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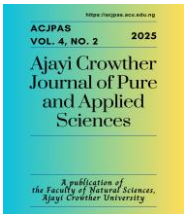
ACJPAS
VOL. 4, NO. 2
2025

Ajayi Crowther Journal of Pure and Applied Sciences

A publication of the Faculty of Natural Sciences, Ajayi Crowther University

Ajayi Crowther Journal of Pure and Applied Sciences
https://acjpas.acu.edu.ng

Ajayi Crowther J. Pure Appl. Sci. 2025, 4(2), pp. 7-14.
https://doi.org/10.56534/acjpas.2025.04.02.02



Article

Hydro-geochemical Study of Groundwater in Ajegunle Area in Oyo Town, Southwestern Nigeria

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Article history: *received, Feb. 5, 2025; revised, Mar. 10, 2025; accepted, Mar. 19, 2025; published, Apr. 8, 2025*

Abstract

The demand for groundwater is high due to its availability and relative purity and it is the major source of fresh water in Ajegunle area in Oyo town, southwestern Nigeria. In the light of this, hydrochemical studies was carried out by analysing the major ions from representative seventeen (17) samples collected from selected hand-dug wells across the study area. The results showed that the pH ranged from 5.6 - 8.0 with an average of 6.37 , total dissolved solids (TDS) was between 40 and 480 mg/L with an average of 278.2mg/L, and electrical conductivity (EC) from 90us/m to 970us/m with an average of 565.8us/cm. Concentration of major ions in mg/L showed that calcium ranged from 16.00 to 62.03; magnesium, 13.73 - 34.32; sodium, 10.02 - 15.01; potassium ranges ranged from 7.11 - 9.96 ; bicarbonate 14.00 - 260.00, sulphate 10.00 - 40.00; nitrate 0.83- 8.32. From average concentrations, the order of ionic dominance was $Ca^{2+} > Mg^{2+} > Na^{+} > K^{+}$ for cations and $HCO_3^{-} > Cl^{-} > SO_4^{2-} > NO_3$ for anions. From Piper plot the hydrochemical facies of sampled water is mainly Ca-HCO_3. Though, the concentrations of the analysed ions as well as the ancillary parameters were not of health concern, there is need for further studies in assessing the microbial counts as well as trace elements concentration before the water can be said to be suitable for drinking purpose.

Keywords: Groundwater, Hand-dug wells, Major-ions, Facies.

1. Introduction

Communities in most developing nations rely on groundwater due to its renewability and relative availability when compared to other fresh water sources. This is more so, in developing communities that are not connected to piped bornewater supply [1,2]. Worldwide, about 2.5 billion people rely on groundwater to satisfy their daily water needs [3] and it is the source of drinking water for human and plant irrigation- for as much as 50% of global human population and 43% of all of water used for irrigation is groundwater [4,5]. However, the utilization of groundwater can be limited by its quality. The major chemical constituents of groundwater are ions of major elements in the crust including calcium, magnesium, sodium, potassium and those of bicarbonate, carbonate, chloride, sulphate and nitrate. These ions are the major dominant components and are the main dissolved solids in groundwater. Some dissolved solids are hazardous in water but most major ions serve as dietary mineral to human [6]. However, the concentrations of these ions are also of importance in water, because concentrations major ions may pose undesirable properties and become harmful to man as

well. This is particularly possible when groundwater has been in contact with rock over a long period of time.

In Ajegunle area of Oyo town located in the southwestern (SW) region of Nigeria, there is need for hydro-chemical assessment of shallow groundwater from the numerous house-hold hand-dug wells to ensure their suitability for drinking purpose. The study area is located within latitude N7°49′20′′ to N7°51′20′′ and longitude E 3°55′40′′ to E 3°57′20′′E (Figure 1.) in Atiba local government area. Catchment communities within the study area are Boroboro, Okoro bakery, Murikas, Oyekola street, Obadokun street, Oyeronke street, Onilada street, Oluleye bakery, Ajebe street, Tafa Street, Adewale street, Olodogbo street, and Iyamayowa. These areas are not connected to any pipe-borne water supply and individual households rely on groundwater tapped from mostly shallow depths hand-dug wells. Ajegunle area lies within the tropical rain forest though in recent years, Oyo town region and environs are now tending to derived savannah forest. The mean annual temperature ranges within 25°C to 30°C.

