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Assessment of Groundwater Quality in Abeokuta North, Nigeria

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Abstract **Background and Objective**: Groundwater (hand-dug wells) is the major source of water for municipal use in the Abeokuta North Local Government of Nigeria. However, there is a tendency for its quality to deviate from recommended standards as most groundwater sources are close to regions prone to erosion and most wells are not usually covered. The adverse effects might creep into the ecosystem and affect human health if a regular check on the quality is not made. **Materials and Methods**: The geographical location and altitude of the wells' locations were taken using Global Positioning System (GPS). The sagging of the water drawer's rope was indicated with a pin, the latter which was used to spot the location. Each instrument employed was inserted into the sample of water as per the procedure. The experiment was carried out at the thirty-six available sites in the region. **Results**: The moderate pH range (6.30-7.36) can be linked to low values of TDS (352 mg/L) and EC (695 µs/cm). Statistical Pearson correlation analysis shows a clear relationship between parameters at $p<0.01$ (2-tailed T-test; MSExcel); supported by a linear plot between EC and TDS, and a clustered column chart that compares EC and pH. The overall water quality index (WQI) of the parameters gives an excellent value of 17.20%.

Keywords: *groundwater, Abeokuta north, global positioning system, pH, total dissolved solids, electrical conductivity, world health organization, water quality index*

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1. Introduction

Water is essential for the sustainability of life. Its continuous supply is important to replenish the fluid lost during respiration, perspiration, and urination [1]. Water can be found beneath the soil; this is known as groundwater. Also, groundwater refers to water found in rocks and fractures beneath the earth and a part of the water cycle. It is the body of water derived primarily from percolation and contained in pore spaces of a permeable rock [2].

Groundwater could be formed via natural precipitation from infiltration or indirectly from rivers, and it represents the water in the rocks and fissures of a particular geological formation [3]. Traditionally, hand-dug wells (groundwater) have been the major source of drinking water in developing countries. However, because they are dug by hand, their use is restricted to suitable types of ground such as clays, sands, gravels, and mixed soils where only small boulders are encountered. Furthermore, leaching from waste dumps and industries makes them susceptible to contamination due to runoff [4].

Water quality describes the physical, chemical, and microbiological characteristics of water. All these determine the purposes for which the water can be used [5]. These properties could be natural with a particular water source or arise from dissolved or suspended substances from human activities [5]. We cannot live without water and municipal activities can impact its quality and quantity [6]. Fresh groundwater is associated with recharge areas, whilst groundwater is more mineralized.

The United Nation goal of access to safe drinking water, especially in developing countries is frequently under threat due to the occurrence of pollutants in drinking water which pose a serious health hazard [7]. pH is one of the most important water quality parameters; although, it has no direct impact on consumers. However, the water of a very low pH is likely to be corrosive to its environment. Corrosion can contaminate water and have adverse effects on its taste and appearance [8].

The pH in the range 6.5-8.5 is usually acceptable, although the nature of the construction materials used in the distribution system as well as the composition of the water both lower and increase this range [9]. In an extreme case, a surge in the pH value could be because of accidental spills, treatment breakdowns, and insufficiently cured cement mortar pipe linings, among others [10]. The dissolved ions in the water sample must be of a low concentration. The electrical conductivity of water indicates the presence of dissolved ions; these two parameters are relative to each other. In the same vein, over-mineralization of groundwater lowers water quality giving an objectionable taste, odor, and excessive hardness [11]. Water contamination needs to be avoided because the quality of the water of the aquifer would be difficult to restore [12]. Aquifer source depth plays an important role in determining the thermal buffering capacity and the water quality of groundwater [13]. The depth and shallowness of groundwater also play important roles in land-use changes and surface contamination [14]. That said, these two factors tend to have different chemical properties [15].

Groundwater is typically referred to as being safe for drinking. However, the quality does vary due to differences in associated rock type and within aquifers along groundwater flow paths [16]. Also, human activities might affect the water source over time.

Therefore, periodic checking of the quality of groundwater is important to develop a strong database for future water resource strategic planning and development [17]. Many researchers have reported the quality of groundwater in different parts of Nigeria. However, no study has been conducted on the groundwater quality in Abeokuta North Local Government

Groundwater is one of the major sources of water supply to the entire populace of the Abeokuta North Local Government and its environment since there is an inadequate supply of pipe-borne water from the waterworks and boreholes. The boreholes found there are very scarce as it is expensive to construct when compared to the average standard of living of people living in the area. The geological formation of this local government is the basement complex, which is very difficult to drill due to the type of rocks beneath this formation.

