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Assessment of Groundwater Quality in Hand-Dug Wells around Achievers University, Owo, Nigeria

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Abstract

The ease of getting clean water for domestic use is very challenging globally, particularly in the underdeveloped world, where groundwater is the main source of potable water. This study evaluates water quality from hand-dug wells around Achievers University Owo, Nigeria, to critically examine their suitability for domestic use. Ten water samples were collected from randomly selected wells and analyzed for physical and chemical parameters, which included pH, electrical conductivity, total dissolved solids (TDS), and concentrations of cations (sodium, magnesium, calcium, potassium) and anions (chloride, sulfate, nitrate, bicarbonate). The results were compared with the standards of the World Health Organization (WHO) and the Standard Organization of Nigeria (SON). Findings indicate that the water samples are slightly acidic to alkaline, with pH values ranging from 5.42 to 6.95. Concentrations of cations and anions were within permissible limits, except for localized variations in nitrate and bicarbonate levels. The results of ions showed that nitrate ranged from 4.19 to 25.11mgL^{-1}, chloride ranged from 10.6-36.58mgL^{-1} Nitrate ranged from 4.19-25.76mgL^{-1}, magnesium ranged from 0.43-1.19 mgL^{-1}, calcium ranged from 0.124-6.19mgL^{-1}, sodium ranged from 0.49-1.79mgL^{-1}. Piper's diagram revealed mixed water types with no dominant ion facies, reflecting the area's geological diversity. The majority of the samples fall under no dominant type. All the water that falls under the water facies of alkalis exceeds alkaline earth. The study concludes that while the groundwater quality generally meets WHO and SON standards, periodic monitoring and treatment are essential to mitigate contamination risks. Recommendations include improved sanitation practices, regular water treatment, and community awareness programs to ensure sustainable access to safe drinking water.

Keywords: Groundwater; Hand-dug wells; Hydrogeology; Nitrate; Owo.

1.0 Introduction

Water is considered the second most vital resource for living organisms, following air. Ensuring access to high-quality water is not only crucial for the survival of all life forms but also stands as one of the most pressing environmental challenges of the 21st century (Zeyneb, 2020). Despite that water supply is limited, it is made up of about 70% of the earth (Popoola, 2025, Omer, 2019,), and about 20% of the freshwater that is being utilized worldwide is obtained from the groundwater. A large number of cities worldwide are facing a crunch from water shortage (Nizel and Islam, 2015; WHO, 2017). The aquifers are usually recharged through effective rainfall, rivers, and their tributaries. The water in various aquifers is usually harnessed through construction wells or boreholes. The majority of these wells are not properly constructed and are sited near sources of pollution (Ocheri and Mile, 2010; Umoren *et al.,* 2024a). Lateritic soil can also provide a shield to prevent groundwater from contamination (Falade *et al.,* 2023). Substantial contaminants find their way into the groundwater through anthropogenic activities such as waste released from industries, urbanization, and inappropriate waste disposal have greatly compromised water quality, worsening the global water crisis and threatening ecosystems and human health (Onwuka, 2013; Muhammad *et al.,* 2011; Falade *et al.,* 2019; Famuyiwa, 2023). In many developing nations, including Nigeria, both surface water and groundwater face significant contamination risks due to unchecked industrial expansion, rapid urbanization, and the discharge of untreated waste from human activities. This has contributed to the steady decline in the quality of the groundwater (Umoren, 2024b; Tirkey, 2017; Adewumi *et al.* 2016). Owo has a moderate-high groundwater potential, and thirty percent of the wells within the study area are of low groundwater potential and are being affected by anthropogenic activities (Adewumi, and Anifowose, 2017).

The study focuses on the physicochemical properties of hand-dug well water around Achievers University, Owo, and Ondo State, Nigeria. The study aims to assess the electrical conductivity, pH, and ions present in the groundwater and compare them with the standardized values. This area depends heavily on groundwater for domestic and agricultural purposes, making it essential to assess the quality of this vital resource. Earlier studies have revealed that groundwater in Nigeria is often polluted with heavy metals, bacteria, and other pollutants, posing significant health risks to users (Agbozu and Ekweozor, 2007; Kumar, 2010).

