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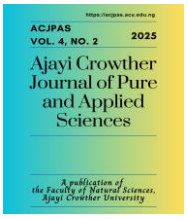

Article

Groundwater quality assessment of Awe Area, Southwestern, Nigeria

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Abstract

Twenty-three groundwater samples were collected from selected hand-dug wells across Awe area of southwestern Nigeria for groundwater quality assessment. The studies involved field measurement of physical parameters, groundwater sampling, analyses of major ions and measurement of the concentrations of five trace elements that included copper (Cu), zinc (Zn), arsenic (As), lead (Pb), and cadmium Cd) in the groundwater samples. The field measurement of the physical parameter showed that pH ranged between 5.1 and 6.8, TDS between 110 and 660 mg/L, and EC between 220 and 1340 µs/cm. From the chemical analytical results the concentrations of major cations in mg/L were; calcium (8.20 –12.60), magnesium (2.44 – 6.23), sodium (0.20 – 0.44), and potassium (1.10 – 4.65). For major anions, bicarbonate was between 17 and 95, carbonate 1 – 6, chloride 2.5 – 11.12 and sulphate was 0.005 – 0.205. For trace element concentrations, Cu, Pb, and Zn occurred below detection limits in most of the hand-dug wells, while the concentration of Cd was between 0.85 and 0.89 mg/L and As was between 0.002 and 0.009 mg/L in the shallow groundwater system of the area. Based on the average concentration, the ionic dominance is in the order of HCO_3>Ca>Cl>Mg>CO_3>K>Na>SO_4, while the water type is predominantly Ca-Mg-HCO_3. In comparison to world health organisation guideline for drinking water, the concentrations of the major ions are within the acceptable limits and pose no danger to human consumption. However, the water is grossly contaminated with cadmium while lead (Pb) concentration was also found to exceed the maximum permissible limit in some samples. This is a great concern for the potability of groundwater of Awe area.

Keywords: Groundwater, Hand-dug wells, Major-ions, Trace elements, Contamination.

1. Introduction

The development of reliable fresh water sources is a major challenge that requires a drastic solution in most developing nations of the world [1,2]. Most areas in southwestern (SW) Nigeria are not connected by pipe borne water supply and human populace both in rural and urban areas largely depends on groundwater due to its reliability, accessibility and renewability [3,4]. In view of the increasing demand of water for various purposes, groundwater is now a major source of freshwater both in urban and rural area. However, the quality of groundwater depends on the quantity and types of the chemical constituents and the level of exposure to contamination. The sources of contamination are either chemical, physical or biological in nature and they often affect the natural condition of groundwater or its intended usage. Some dissolved solids in groundwater are useful for human while others are injurious. For examples, chemicals such as calcium and magnesium are major elements that serve as dietary mineral for the human body while most trace elements, though equally essential become toxic to human if they occur a little more than the required amount. Most of these trace elements occur naturally in water but large contributions are often due to human inputs. Trace elements such as

arsenic, cobalt, zinc, cadmium, nickel, lead, manganese, tin, and copper are found and/or associated with gasoline, tyres, fertilizers, diesel oils, batteries and vehicular exhaust, etc. Additionally, in rural areas, these elements are associated with human activities such as coal and wood combustion and open refuse incineration. For the present study, the groundwater quality study involved the assessment of major ions and trace element concentration in the groundwater system of Awe area of the south-western, Nigeria.

1.1 The Study Area

The township of Awe and its environs lies within latitude 7°48' 30"N - 7°50' 30"N and longitude 3°56' 30"E - 3°58' 40"E in Afijio local government area of Oyo state, SW Nigeria (Fig. 1). The relief is low to medium lying with dotted hills that are the residual outcropping sections of the basement rocks. The climate is moist sub-humid with mean average annual temperature varying from 26.5°C to 27.8°C [5]. The area experiences two distinct season annually; the wet season which extends from April to October and a dry season between November and March. The geology of Awe is part of the Precambrian Basement Complex of south-western Nigeria. The rock types that underlie the area (Fig. 2) are mainly undifferentiated schist and quartzite [6]. The undifferentiated schist composes of garnet-schist and gneisses. The garnet-schist is dark and the outcropping sections are flat- to - low lying. The garnet occurs as nuggets within the schist and are dark-reddish in colour. The major minerals in schist are micas and feldspars. There are also minor occurrences of doleritic dykes, quartz and pegmatite veins that intruded into the main rock bodies, [7]. The structural elements that are notable within the study locality include foliations, folds, minor faults and lineation. The structural elements that are notable within the study locality include foliations, folds, minor faults and lineation [6].