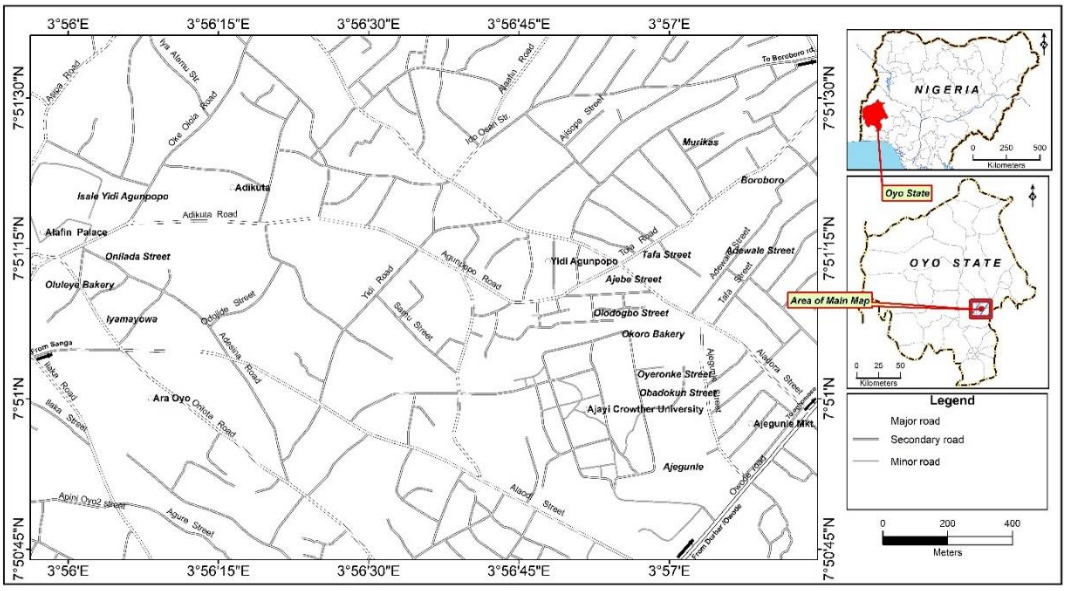

Figure 1: Location map of the study area.

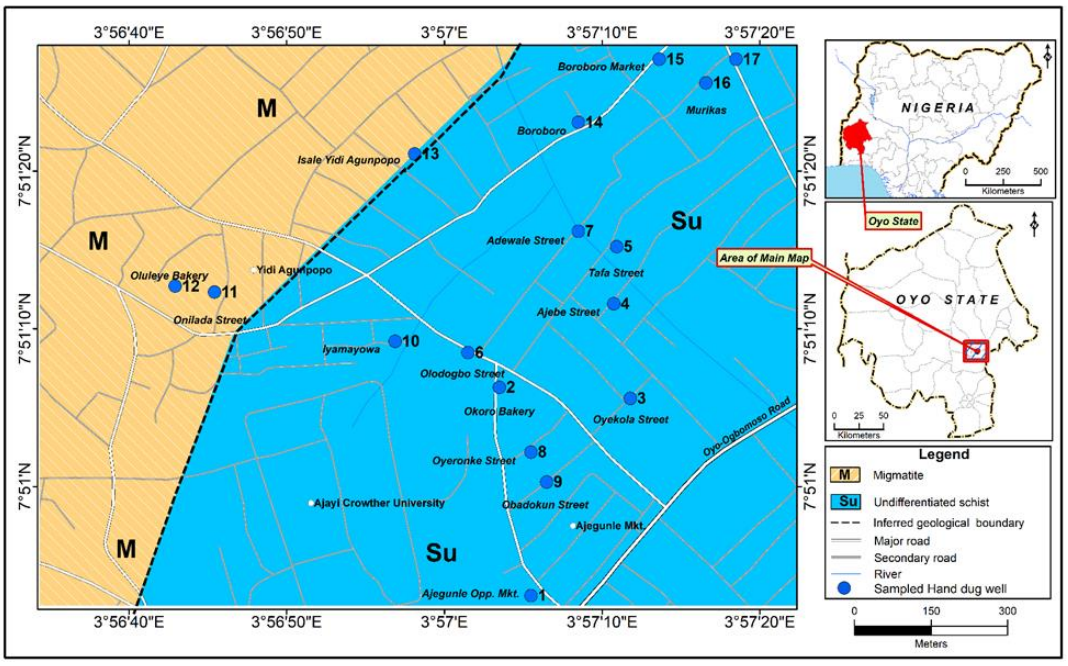

Figure 2: Geological map with locations of sampled hand-dug wells (after NGSA, 2009)