1. Materials and methods

a. The study area

Owo is located at latitude 7°11'N of the equator and longitude 5°33'E of the Greenwich meridian. It is bounded by Emure-Ise Orun Local Government Area of Ekiti State to the north, Akure and Idanre to the east and south, respectively, while Ose Local Government Area forms the border to the west and part of the south. River Ogbese and River Ose form the natural boundaries between Owo and some of these neighboring local government areas. The establishment of institutions such as the Federal Medical Centre, Rufus Giwa Polytechnic, the State Technical College, and Achievers University has contributed to a rapid increase in population (Oyinloye and Tokunbo, 2013).

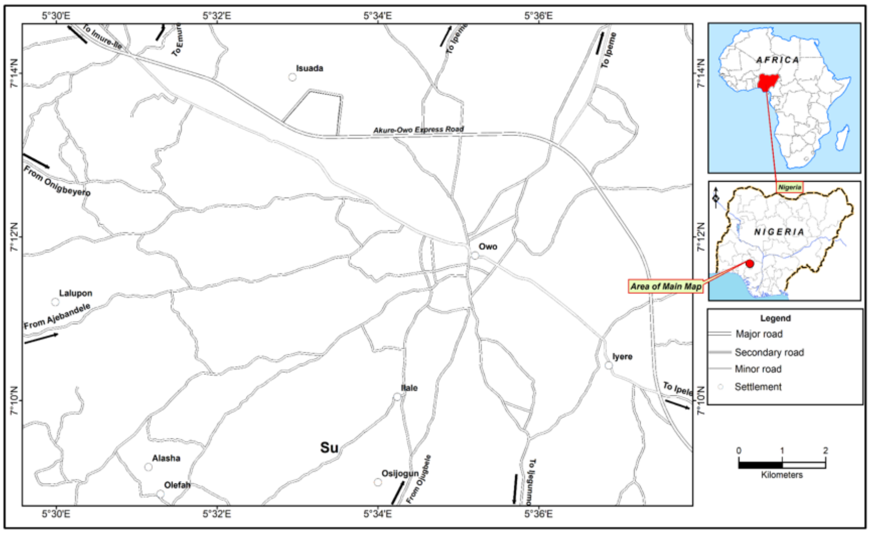

Figure 1: Location Map of Owo

2.2 Topography and drainage

The study area has a high topography, with elevations reaching 1,200 feet above sea level, which accounts for the ridges observed during the field study. In Owo township, the quartzite ridge goes from Emure-Owo (the

Western part of the study area) to Ipele-Owo (the Eastern part of the study area). This topography facilitates the flow of major rivers in the area. The area is characterized by a dendritic drainage pattern, which is geomorphologically controlled. The rivers that can be found in the area include Rivers Iporo, Ubeze, and Aisenwen, which flow from east to west and are main streams of the Ose River. Other important rivers include the River Ogbese, which courses from north to south, and the River Aisenwen, which runs from northeast to southwest. These rivers are generally perennial, while their tributaries are mostly seasonal, reaching maximum dryness during the peak of the dry season (Kumar, 2010; Maness, 2015).