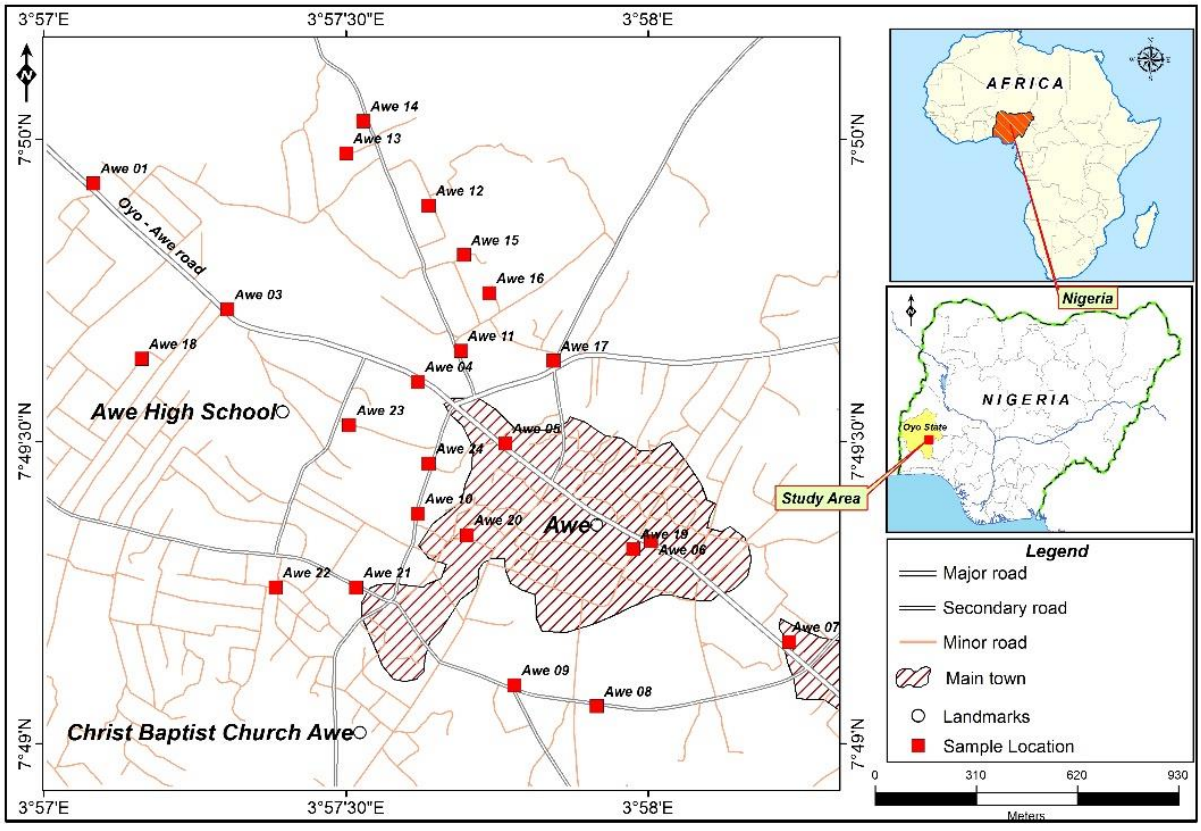

Figure 1: Location map of the study area with sampled hand-dug wells

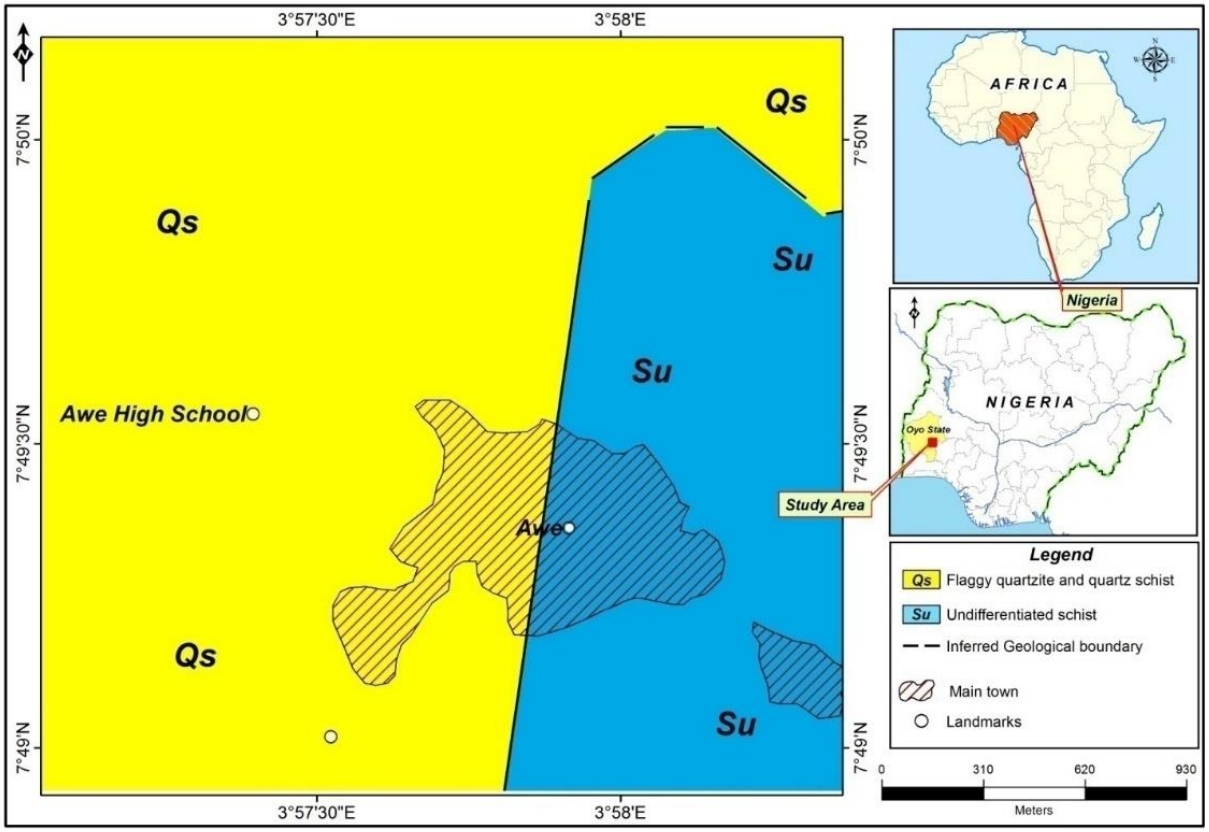

Figure 2: Geological Map of the Study Area

2. Methodology

The study approach involved water sampling from twenty-three hand dug wells, laboratory analyses and evaluation of results. The field sampling involved collection of water samples from hand –dug wells across Awe township (Fig. 1). The samples were collected in sterilised new 1litre plastic bottles and sensitive groundwater parameters including total dissolved solids (TDS) and electrical conductivity (EC) were measured in the field with the use of a digital Milwauker SMSOI pH/EC/TDS calibrated meter while pH was measured with a Whatman universal indicator papers with pH range of 1-14 which may not be accurately determined in the laboratory due possible changes during transportation. The samples were adequately prepared for laboratory analyses. The coordinates (longitude and latitude) of each well location were measured with Etrex GPS meter. The water sampling was carried out in the month of February during the dry season when the effects of surface run-off and infiltration would be minimal. The chemical analyses for major ions analyses and trace element concentrations were carried out at the multidisciplinary central research and geochemistry laboratories of the Department of Geology in University of Ibadan, Nigeria. The