Oyo town lies within the Precambrian Basement complex of Southwestern (SW) Nigeria predominantly made up of undifferentiated schist and migmatite [7] Figure 2). Schist is a metamorphic rock with foliated banded texture of medium grained minerals such as feldspar, quartz and mica. Migmatite is a mixed rock of igneous and metamorphic components. There is presence of light coloured quartz and feldspar minerals of typical felsic igneous rock mixed with older metamorphic rock that are normally banded and consists of darker minerals such as biotite and amphibole. Migmatite underlie the western portion of the study area Figure 2.

2. Methodology

2.1 Field sampling and well inventories

A total number of seventeen (17) hand-dug wells were sampled and water samples were collected in newly sterilized 1-liter bottles. The bottles were labelled and sealed, corked and were transported immediately to laboratory for chemical analyses. Physico-chemical parameters such as pH, electrical conductivity (EC) and total dissolved solids (TDS) were measured and recorded in the field using digital meter. Also, the hygienic conditions of the wells and information regarding treatment history were collated. The total depth of the wells and water table were also measured in metric scale using water meter sounder. The coordinates of sampled wells were measured with digital meter and are plotted on geological map (Fig. 2).

2.2 Laboratory Analyses

Water samples were analysed for major ions at Temsol Consult Limited laboratory in Ibadan. The analyzed cations were calcium (Ca^{2+}), magnesium (Mg^{2+}), potassium (K^{+}), sodium (Na^{2+}) and for anions-bicarbonate (HCO_3^{-}), sulphate (SO_4^{2-}), Chloride (Cl^{-}) and nitrate (NO_3^{-}). The cations were analysed using flame photometry method. The procedure makes use of a hose to allow aspiration of the sample through flame, which is calibrated by series of known standard of the parameters. The concentration of the tested parameters is displayed on the photometer screen. Apart from chloride, other anions concentrations were determined by spectrophotometer. 10ml samples cells were filled with the samples that will be tested, to the samples in the cell 1 pillow of test parameter was added to one of the samples and shaken. Chloride concentration was determined with titrimetric method using 2 drops of potassium dichromitate (K_2CrO) indication to each water sample in a conical flask titrate you with Silver Nitrate (0.0014 AgN06).

2.3 Data Evaluation

Field data were processed and statistical evaluations were done using Microsoft office tools. Graphs such as charts were obtained with Microsoft Excel. The coordinates were geo-referenced and imposed on location and geological maps with ArcGIS software. Chemical plots expressing dominance ionic parameters were done using Piper/Trilinear plots. The results of the laboratory analyses of major ions obtained in mg/L are converted to milliequivalent per litre (meq/L). These values are then added up under cations and anions to obtained the relative percentages of each ion in water. These percentage values are then plotted on Piper plot which is a graphical representation used in geochemistry to display the relative proportions of three major components in a chemical composition; namely, cation and anion triangular plots as the bottom plots and the upper central diamond shaped plot which is the combinations of all ions concentrations in each water sample. From the plots, water samples from all hand-dug wells are represented and the spread of the ionic concentrations are graphically represented on the plots. The central field represents the total ion concentration and the mixture of ions. The point where the sample is plotted display the dominant ions and the water type based on dominant ions in water in each sample. The spread and the variations in the dominant major ions based on concentration levels in all the water samples (from the hand-dug wells) are then represented diagrammatically in the diamond shaped plots. Also, the dominant cations and anions are known.

3. Results and Discussion

The results of physico-chemical parameters measured in the field, well inventories including well elevation, well depth and treatment history are presented in Table 1. Also, the results of major ion concentration are presented along with other parameters in Table 1. The statistical summary of the measured and analysed parameters are presented along with the guideline limits of Nigerian industrial standards [8] and world health organization [9] in Table 2.