This study, therefore, became necessary to ascertain the quality of the wells and invariably its suitability for various purposes, to ensure the protection of the health of users and determine liable sources of pollution. The information will be of great importance to relevant authorities. This study will serve as a database for future research in water quality assessment of hand-dug wells in the study area and influence decision-making concerning future groundwater development.

The wells are not properly maintained due to a lack of information on maintenance procedures such as consistent closing of the cover, rinsing of the drawers before dipping inside wells, et cetera. Also, most wells in the study area are sited close to regions prone to erosion due to the poor drainage system. This novel research work aims to draw out a verdict on the quality of groundwater in Abeokuta North Local Government area from its electrical conductivity (EC), total dissolved solids (TDS), pH, temperature, and water quality index (WQI) to ascertain whether or not the quality of water in this area is within standard recommended by World Health Organization.

2. Study Area

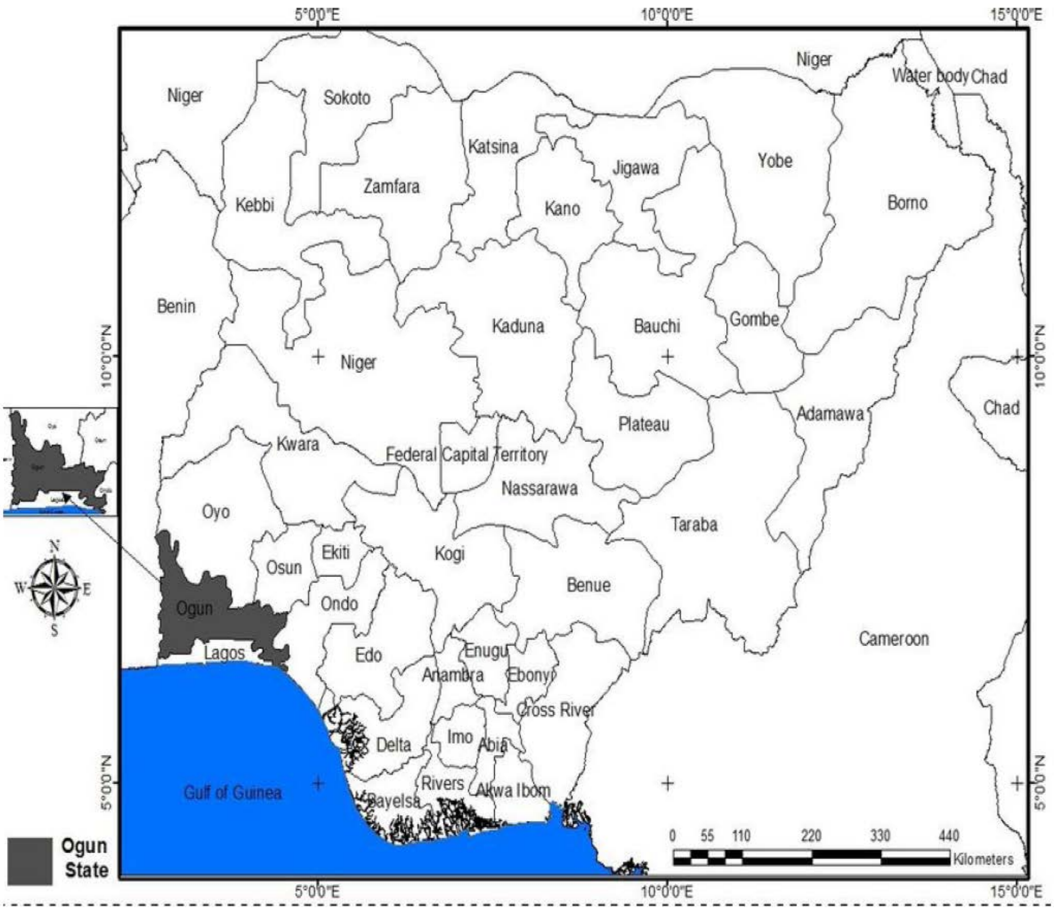

Figure 1. Map of Nigeria showing Ogun State [28]