major ions analysed were Na^+, K^+, Ca^{2+}, Mg^{2+}, Cl^-, CO_3^{2-}, HCO^- and SO_4^{2-}. Six trace (and minor) elements were analysed including copper (Cu), lead (Pb), zinc (Zn), cadmium (Cd), arsenic (As) and iron (Fe). Anions were analysed using Spectrophotometer (Genesys 20 Spectrophotometer) while cations were analysed by Flame Photometry method. The flame photometer used for this work is Buck PFP-7 flame photometer. Trace and minor elements were analysed using the Atomic Absorption Spectrophotometer (AAS). The analyses were carried out following international acceptable standards and procedures. Chloride was measured using titrimetric methods by adding 2 drops of potassium dilichromite (K_2CrO) indicator to each water samples in a conical flask, and titrate with Silver Nitrate (0.014N AgNO). The end point is the brownish coloration of the solution while Na was determined by flame spectrophotometer. For chemical plot, each groundwater sample was classified using Piper plot [8]. Piper plot is a graphical classification of natural waters that has proven to be effective in segregating analytical data for critical study with respect to source of dissolved constituents in waters and modification in the water as it passes through an area and related geochemical problems. On the piper's diagram, the relative percentages of cations and anions are plotted in the lower triangles, and the resulting two points are