Table 1: Results of Physico-chemical parameters, well inventories and major ions concentrations of the water samples

			Physico-chemical parameters and well inventories							Major ions concentrations in mg/L							
S/N	Sample No	Location	pH	EC	TDS mg/L	TEMP °C	Elevation m	Well Depth m	Treatment	Ca^{2+}	Mg^{2+}	Na^{+}	K^{+}	HCO_3^{-}	SO_4^{2-}	Cl^{-}	NO_3^{-}
1.	AJ01	Ajegunle	6.3	480	230	28°C	309	6.8	Unknown	48.62	23.17	11.01	9.02	208	21	42.99	3.92
2.	AJ02	Okoro	7.1	970	480	28°C	292	7.6	Untreated	52.80	19.45	11.82	10.36	194	14	48.48	3.72
3.	AJ03	Oyekola	7.1	760	370	29°C	292	5.4	Untreated	64.00	34.32	14.08	10.11	260	40	60.70	8.32
4.	AJ04	Ajebe	7.4	460	230	28°C	283	6.3	Untreated	60.11	22.88	15.01	10.02	240	28	42.60	2.36
5.	AJ05	Tafa	7.3	580	290	28°C	280	4.3	Untreated	54.40	20.02	10.32	7.91	206	24	40.47	4.32
6	AJ06	Olodogbo	6.7	360	180	29°C	292	7.7	Untreated	50.40	22.88	10.96	7.11	200	18	49.69	3.04
7.	AJ07	Adewale	6.7	180	90	29°C	280	5.3	Untreated	52.03	19.42	10.99	8.67	200	20	42.61	2.96
8.	AJ08	Oyeronke	7.3	780	390	28°C	304	11.5	Untreated	56.00	20.02	12.96	10.12	200	22	53.25	5.36
9.	AJ09	Obadokun	6.8	780	390	29°C	305	10.4	Untreated	56.80	18.88	11.24	8.70	202	22	47.25	3.41
10.	AJ10	Iyamayowa	6.6	610	300	30°C	294	5.2	Untreated	60.00	18.89	14.12	9.26	224	26	42.60	4.38
11.	AJ11	Onilada	6.3	480	240	30°C	309	9.2	Untreated	53.61	18.87	12.49	9.63	198	24	47.93	3.81
12.	AJ12	Oluleye	5.6	690	340	29°C	316	10.8	Untreated	48.00	13.73	10.84	7.36	140	10	5.50	0.83
13.	AJ13	Isaale yidi	6.9	600	300	29°C	298	3.9	Untreated	56,41	28.89	10.82	7.93	240	30	46.15	4.62
14.	AJ14	Boroboro 1	6.9	890	440	32°C	286	3.2	Untreated	48.26	27.68	10.22	8.31	222	32	49.67	3.49
15.	AJ15	Boroboro 2	8.0	790	360	30°C	290	4.4	Untreated	55.84	18.42	11.04	8.62	206	24	47.15	3.48
16.	AJ16	Murikas	5.9	120	60	29°C	299	8.2	Untreated	56.81	18.30	11.18	8.69	200	20	53.25	3.35
17.	AJ17	Boroboro 3	6.1	90	40	29°C	299	6.9	Treated	50.12	18.03	12.02	9.96	198	16	44.48	3.65

Table 2: Statistical summary of parameters and drinking water guidelines

Parameters	Minimum	Maximum	Mean	Std. Dev.	Drinking water standards		Health effect on human
					NIS (2007)	WHO (2017)	
pH	5.6	8.0	6.76	0.60	6.5 – 8.5	-	Not Pertinent
EC	90	970	565.88	263.30	1500	1500	Not pertinent
TDS (mg/L)	40	480	278.24	129.29	500	600	Unpalatable taste
Temperature (^{0}C)	28	32	29.06	1.03	NHC*	NHC	Not pertinent
Elevation (m)	280	316	295.76	10.53	-	-	Not pertinent
Well Depth (m)	3.2	11.50	6.89	2.51	-	-	Not pertinent
Ca^{2+} (mg/L)	48	64	54.37	4.55	-	2500	Kidney stone formation
Mg^{2+} (mg/L)	13.73	34.32	21.40	4.93	-	250 - 350	Osmotic Diarrhea
Na^{+} (mg/L)	10.22	15.01	11.83	1.43	200	200	Unacceptable taste
K^{+} (mg/L)	7.11	10.36	8.93	1.01	NHC	3000	Not pertinent
HCO_3^{-} (mg/L)	140	260	208.12	25.65	NHC	100	Not pertinent
SO_4^{2-} (mg/L)	10	40	23.00	7.09	100	500	Laxative effect
Cl- (mg/L)	5.5	60.70	44.99	11.35	250	250	Methemoglobinemia in infants
NO_3^{-} (mg/L)	0.83	8.32	3.82	1.52	50	50	Detestable taste