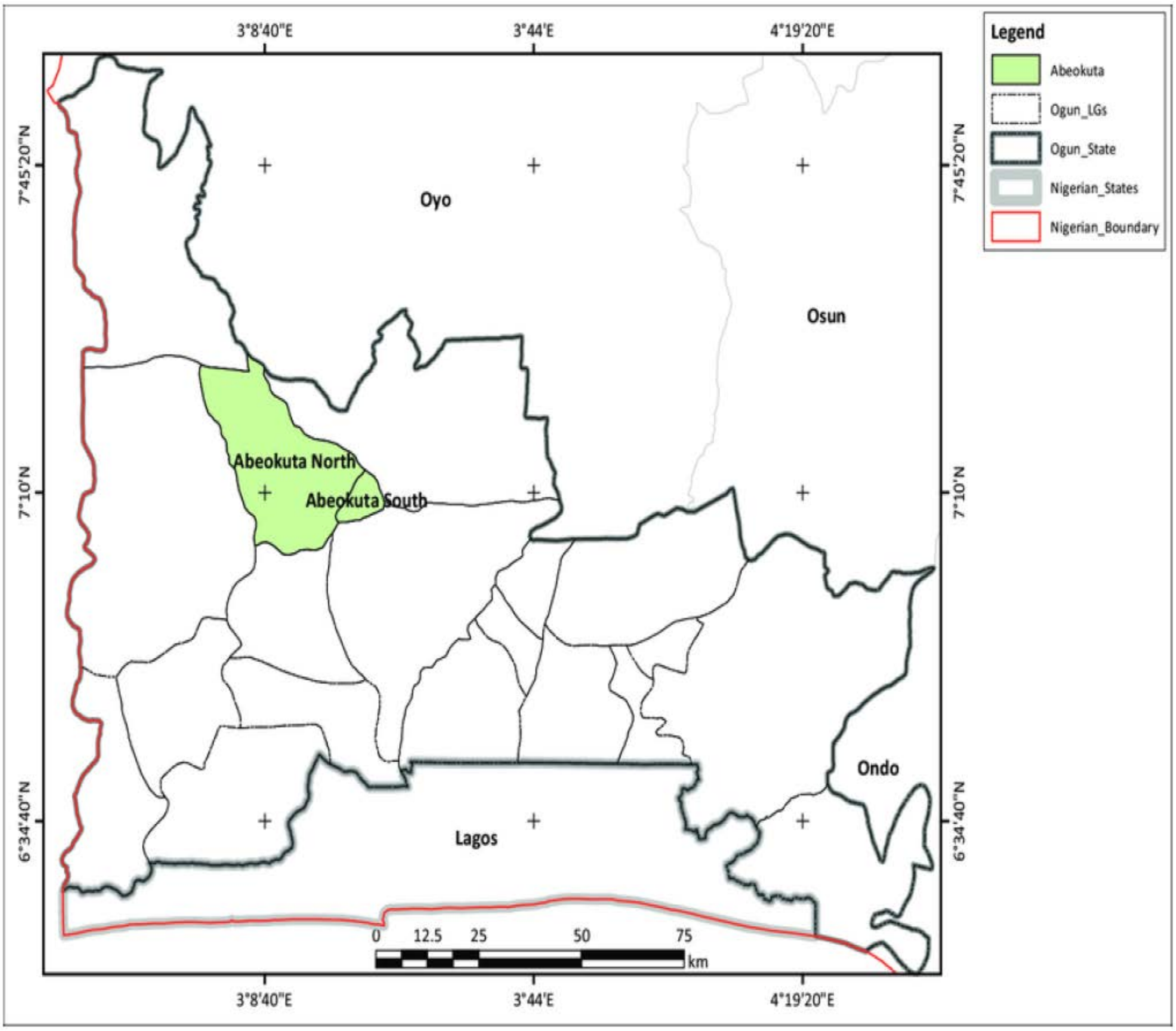

Figure 2. Map of Ogun State Showing the area of interest [29]

This study was carried out at the start of the dry season in 2017. Figure 1 represents the map of Nigeria which shows Ogun state, whilst Figure 2 is the map of Ogun state (and its neighboring state), indicating the study area with a green shade. Table 1 represents the mean values of the water quality parameters respectively taken in 36 available sites in the ten sub-districts of Abeokuta North, local government area, Ogun, Nigeria. The study area lies on latitude 7°10´N and longitude 3°40´E and it has a landed area of 808 km^2 (312 square miles). Its headquarter is in the town of Akomoje near Abeokuta. It is bounded to the west by Yewa North Local government, the east by Abeokuta South Local government, the north by Odeda Local government, and to the south by Ewekoro Local government. The average temperature and annual rainfall of the groundwater sources are 27.6 °C and 1238 mm, respectively.

3. Materials and Methods

3.1. Materials Used

Rope, distilled water, toilet roll, drawer, thermometer, and EC/TDS/pH meter, were employed.