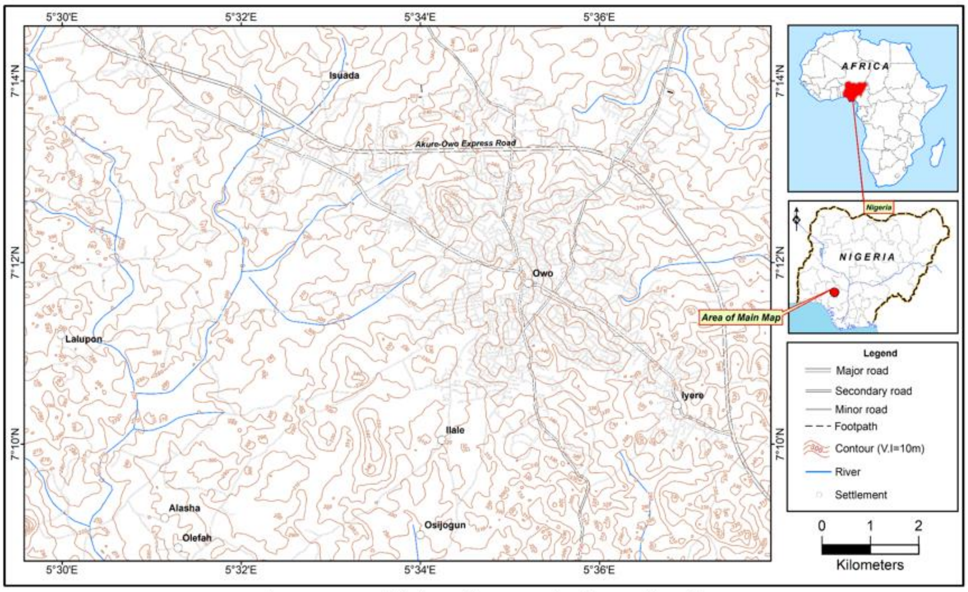

Figure 2: Topographical map of Owo

2.3 Geology of the study area

The study area can be found in the Pan-African mobile belt flanked by the West African and Congo cratons (Goudie, 2004; Seetharaman *et al.,* 2014). Nigeria's geology is composed of sedimentary and crystalline rocks, which occur in almost equal proportions. The Precambrian basement rocks in Nigeria are made up of the migmatite gneissic-quartzite complex, dating back to the Archean to Early Proterozoic era (2700–2000 Ma) (Anifowose and Borode, 2007). Other geological units in the area include the NE-SW trending schist belts, which are prominent in the western half of the country, and the granitoid plutons of the older granite suite, dating to the Late Proterozoic to Early Phanerozoic era (750–450 Ma). The main lithologies in the southwestern part of Nigeria include amphibolite, migmatite gneisses, granites, and pegmatites. Other rock units that are of significant consideration are the schists, which consist of biotite schist, quartzite schist, talc-tremolite schist, and muscovite schist. Crystalline rocks intrude into these schistose rocks (Akinola and Adeyemi, 2015). The rocks that are common in the area are quartzite, migmatite, and schist. The majority of the rocks are trending in the ENE-WSW (Adewumi *et al.* 2017). The quartzite and schist are found predominantly in Owo and Ipele, while Amurin-Owo, Oba-Akoko, Ogbese, Uso-Owo, and Epore are positioned on migmatite. About 60% of the study area is covered by migmatite gneiss and quartzite. Areas with granite have low groundwater potential, while most wells in the study area are located in zones of moderate to high groundwater potential. However, basement aquifers in the area occur at shallow depths and may be susceptible to contamination (Omosuyi *et al.* 2003; Falowo, 2016).