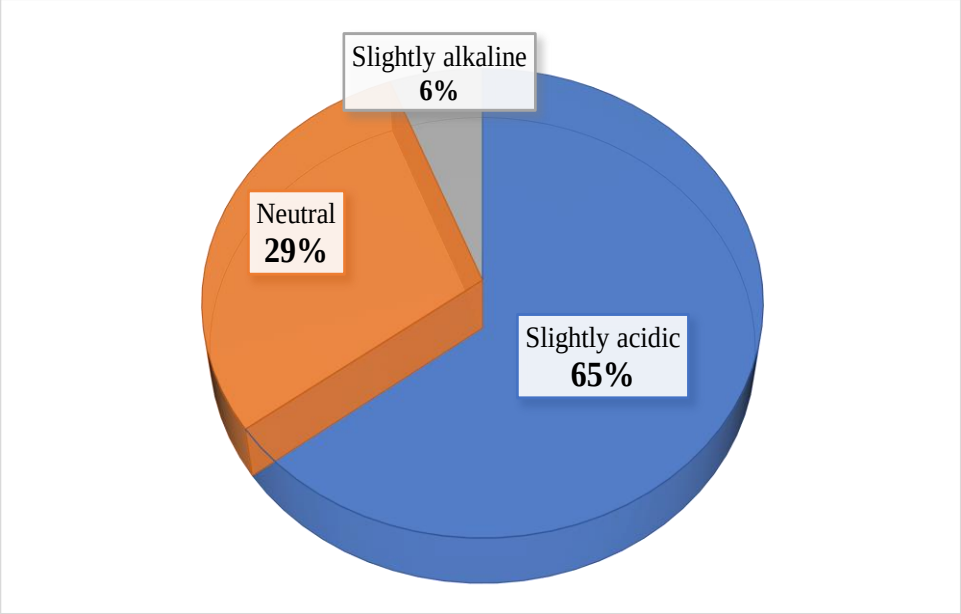

Figure 3: Water classification based on pH values

3.1 Physio-chemical parameters and Well inventories

The analysed chemical parameters are taken to represent the natural concentrations of groundwater in the wells since almost all the sampled hand-dug wells have not been treated in recent times. The depths of the sampled wells were between 3.2 to 11.5 m with an average of 6.89 m. These are shallow wells that are susceptible to pollution from the surface environment and through direct recharge [10].

The pH of the study area is high ranging from 5.6 to 8.0 mg/L (avg. 6.37 mg/L). Water with pH of 7 are neutral, whereas those with pH less than 7 are regarded as being acidic while those with greater than 7 are alkaline in state. From the frequency of classification based on pH values presented in Figure 3, the groundwater is classified as slightly acidic to neutral.

Total dissolved solids (TDS) which is the degree of ionic concentration in water is less than 100 mg/L in all samples which showed that the water is fresh [11]. The TDS was between 40 and 480 mg/L with an average of 278 mg/L. From this ionic concentration, the degree of mineral dissociation is low typical of water in crystalline rock terrains. Also, the water is not only fresh but suitable for consumption based on guidelines for drinking water regarding TDS [8,9].

3.2 Ionic Dissolution: Cations

Calcium is the most abundant cations on the earth crust as a result of cation exchange process and its mobility in water. Even, from the present work calcium has higher concentrations than other analysed cations. The concentration of calcium ranged from 48 – 64 mg/L (avg. 54.37 mg/L). The location with the highest calcium ionic concentration is at Oyekola AJ03. Though, calcium is tolerable and of good health benefit to man, ingestion of calcium in excess of 2500 mg/L in drinking water could be injurious to the kidney (Table 2).

Magnesium is another divalent ion in water. Magnesium ionic concentration was 13.73 to 34.32 mg/L with an average of 21.40 mg/L**.** The location with the highest magnesium concentration is also at Oyekola AJ03. For water potability, the recommended permissible limit for magnesium is 250 mg/L.