extended into the central field to represent the total ionic concentration. The degree of mixing between waters can also be shown on piper's diagram. The raw data obtained from the laboratory in mg/L was converted to milliequivalent per liter (meq/L). An ionic concentration in mg/L is divided by equivalent weight of the particular ion. Equivalent weight equals molecular weight divided by the ionic charge.

3. Results and Discussion

3.1 Major ion concentrations

The concentrations of major ions and toxic elements along with hand-dug wells location names as well as the results of the physical parameters measured in the field is presented in Table 1. The pH of the water was between 5.1 and 6.8, and can be said to be slightly acidic. The TDS lies between 110 to 660 mg/L and can be classified as fresh according to [9] and the EC ranges from 220 to 1340 μS/cm.

Table 1: Statistical Summary of the Physical and Chemical Parameters of Water Samples

Parameters	Min	Max	Mean	WHO (2017)
TDS (mg/L)	110	660	330.8	1500
pH	5.1	6.8	6.1	7.5
Calcium (mg/L)	8.20	12.60	11.07	200
Magnesium (mg/L)	2.44	6.23	3.90	150
Sodium (mg/L)	0.20	0.44	0.32	200
Potassium (mg/L)	1.10	4.65	2.95	12
Bicarbonates (mg/L)	17.00	95	67.98	500
Carbonate (mg/L)	1.00	6	3.76	---
Chloride (mg/L)	2.54	11.12	5.07	600
Sulphate (mg/L)	0.01	0.21	0.09	250
Copper (mg/L)	0.00	0.08	0.043	2
Lead (mg/L)	0.00	2.475	1.084	0.01
Zinc (mg/L)	0.00	0.37	0.205	3
Cadmium (mg/L)	0.85	0.89	0.866	0.003
Arsenic (mg/L)	0.002	0.009	0.005	0.01

In this study, calcium is the most dominant cation in the water sample, the concentration ranged from 8.20 - 12.60 mg/L with a mean value of 11.07 mg/L. Magnesium concentration in the analysed water sample ranged between 2.44 and 6.23 mg/L with a mean value of 3.90 mg/L while sodium concentration was between 0.20 and 0.44 mg/L with a mean value of 0.32 mg/L. Sodium is the least abundant cation in the analysed water samples. Potassium concentrations ranged between 1.10 and 4.65 mg/L with a mean value of 2.95 mg/L. For anionic concentrations, bicarbonate is highly concentrated in the samples with a range of 17 mg/L to 95 mg/L. Carbonate in the analysed water sample ranged from 1 to 6 mg/L with a mean value of 3.76 mg/L. Chloride is the second most dominant anion in the water sample. Sources of chloride in water is often through fertilizer, sea spray and from human excrement especially in places where the water wells are close to septic tank. The concentration of chloride in the sampled water was between 2.5 and 11.12 mg/L with a mean value of 5.07 mg/L. Sulphate occurrence in water is comparatively lower compared to other ions with concentration of 0.01 - 0.21.

Based on average concentration, cationic dominance in the groundwater is in the order Ca>Mg>K>Na while the concentration of the anions is in the order of HCO_3>Cl>CO^2_3>SO_4^2. The predominant hydrogeochemical facies from the piper plot is Ca-Mg-HCO_3 water type (Fig. 3).