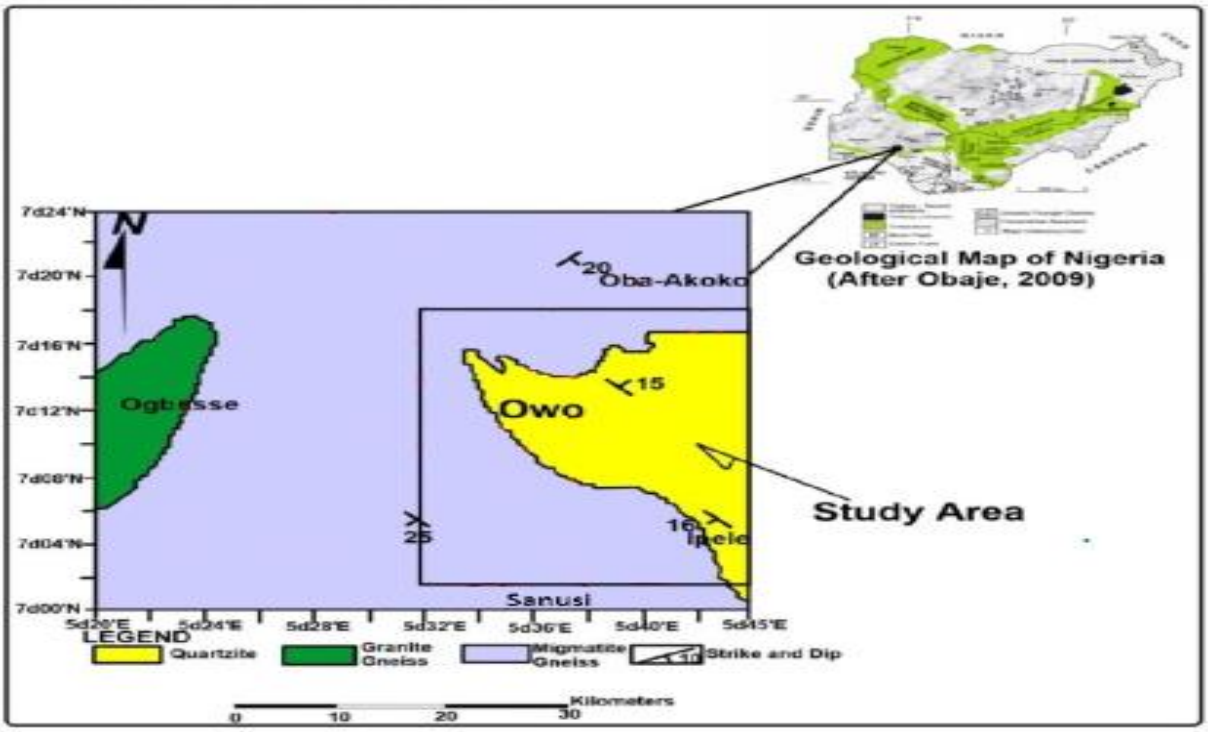

Figure 3: Geology of the Study Area (After Adewumi *et al.* 2018)

2.4 Sampling and preparation

Ten (10) water samples were collected from various wells located around Achievers University, Owo (Figure 4). The samples were taken in the beginning of raining season, in the month of April. Before sampling, all sample bottles were properly labeled to ensure accurate identification. To prevent contamination, the bottles were washed with the same well water being sampled. Additionally, hands were washed with the sample water to avoid cross-contamination from previously sampled wells. The bottle caps were also rinsed with the sample water and securely tightened to prevent leakage.

During the sampling process, detailed documentation was maintained to record essential information, including the structural characteristics of the wells (e.g., whether they were cased or uncased). After collection, the 10 water samples were immediately placed on ice to inhibit flocculation and bacterial growth. They were then transported to the laboratory in Akure within 24 hours for further analysis.

2.5 Analytical Methods

The major elements analyzed in the study included potassium (K^+), magnesium (Mg^{2+}), sodium (Na^+), calcium (Ca^{2+}), nitrate (NO_3^-), chloride (Cl^-), sulfate (SO_4^{2-}), bicarbonate (HCO_3^-), and carbonate (CO_3^{2-}).

2.6 Chloride Ion Concentration

The chloride ion concentration was determined using the silver nitrate titrimetric method. In this process, a 0.014N silver nitrate ($AgNO_3$) solution was titrated against the water sample. Two drops of potassium dichromate (K_2CrO_4) were added to the sample as an indicator. The titration endpoint was indicated by a brownish coloration, signaling the completion of the reaction.

