However, samples 'B' and 'C' had relatively high turbidity (2.26 and 2.15 NTU), which might explain the observed unclear appearance. Nawaz *et al.,* (2023) noted that water with high turbidity is generally unclear, poor in quality and poses higher risk to toxicity and waterborne diseases. Odour was present in all samples, which is against the standard requirement for portable water by World Health Organization (WHO) standard, which specifies no odour. The presence of had been attributed to elevated levels of microbial activities or organic matter contaminants (Zhand *et al.,* 2023). Similarly, colour was within acceptable limits, with all samples meeting the WHO standard of ≤ 3.0 TCU. However, samples 'B' and 'C' had slightly higher colour values (1.01 and 1.20 TCU). Again, the colour of water in well 'B' and 'C' correlated with their turbidity and unclear appearance. Colours observed suggest elevated metal contamination and dissolved organic materials in water sources (Riyadh and Peleato, 2024).

Table 1: Physico-chemical characteristics of well water samples collected in the study area

Parameter	A	B	C	D	E	WHO
Appearance	Clear	Not clear	Not clear	Clear	Clear	Clear
Turbidity (NTU)	1.50	2.26	2.15	1.18	0.95	5.0
Odour	(+)	(+)	(+)	(+)	(+)	(-)
Colour (TCU)	0.85	1.01	1.20	0.83	0.52	≤ 3.0
Total Dissolved Solids (mg/L)	289	330	244	352	432	≤ 500
Total Suspended Solids (mg/L)	(-)	(+)	(-)	(-)	(-)	(-)
pH	7.58	7.61	7.43	7.25	7.48	6.50 – 8.50
Electrical Conductivity (uS/cm)	250	450	650	380	750	≤ 1000
Iron (mg/L)	0.46	0.47	0.54	0.44	0.48	≤ 0.30
Total Hardness as $CaCO_3$ (mg/L)	185	195	150	155	225	≤ 100
Total Alkanity (mg/L)	290	260	235	335	410	≤ 100
Nitrate (mg/L)	3.45	1.34	1.12	3.60	4.80	≤ 10
Manganese (mg/L)	0.30	0.20	1.0	0.12	0.34	≤ 0.05
Magnesium (mg/L)	21.0	26.0	10.0	30.0	60.0	≤ 2.0

Key: (+): Present, (-): Absent

The total dissolved solids (TDS) values were within the WHO limit of ≤ 500 mg/L for samples collected in residential areas ‘A’, ‘B’ and ‘C’, but samples in residential areas D and E showed relatively higher TDS values (352 and 432 mg/L). This suggests a greater concentration of dissolved substances in that well water samples. On the other hand, total suspended solids (TSS) were detected only in sample B, and this is consistent with its unclear appearance. Dissolved and suspended solids have been found to harbour pathogens and responsible for turbidity of water and thus major indicators of compromised water quality and safety (He *et al.,* 2010). The pH and Electrical conductivity of all samples (A-E) fell within the WHO standard limits of 6.50–8.50 and ≤ 1000 uS/cm. The well water samples with lower pH value are slightly more acidic water than those with higher pH.
pH is important property of water because it influences the solubility of inorganic and organic materials (Maspolim *et al.,* 2015). The electrical conductivity of sample ‘E’ yielded the highest conductivity (750 uS/cm), and this suggest that it contains higher level of dissolved ions impurities and inorganic mineral pollution. This is in line with the report of Tahraoui *et al*. (2024).

For the nitrate levels determined, they were within WHO standards, with well water sample in E having the highest level (4.80 mg/L). According to Zendehbad *et al.* (2022), traces of fertilizers or sewage runoff are potential source of elevated nitrate in underground water. The levels iron (Fe) of in all samples exceeded the WHO standard of ≤ 0.30 mg/L. High contents of iron in water indicate a potential source of corrosion or soil-based contaminants which have negative health effects (Zhai *et al*., 2021). In the same vein, manganese (Mn) and magnesium (Mg) both exceeded WHO limits. Sample C had the highest manganese level (1.0 mg/L). Previous study revealed that the levels of Fe and Mn in soil and water are correlated (Zhai *et al*., 2021) and thus in agreement with the elevated levels of both metals in this study. The elevated levels of Mn and Mg in the well water might have caused the observed colours and hardness. This confirm the findings of Nerbrand *et al.* (2003) that some elements such as Mn and Mg and organic matters impact on the physical appearance and hardness of water.