3.2 Trace elements contamination

The concentrations of trace elements that were analysed in groundwater samples are presented along with those of major ions in Table 1. Cu, Pb and Zn occurred below detection limits in many of the sampled hand-dug wells. These trace elements occurred only in six locations across the study area. Pb was detected in groundwater at Lane 3, Odofin and Crystal water areas at substantial levels that is above 1.0 mg/L, while the concentrations of Cu and Zn occurred below 1.0 mg/L in hand-dug wells where they

were detected. Cd and As were detected in all groundwater samples. Arsenic occurred at very low concentrations ranging between 0.002 to 0.009 mg/L, while the level of concentrations of Cd were comparatively higher with concentrations of 0.85 - 0.89 mg/L with a mean value of 0.87 mg/L. This astronomical concentration in water samples when compared with World health organisation guidelines [10] for drinking water showed that the shallow aquifers at Awe is clearly polluted with cadmium in all locations and with lead (Pb) in five wells where it was detected.

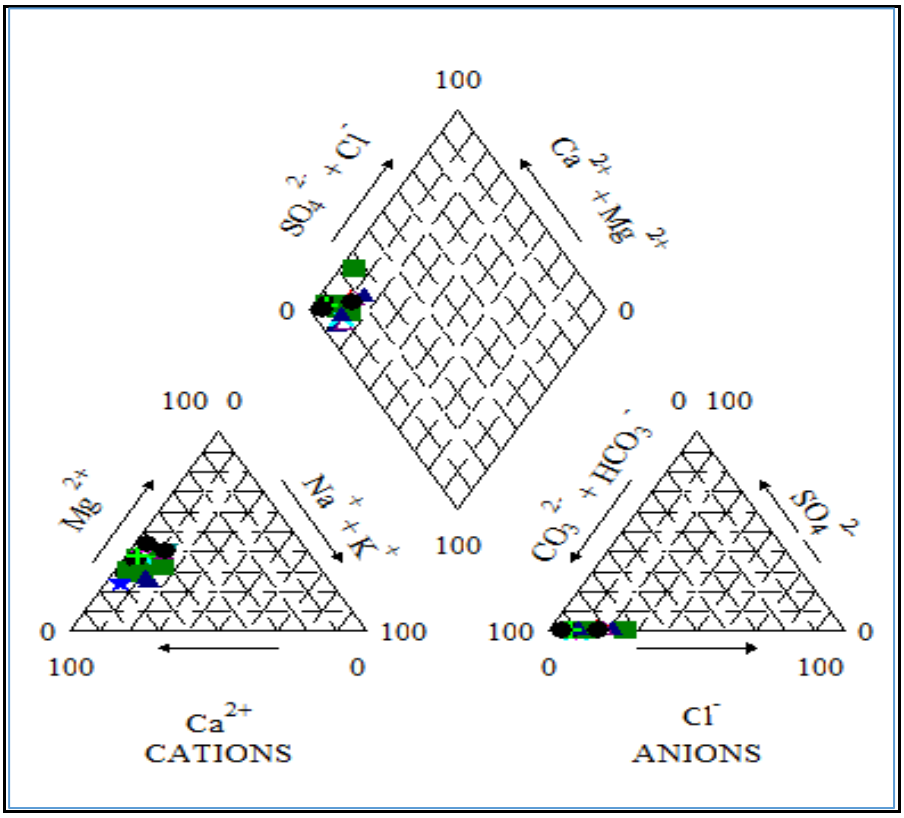

Figure 3: Piper diagram showing the dominant water type in the study area

4. Conclusion

Groundwater quality assessment of Awe has been carried out by analysing the major-ions and trace elements in representative samples. The evaluation of the hydrochemical results revealed that the groundwater of the study area belongs predominantly to the Ca-Mg-HCO_3 water type. With respect to chemical parameters alone, the groundwater is suitable for most domestic applications such as washing, cooking, and bathing. However, sampled hand-dug wells were contaminated with cadmium and lead while arsenic, copper, and zinc were found below the permissible limits in all locations.

For human consumption, it is expedient that further studies such as microbiological analysis be carried out across the study area. Also, hand-dug wells that are contaminated with toxic elements are to be plugged and the entire groundwater system of the area should be treated as appropriate.

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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.

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Conceptualization – OAA; Design – OAA, Supervision – OAA; Resources – OAA, OA Data Collection and/or Processing – OAA, OA; Writing - OAA

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