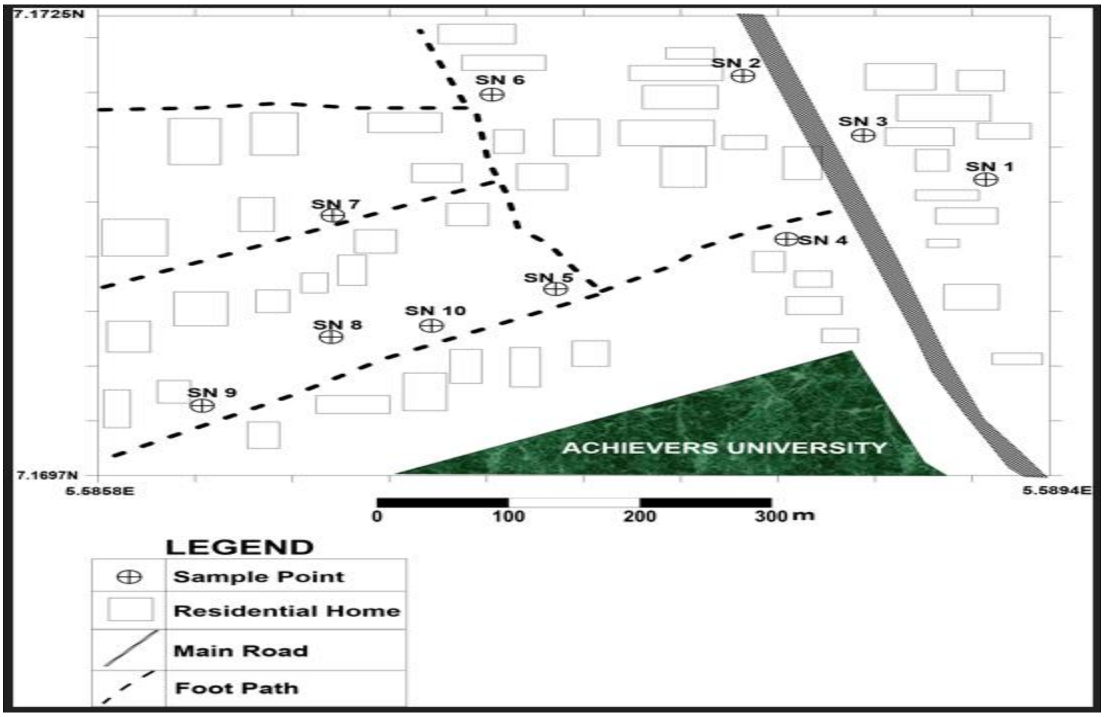

Figure 4: Sample location map

2.7 Spectrophotometric Analysis

The concentrations of most anions were determined using spectrophotometry. The test manager of the spectrophotometer was used to select the parameters for analysis. For each test, two 10 mL sample cells were prepared. One cell was filled with the sample, and a test reagent (in the form of a powder pillow) was added to it. The mixture was shaken thoroughly, and the reaction time was monitored at intervals of 0, 5, and 10 minutes.

2.8 Cation Concentration

The concentrations of cations (K^+, Mg^{2+}, Na^+, and Ca^{2+}) were determined using the flame photometry method. This technique measures the intensity of light emitted by the cations when they are excited in a flame, allowing for the accurate quantification of their concentrations.

3.0 Results and discussions

3.1 Physical parameters

The conductivity ranges from 140 to 528Ns/cm, with the annual mean of 334, compared to the SON standard limit (1000Ns/cm). All the samples fell within the desired SON standards. High conductivity in any sample might be from metallic ore bodies in the study area. Low EC indicates low levels of dissolved ions, suggesting pure or minimally contaminated water (e.g., distilled water or rainwater). High EC indicates high levels of dissolved ions, which may result from natural sources (e.g., mineral dissolution) or anthropogenic activities (e.g., industrial discharge, agricultural runoff) (WHO, 2017). It can stress aquatic organisms by disrupting osmoregulation (the balance of water and salts in their bodies). This can affect fish, invertebrates, and plants, leading to reduced biodiversity (SON, 2007). Low EC may indicate insufficient mineral content, which can limit the growth of aquatic organisms that rely on dissolved ions for nutrients (Wetzel, 2001).

The pH value ranges from 5.42 – 6.95 with a mean of 6.185, compared with the World Health Organization standard limits, which range from 6.50 – 9.50. About 7(seven) locations have water samples that range below the maximum permissible by WHO standards, except A3, A4, and A8. The study area is found to be slightly acidic to Alkaline. The total dissolved solids in the sampled wells range from 69.00 – 259.0mg/L^{-1}, though the World Health Organization standard limit is 500mgL^{-1}. All the water samples fell within the WHO and SON standard limits, which showed that the well water is acceptable and recommended for human consumption.

3.2 Major Ions

The HCO_3^- content in the hand-dug well water varies from 22.60mgL^{-1} to 92.00mgL^{-1}, with an average of 57.00mgL^{-1}. Location A3 (around Achievers) has the highest value, whereas location A9 has the least value of HCO_3^-. The permitted quantity of bicarbonate in hand-dug well water is 150 mgL^{-1} under SON and 300mgL^{-1} under WHO Na^+ concentration ranges between 0.495 mgL^{-1} and 1.779 mgL^{-1}. Location A7 has the highest amount of Na at 1.779mgL^{-1}, whereas A2 contains the lowest amount of sodium. The acceptable level of Na^+ in hand-dug well water suited for consumption is 200mgL^{-1} by WHO and 200 for SON Magnesium concentrations in the hand-dug well water sample varied from 0.438 mgL^{-1}. to 1.197mgL^{-1}. The content of magnesium is lowest at location A1 and highest at location A7. The WHO states that 50mgL^{-1} of magnesium per liter and 20mgL^{-1} of magnesium are suitable for S.O.N (Table 1).