Previous studies have shown that Mn and Fe are essential elements needed by humans for normal and efficient cellular physiology. According to Rushdi *et al.,* (2023), appropriate levels of Fe and Mn are essential activations of normal functioning of brain, memory, efficient oxygen movement and syntheses of cellular metabolic enzymes. However, prolonged exposure to elevated levels of these elements, particularly, Mn, in water has been linked to neurotoxicity, neurodegenerative disorders, intellectual impairments, and diverse health complications such as organ damage and increased risk of cancer (Gosh *et al.,* 2020; Aiken *et al.,* 2023; Baj *et al.,* 2023; Rushdi *et al.,* 2023; Subhanullah *et al.,* 2024). Since, Mn is a common by-product in steel manufacturing, and found to be above the permissible limit in the water samples analysed, persistent consumption of the well water by the residents of Ajaokuta Estate may pose significant health risk.

The levels of total hardness and total alkalinity followed the same trend as expected in that they were above the WHO standard of ≤ 100 mg/L, with sample ‘E’ showing the highest hardness (225 mg/L) and highest alkalinity (410 mg/L). The two major elements, calcium and magnesium, associated with water hardness, not only causes scale build-up in pipes and reduce the effectiveness of soaps (Gotoh *et al.,* 2016), but can health risks, including kidney stone, osteoporosis, bone damages and gastrointestinal disorders (Ciosek *et al.,* 2021; Bykowska-Derda *et al,* 2023). Prolong consumptions of hard water has been linked to the risks of cardiovascular disorder, reproductive issues and organ damages (Nerbrand *et al.,* 2003; Sangupta, 2013). High alkalinity could be associated with high mineral content in water. The huge volume of wastewater generated from steel production over the years could have impacted on the levels of the observed physico-chemical characteristics. Steel productions have been documented to employ large volumes of water for cooking, cleaning and operation and thus potential source of environmental contamination (Chalaris *et al.,* 2023).

The results presented in Table 2 shows the total viable count (TVC) of bacteria across the well water samples from Ajaokuta Housing Estate, Kogi State. The highest TVC was observed in Sample location ‘B’ with an average count of 12.17 × 10^3 CFU/mL, while the lowest was found in Sample location ‘E’ with an average count of 7.00 × 10^3 CFU/mL. Despite observed variations in the TVC range, there was no significant difference across the mean values (p=0.85), indicating that the variability in bacterial counts might not be due to systematic differences among the samples. These

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findings suggest that some wells could be experiencing varying levels of contamination. The high counts observed in certain samples, particularly Samples 2 and 3, might indicate potential contamination sources such as nearby septic systems or waste dumpsites. This finding is in line with study of Springe *et al*. (2021), who reported that elevated bacterial counts often indicate organic matter contamination and pose a risk to public health. Conversely, the lower or zero counts in some of the sample's locations could suggest that these wells probably situated probably far away from dumpsites and with better construction/maintenance. This agrees with Swistock and Sharpe (2005) who noted that regular maintenance and proper well design can minimize bacterial contamination.

Table 2: Total Viable Count (TVC) of bacteria in well water samples collected in the study area

Well Water sample	Total viable count (TVC) (× 10^3 CFU/mL)				
	A	B	C	D	E
1	9.0	1.0	13.0	12.0	3.0
2	5.0	4.0	4.0	9.0	19.0
3	8.0	0.0	16.0	0.0	3.0
4	22.0	30.0	1.0	4.0	11.0
5	0.0	11.0	18.0	10.0	6.0
6	2.0	27.0	0.0	12.0	0.0
Average*	**7.67**	**12.17**	**8.67**	**7.83**	**7.00**