Sodium occurs in water from dissociation of weathered plagioclase feldspar and atmospheric dust from rain water. The concentration of sodium in the water samples ranged from 10.22 to 15.01 mg/L with an average value of 11.83 mg/L. The location with the highest sodium concentration is AJ04 at Ajebe street.

The recommended limit for sodium in drinking water is 200 mg/L (Table 2), else the water taste will be detestable. Sodium concentration in sampled wells is far below this limit.

The concentration of potassium in the wells was between 7.11 and 10.66 0mg/L with an average value of 8.93 mg/L. Potassium is the least abundance cation in the analysed sampled hand-dug wells. Normally, potassium is not of health concern and it is also needed for human body metabolism, concentration in excess of 3000 mg/L is however dangerous to human health.

3.3 Ionic dissolution: Anions

Bicarbonate is the most abundant ion in the analysed water samples. Groundwater is enriched in bicarbonate from carbondioxide (CO_2) dissolution in atmospheric precipitation [12]. The concentration of bicarbonate was between 140 mg/L at Oluleye in location AJ12 and 260 mg/L at Oyekola in AJ03 (avg. 208 mg/L).

Sulphate in the study area is less abundant. It can originate from weathering of rocks and minerals that contains Sulphur compounds. Over time, these compounds can dissolve and release sulphate ions into groundwater. The provenance of sulphate in ground water can be either from the oxidation of pyrite. Sulphate concentration in the study area ranges from 10 to 40 mg/L with an average value of 23 mg/L. Location with the highest sulphate concentration is at Oyekola street with sample number AJ03 having a value of 40 mg/L and the location with the lowest concentration of sulphate is at Oluleye Bakery (AJ13) with value of 10mg/L. According to world health organization guideline limits [9], sulphate content should not exceed 250 mg/L and all samples fall within it standard.

Chloride ion provenance in water can be from weathering of rocks and minerals, through fertilizer, domestic waste water such as household cleaning products, detergents contain chloride-based compounds that can enter the water system through sewage discharge, chloride can also have sedimentary rocks as its provenance. Chloride concentration in the study area ranges from 5.50 to 60.70 mg/L with an average value of 44.98mg/L. The lowest value of chloride ion basically indicates that the salinity is low in the study area.

The location with the highest concentration of chloride is AJ04 having a value of 60.7mg/L and the location with the lowest concentration of chloride is at Oluleye Bakery AJ13 with a value of 5.5 mg/L. According to the WHO standard [9], chloride content should not exceed 600mg/L and all samples fall within it standard.

Nitrate provenance in water can be from both natural and anthropogenic sources which may include, septic systems whereby in areas without access to centralized sewage treatment, if septic systems are not properly designed, installed , or maintained, nitrates from the treated wastewater can seep into the surrounding soil and contaminate groundwater, Atmospheric Deposition; nitrogen compounds, including nitrates can be present in the atmosphere due to industrial emissions, vehicle exhaust, and agricultural practices. These nitrogen compounds can be deposited on the land surface through rainfall or dry deposition, after some time they infiltrate into groundwater. Nitrate concentration in the study area ranges (ranged) from 0.83mg/L to 8.32mg/L with an average value of 3.82mg/L. The location with the highest concentration is also at AJ03 with a value of 8.32mg/L and location with the lowest concentration of Nitrate is AJ13 with a value of 0.83mg/L. According to the WHO [9] nitrate content should not exceed 45mg/L and all samples fall within it standard.

3.4 Hydrochemical Facies Classifications

Hydrochemical facies classification is a method used to categorize the chemical composition of water samples collected from different sources. The classification helps in understanding the water quality and its suitability for various purposes such as drinking, irrigation, or industrial use. Cationic concentrations were in order of $Ca^{2+} > Mg^{2+} > Na^{+} > K^{+}$ while the order of anionic dominance is $HCO_3^{-} > Cl^{-} > SO_4^{2-} > NO_3^{-}$. The studied area is dominated by Ca-HCO_3 water type as indicated in the piper plot (figure 4) and Table 1.