The values varied from 2.379mgL^{-1} to 6.196mgL^{-1}. The content of calcium is lowest in sample A6 and highest in sample A2. The WHO recommended 75mgL^{-1} as the maximum permissible content of calcium.
Potassium is essential for the growth and well-being of living Organisms. It regulates the acid-base balance. Sodium is another abundant compound that is very soluble. A high level of sodium intake can lead to high blood pressure, heart disease, and stroke (Amu *et al.,* 2021) though it falls within the WHO standard limit. Hence, a high concentration of Sodium is detrimental to consumers. Thus, the recommended concentration of sodium in drinking water is 200mgL^{-1}. Also, excessive concentration of magnesium is undesirable in domestic water because it has cathartic and direct effects when associated with the level of Sulphate. Magnesium concentration in samples falls within the World Health Organization guidelines (20mgL^{-1}). The overall mean and average value of the parameters are summarized in Table 2, the sodium ion has the minimum value, and bicarbonate has the highest value.

3.3 Nitrate

The result of nitrate amount found in the well water ranges from 4.19 to 25.76 mgL^{-1}; location A3 (Idasen Ute 3) has the highest concentration of nitrate, while location A10 has the lowest (Table 1). This means it is suitable for drinking, agriculture, and other industrial uses. The level of nitrate is not higher than the recommended limit by WHO and SON (50mgL^{-1}), but the concentration is high in samples A3 and A6, which are 25.76 and 25.11 mgL$^{-1,}$ respectively compare to other location. The increase might be to anthropogenic activities like farming and contaminants from sewage (David and Belen, 2023). High level of nitrate has various adverse effects on human health, which range from infant methaemoglobinaemia, hypertension, the 'hot dog headache', cancers, and other adverse effects such as birth defects (congenital malformations) and spontaneous abortions (Adelana and Olasehinde, 2003).

3.4 Piper's diagram

A piper diagram is a graph that displays the chemistry of water samples. The ternary plot separates the cations and anions. The highest point of the cation plot Ca^{2+}, Mg^+, Na^+, K^+. The apexes of the anion plot are SO_4^{2-}, Cl^-, and CO_3^- plus HCO_3^- ions. The two ternary plots are then projected onto a diamond. The diamond is a matrix transformation of a graph of the anions (SO_4^{2-} + Cl^- total anions) and cations (Na^+ + K^+ total cations) (Piper, 1944). According to t, the cation represents the relative proportion of major cations such as Ca^{2+}, $Mg^{+,}$ and (Na^+ + K^+). Each corner of the triangle indicates the relative percentage. The anions represent the relative proportion of major anions such as chloride, sulfate, and biocarbonate plus carbonate (HCO_3^- + CO_3^-). It is similar to the diagram; each corner represents 100% of one anion. The diamond-shaped plot combines the information from both ternary diagrams. Each point in the diagram-shaped plot represents overall water chemistry for the comparison and classification of different water types, calcium types, and bicarbonate types. The majority of the samples fall under no dominant type.

3.5 Hydrogeochemical facies

The dominance of alkali elements and alkali earth element, which are potassium, sodium, and calcium, in the groundwater is associated with weathering and dissolving of the underlying rock that is mostly migmatite (Figure 5). The feldspars have a high content of calcium, sodium, and potassium (Akanbi, 2016). This gives a clue that anionic facies such as bicarbonate and carbonate may be derived from the dissolution of CO_2 in the atmosphere and within the soil zone. Usually, limestone and dolomite, which are carbonate rocks, are the source of bicarbonate and carbonate. Although the study area is a crystalline area, carbonate and bicarbonate are likely to be sources from precipitation. Nitrate abundance in the area cannot be sourced from weathering activities of rock, but from anthropogenic and biogenic.

3.6 Water Quality Index

The water quality index method categorizes the water quality based on the degree of purity using the most regularly measured water quality variables. Many scientists have extensively used this method (Balan *et al.*, 2012; Chauhan and Singh, 2010). The summary of the water quality index is represented in Table 3. Also, the result of WQI obtained from the study area shows that the water is good for drinking (Table 4). Sample A10 is rate as best with WQI of 13.85, while sample A3 has the WQI of 34.07 which is the worst WQI in the study area.