**One factor ANOVA showed no significant difference across the mean values (p=0.85)*

The total coliform count (TCC) of bacteria in well water samples collected from wells in the study area are shown in Table 3. There was a wide range of variations in the levels of coliform bacteria across the different samples. The TCC ranged from 0 CFU/100 mL to 1200 CFU/100 mL. Sample E had the highest average TVC of 299.2 CFU/100 mL, with Sample A exhibiting the lowest average of 18.5 CFU/100 mL. Notably, Sample D had a wide range of results, from 0 CFU/100 mL in some locations to 1200 CFU/100 mL in others, suggesting inconsistent contamination levels, possibly due to fluctuating sources of contamination or well maintenance/management practices. This inconsistency is in consonance with the findings of (Al-Khatib *et al.,* 2023), which emphasized that coliform contamination could arise from a broad range of factors like septic system leaks, animal waste, or agricultural runoff within the vicinities of underground water system. Using Tukey's HSD test with a significance level of p=0.05, it was found that Samples A, D, and E did not differ significantly from each other, indicating that these samples had similar levels of coliform contamination on average.

On the contrary, Sample C had a significantly lower average TCC, suggesting a comparatively cleaner water source or better well management practices. These results is in line with previous findings (Swistock and Sharpe, 2005; Maran *et al.,* 2016) that proper well construction and regular maintenance can significantly lower the risk of coliform contamination. The presence of high total coliform counts in some of the well water samples, especially Samples B and E, raises concerns about water safety and potential health risks. High coliform counts are often indicative of contamination by faecal waste, which suggest that the water might harbour public health pathogens (Getachew *et al.,* 2018).

Table 3: Total Coliform Count (TCC) of bacteria in well water samples collectedin the study area

Well Water sample	Total coliform count (TCC) (CFU/100 mL)				
	A	B	C	D	E
1	21	950	26	1200	1200
2	10	150	28	29	93
3	28	0	15	0	460
4	58	12	27	21	21
5	0	12	15	22	21
6	1200	22	0	29	0
Average*	**219.5^b**	**191^b**	**18.5^a**	**216.8^b**	**299.2^b**

**Values with similar alphabets are not significantly different using Tukey's HSD test (p=0.05)*

The phenotypic characterization and identification of bacterial isolates from well water samples collected in Ajaokuta Housing Estate, Kogi State, revealed the presence of prominent bacteria such as *Salmonella* sp., *Staphylococcus* sp., *Micrococcus* sp, *Bacillus* sp. and *Escherichia coli* (Table 4). The occurrence of bacterial isolates in well water samples collected from some selected residential areas in Ajaokuta Housing Estate, Kogi State is shown in Table 4. Among the bacterial isolates, *Bacillus* sp. occurred most, constituting almost half of the total bacterial isolates (47.13%) (Table 5) This high occurrence could be linked to the capacity of the bacterium to survive various environmental conditions. *S. aureus* occurred in four out of five sample locations accounting for approximately a quarter of the total isolates (22.98%). *Micrococcus* sp. was found in three locations, at a rate of 13.79% of the isolates. Finally, *E. coli* and *Salmonella* sp., both of which are intestinal pathogens and indicators of faecal contamination accounted for 4.60% each of the total isolates, with *E. coli* found in two locations and *Salmonella* in three locations (Table 5). Among the identified isolates, *E. coli,* a common indicator of faecal contamination of food and water, indicates that the well water might be exposed to contaminations directly or indirectly by human or animal waste. The detection of *S. aureus* and *Salmonella* sp. in the well water samples raised additional concerns about contamination from human and animal contacts or improper water handling. The three major human pathogens (*E. coli, S. aureus* and *Salmonella* sp.) recovered from the water samples raises concerns on the water safety and risk of diverse diseases of which these microbes have been implicated (Cabral, 2010; Wamyil *et al.,* 2023).

Table 4: Phenotypic Characterization and identification of bacterial isolates in well water samples collected in the study area