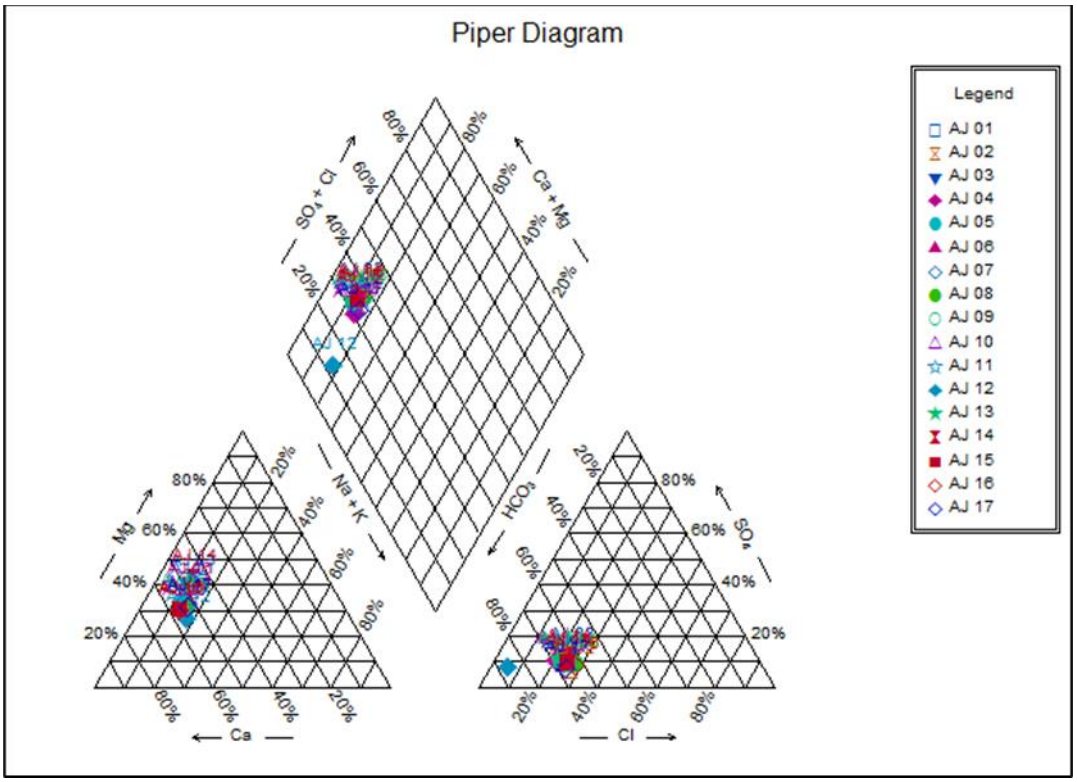

Figure 4: Piper Diagram of Analyzed Water Samples

4. Conclusion

Hydro-chemical characteristics of the seventeen 17 samples within the studied area revealed general cationic concentration in the order $Ca^{2+} > Mg^{2+} > Na^{+} > K^{+}$ while the anionic concentration is in the order of $HCO_3^{-} > Cl^{-} > SO_4^{2-} > NO3$. Ca and Mg are the dominant cations while $HCO^{-}3$ and Cl^{-} are the dominant anions. The pH showed that the water is slightly acidic to neutral. All the water samples fall into the fresh water category from the average value of TDS. Piper trilinear diagram showed dominant Ca-HCO3 water facie(s) indicating their suitability for drinking purpose when compared with the WHO standard. The concentrations of all the cations and anions also falls within the WHO standard. The interaction of all cations and anions with TDS from statistical analysis showed that there is a weak correlation between each of the constituents.

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Funding
Not applicable.

Institutional Review Board Statement
Not applicable.

Informed Consent Statement
Not applicable.

Acknowledgements
Not applicable

Conflict of Interest
The author declared no conflict of interest in the manuscript.

Authors' Declaration
The author(s) hereby declare that the work presented in this article is original and that any liability for claims relating to the content of this article will be borne by them.

Author Contributions
Conceptualization – O.A.A; Design – O.A.A; Fieldwork and Data collection - OAA, OAF, AOJ; Processing and Interpretation – OAA, AOJ; Supervision – O.A.A, OAF; Resources – O.A.A, A.O.J, OAF; Literature Search – O.A.A, A.O.J; Writing – O.A.A.

Cite article as:
Akanbi, O.A., Falana O. A. and Owasanoye, A. Hydro-geochemical study of Groundwater in Ajegunle area in Oyo Town, southwestern Nigeria. *Ajayi Crowther J. Pure Appl. Sci.* **2025**, 4(2), pp. 7--14. | **doi:** https://doi.org/10.56534/acjpas.2025.04.02.02