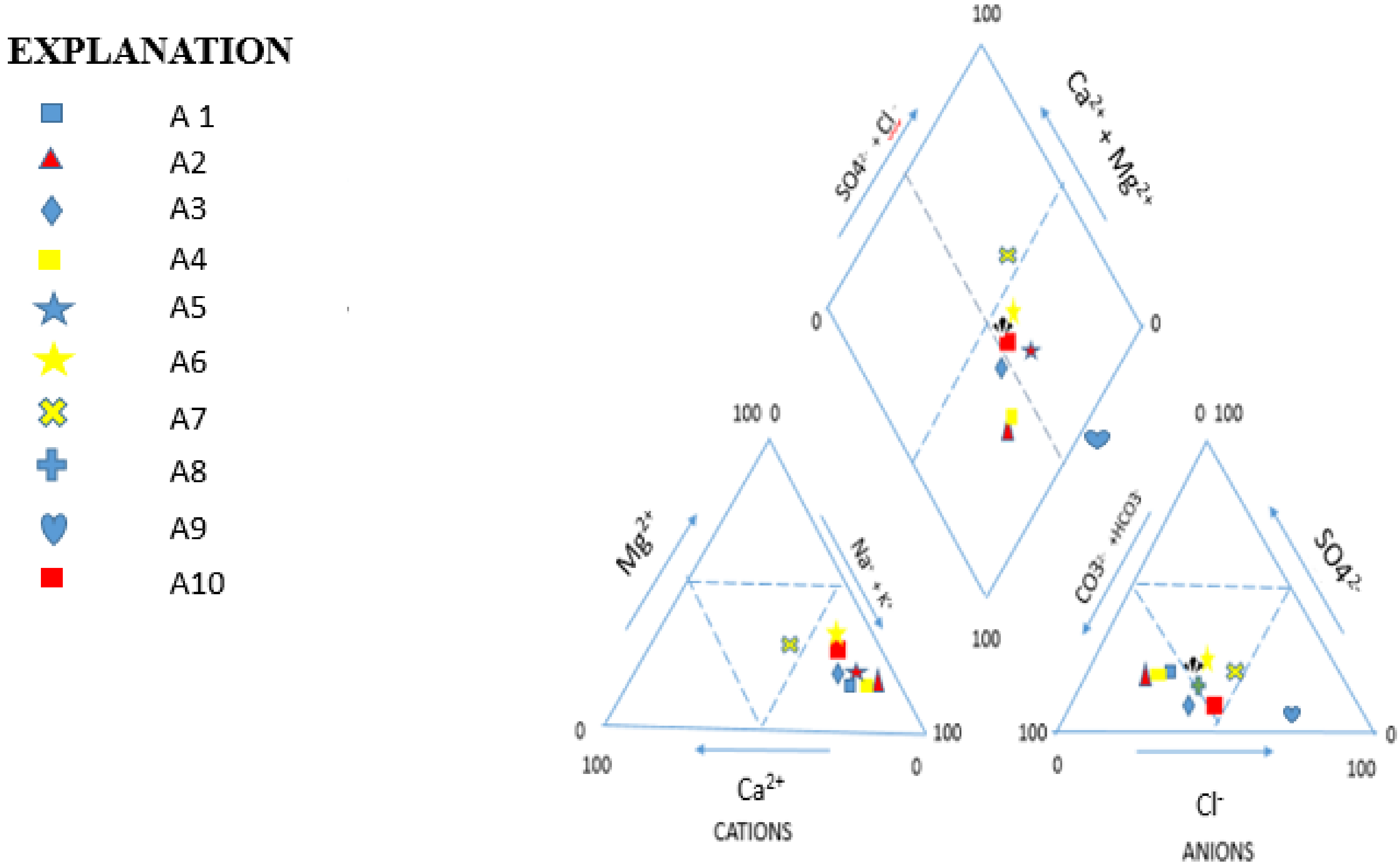

Figure 5: Trilinear diagram of chemical data for all sampled wells

Table 1: The Well Inventory and the Analyzed Major Ion Concentration

	Physical Properties					Anions				Cations					
Sample ID	**TDS (mgL^{-1})**	**Temp (^oC)**	**Well depth (m)**	**E/C (µS/cm)**	**pH**	**Cl^- (mgL^{-1})**	**SO_4^{2-} (mgL^{-1})**	**NO_3^{2-} (mgL^{-1})**	**HCO_3^- (mgL^{-1})**	**Ca^{2+} (mgL^{-1})**	**Mg^{2+} (mgL^{-1})**	**K^+ (mgL^{-1})**	**Na^+ (mgL^{-1})**	**Longitude**	**Latitude**
A1	113	30.0	>20	235	6.30	12.80	14.86	12.52	50.00	2.82	0.43	0.86	0.49	N 7 10 17.61	E 5 35 20.32
A2	188	29.6	>20	377	6.31	10.97	14.29	15.65	60.00	6.19	0.66	1.01	0.49	N 7 10 19.96	E 5 35 17.51
A3	259	28.5	>20	528	6.56	36.58	13.71	25.76	92.00	5.04	0.96	1.19	1.14	N 7 10 18.53	E 5 35 19.10
A4	195	29.4	>20	391	6.95	17.56	21.14	19.41	71.50	5.80	0.70	0.92	0.53	N 7 10 16.12	E 5 35 18.12
A5	116	39.0	>20	315	6.18	21.95	20.08	22.31	42.00	3.75	0.62	0.96	0.61	N 7 10 15.08	E 5 36 15.08
A6	119	28.9	>20	395	6.12	23.77	23.17	25.11	45.00	2.37	0.91	1.28	0.54	N 7 10 19.31	E 5 35 14. 31
A7	117	30.0	>20	330	5.58	36.58	22.29	7.95	42.00	2.78	1.19	0.95	1.79	N 7 10 17.22	E 5 36 12.78
A8	69	39.8	>20	140	6.90	11.70	7.36	8.32	25.50	3.07	1.03	0.94	0.56	N 7 10 13.94	E 5 35 12.59
A9	86	29.3	>20		6.26	10.60	8.86	5.04	22.60	0.124	0.99	0.89	0.52	N 7 10 12.09	E 5 35 11. 25
A10	81	28.9	>20	160	5.42	18.29	4.13	4.19	30.00	3.50	1.16	0.93	0.68	N 7 10 14.01	E 5 35 13.93
WHO 2017	600		>20	1500	NHC	NHC	NHC	50	100	75	250-300		200		
SON 2007	600		>20	1000-1500	6.5-8.5	250	100	50					200		

*NHC:Not of health concern at levels found in natural water

Table 2: Statistical results of the parameters

Parameter	Mean	Standard Deviation	Minimum	Maximum	Range
Cl^- (mgL^{-1})	20.18	9.40	10.60	36.58	25.98
SO_4^{2-} (mgL^{-1})	14.87	6.36	4.13	23.17	19.04
NO_3^- (mgL^{-1})	14.63	8.41	4.19	25.76	21.57
HCO_3^-(mgL^{-1})	48.06	20.41	22.60	92.00	69.40
Ca^{2+} (mgL^{-1})	3.55	1.77	0.124	6.19	6.07