Parameters	**1**	**2**	**3**	**4**	**5**
Colonial Morphology	Colourless small, smooth, round colonies	Golden-yellow, smooth, convex, colonies	White, round Transparent shiny, colonies.	Medium, pale, smooth, round, raised colonies	White, opaque, Large, rough colonies
Grams stain	(-)	(+)	(-)	(+)	(+)
Shape/arrangement	Short rods, singly, paired	Clusters cocci/bunches	Singly, short paired chains	Singly cocci	Singly paired chains
Spore test	(-)	(-)	(-)	(-)	(+)
Catalase test	(+)	(+)	(-)	(+)	(+)
Oxidase test	(-)	(-)	(-)	(-)	(+)
Coagulase test	(-)	(+)	(-)	(-)	(-)
Motility test	(+)	(-)	(+)	(-)	(+)
Indole test	(+)	(-)	(-)	(-)	(+)
Methyl red	(+)	(-)	(+)	(-)	(-)
VP test	(-)	(-)	(-)	(+)	(-)
Citrate test	(-)	(+)	(+)	(+)	(+)
Urease test	(-)	(-)	(-)	(-)	(-)
Lactose test	(+)	(+)	(-)	(-)	(+)
Sucrose test	(+)	(+)	(-)	(-)	(+)
Glucose test	(+)	(+)	(-)	(+)	(+)
Mannitol test	(+)	(+)	(-)	(-)	(+)
Probable Organism	*Escherichia Coli*	*Staphylococcus aureus*	*Salmonella* sp.	*Micrococcus* sp.	*Bacillus* sp.

Key: (+): positive test result; (-): negative test result

These isolates are regarded as public health important pathogens because they are commonly implicated in food-borne diseases, with symptoms such as haemorrhage, vomiting, enteric fever, abdominal discomfort, fever, diarrhoea, and nausea, particularly among young children, elderly and immuno-suppressed persons, among others (Cabral, 2010; Elbehiry *et al.,* 2023). Mild to severe forms of gastrointestinal disorders have been reported among populations who consumed water with the presence of these isolates (Ashbolt, 2004; Cabral, 2010; Leonard *et al.,* 2015). Waterborne bacterial diseases accounted for over 20% of death reported in developing countries (Malik *et al.,* 2012). The well water samples also contained *Micrococcus* sp. and *Bacillus* sp, which are generally non-pathogenic but are major indicators of exposure of water to non-human environmental pollution. Though, these bacteria may not pose an immediate threat, their high level of occurrence points to the need for regular water quality monitoring and well maintenance to prevent more serious contamination and public health risk.

Table 5: The Occurrence of bacterial isolates in well water samples collected in the study area

Bacterial Isolates	**Sample location**					**Total (%)**
	A	**B**	**C**	**D**	**E**	
Escherichia coli	2	2	0	0	0	4 (4.60)
Salmonella sp.	2	0	2	0	0	4 (4.60)
Staphylococcu saureus	8	2	6	4	0	20 (22.98)
Micrococcus sp.	5	0	4	3	0	12 (13.79)
Bacillus sp.	10	8	12	4	7	41 (47.13)
Total (%)	**29 (33.33)**	**14 (16.09)**	**26 (29.88)**	**11 (12.64)**	**7 (8.05)**	**87**

Conclusion

In this study, the physico-chemical and bacteriological characteristics of well water from the Ajaokuta Housing Estate, Kogi State, Nigeria, was evaluated. Some of the physico-chemical parameters, particularly iron, total hardness, total alkalinity, manganese, and magnesium, were found to exceed WHO permissible limits in some samples. The high levels of iron, total hardness and alkalinity could lead to long-term health problems such as cardiovascular and reproductive disorders and scale build-up. The bacteriological analysis revealed that total viable counts (TVC) and total coliform counts (TCC) exceeded recommended levels in many samples. The presence of pathogenic bacteria like *Salmonella* sp., *Staphylococcus aureus* and *E. coli* poses serious risk waterborne diseases. Since there were no significant discrepancies in the physicochemical and bacteriological quality of the well across the different well samples, these findings suggest that well water in the study area is below WHO standard for portable water. Hence, a regular and proper thermal or chemical treatment of well water in the Ajaokuta Housing Estate is recommended to ensure safe drinking water for the community/environs and prevent waterborne diseases.

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Appendix:
ANOVA: Single Factor analysis of TVC

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
A	6	46	7.666667	61.06667
B	6	73	12.16667	175.7667
C	6	52	8.666667	63.06667
D	6	47	7.833333	23.36667
E	6	42	7	48.4

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	100.3333	4	25.08333	0.337444	0.850093	2.75871
Within Groups	1858.333	25	74.33333			
Total	1958.667	29				