Mg^{2+} (mgL^{-1})	0.85	0.25	0.43	1.19	0.76
K^+ (mgL^{-1})	0.99	0.13	0.86	1.28	0.42
Na^+ (mgL^{-1})	0.71	0.40	0.49	1.79	1.30

Table 3: Water Quality Index and Respective Water Type (Nusrat *et al.,* 2020).

S/N	Range	Types of water
1	< 50	Excellent
2	50-100	Good
3	100-200	Poor
4	200-300	Very Poor
5	>300	Unsuitable for drinking

Table 4: Water Quality Index of the Study Area

Sample	WQI	Water Quality Grade
A1	18.36	Excellent
A2	22.19	Excellent
A3	34.07	Good
A4	25.88	Excellent
A5	20.14	Excellent
A6	28.45	Good
A7	31.92	Good
A8	16.53	Excellent
A9	14.27	Excellent
A10	13.85	Excellent

Mean WQI= 22.57 (Excellent overall)

4.0 Conclusions

This study highlights the critical importance of groundwater quality assessment in ensuring safe drinking water for communities reliant on hand-dug wells. The physicochemical analysis of water samples from wells around Achievers University, Owo, revealed that the water is generally suitable for human consumption; each sample was within limits for every parameter, with most parameters falling within WHO and SON standards. However, localized contamination, particularly nitrate levels in samples A3 and A6, which are 25.70, and 25.11 mgL^{-1}, respectively. This underscores the need for regular monitoring and intervention to prevent high blood pressure and diseases that are associated with high concentrations of nitrate. The study emphasizes the role of geological formations and anthropogenic activities in influencing groundwater quality. To safeguard public health, it is recommended that wells be treated periodically, covered to prevent contamination, and situated away from potential pollution sources. Additionally, community education on proper waste disposal and sanitation practices is crucial. By addressing these issues, stakeholders can ensure the sustainability of groundwater resources and increase access to clean drinking water in the region.

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