3.2. Data Collection

Groundwater samples were collected and analyzed in-situ (on-site) from thirty-six (36) hand-dug wells around Abeokuta North Local government area. The geographical location of all the wells was obtained using a global positioning system (GPS), the areas of the location of each well were recorded, and the time of collection was recorded. The altitude of each location of the wells was also obtained using the GPS. The depth of the wells and the height of the apron (ring above the ground surface) were obtained. The depth of the well was gotten by immersing a water drawer (rubber) inside the well and a pin is used to spot the location when the rope attached to the drawer starts sagging. The sagging of the rope indicates that the drawer has reached the bed. The measuring tape was then used in measuring the point located on the rope to the drawer and the readings were taken and recorded. A miniaturized single probe TDS/EC/pH meter which utilizes three sensors was used. The probe has an amplifier that helps to eliminate background noise from electrical interference and humidity, which could come from sources such as pumps, ballasts, pumps, et cetera. The instrument was calibrated to a pH of 7.01 and an EC value of 1413 µS/cm.

EC/TDS readings are done by an amperometry sensor in the probe. The working principle is akin to Faraday's first law of electrolysis, except that there is no product in this case. When a potential difference is supplied to the sensor, the amount of current that flows through the circuit is proportional to the mass of the dissolved solids present in the sample. The temperature of the samples of water collected from the well was obtained using a thermometer.

Groundwater samples taken from the wells were tested and analyzed immediately after collection. The samples were analyzed for the following physicochemical parameters explained below.

3.3. Method of Analyzing Physicochemical Parameters

3.3.1. pH

This is the measure of acidity/alkalinity of water. The water in the well was drawn, and the electrode of the pH meter to be used was cleaned with distilled water to remove particles that may remain after the previous use. It was inserted inside the drawer with the water. Immediately after insertion, there appears a clock on the surface of the meter indicating that the water is still been tested. The result obtained is being recorded immediately after the clock disappears.

3.3.2. Electrical Conductivity

EC is the measure of the ionic components in water, and it signifies the electrical properties [18]. The water in the well was drawn, and the meter to be used was first cleaned with distilled water to remove particles that may have remained after the previous use. The same procedure was followed as above using the EC/TDS/pH meter.

3.3.3. Total Dissolved Solids

TDS represents the dissolved minerals or substances in water. The same procedure was followed as described above.

3.3.4. Water Quality Index (WQI)

The WQI was determined using the weighted arithmetic method [19]. The four steps calculation is summarized as given below:

$$K = \frac{1}{\Sigma S_n} \tag{1}$$

Where S_n is the value (mean) for each parameter; and K is the proportionality constant in equation 2.

$$W_i = \frac{K}{S_n} \tag{2}$$

Where W_i is the unit weight for each parameter.

$$Q_i = \frac{[V_o - V_i]}{[S_n - V_i]} x100 \tag{3}$$

V_i (idea value) for all parameters in water quality analysis is zero, except pH and dissolved oxygen (DO) which have an ideal value of 7 and 14.6 mg/L, respectively. V_o is the observed (mean) value, while Q_i is the quality rating of the individual parameter.

$$WQI = \frac{\Sigma W_i . Q_i}{\Sigma W_i} \tag{4}$$

4. Results and Discussion

The experimental values for the determined parameters are given in Table 1. Furthermore, Table 1 shows low standard deviation and mean values. That is, little differences difference between each parameter from one site to another, which implies that the sites are affected almost the same way by human and environmental factors. Temperature values are not beyond what is expected of a tropical rainforest region. It ranges from 26.0 to 29.2°C with an average of 27.6°C. This ambient temperature is good for consumption. The temperature must not be too high to prevent microbial growth, which might lead to unpleasant taste, odor, color, and corrosion issues [20].

Table 2 shows a strong correlation/relationship of 0.9794 between TDS and EC, which is also represented as a linear graph in Figure 3. In other words, TDS led to an increase in the EC found in the area. Both the parameters are within the World Health Organization's recommendation of 300-1200 mg/L and 500-1000 µs/cm respectively. The average values are approximately 352 mg/L and 695 µs/cm, in the same sequence. As a result, the water in the surveyed region can be said to have a relatively low salt concentration. The dissolved solids might be Ca^{+2} and/or Mg^{2+}, and carbonates from rainfall as has been previously mentioned that most wells in the study area are not properly/consistently covered. In continuation, the average EC is far greater than the 11.08 µS/cm reported by [18], the latter which is attributed to the rapid ion exchange between the soil and water due to the presence of few insoluble mineral types in Agbor/Owa (Boji-Boji) area. However, in the case of Abeokuta north, the region is typical of hills, mountains, and deposited minerals which suggest the possibility of mineral leaching through the porous sand bed into the groundwater. The water samples meet the requirement of "freshwater" and can be used for irrigation purposes as this would not affect the osmotic pressure of soil solution [21]. In addition, there is a slightly strong inverse correlation between the pH and EC as shown in Table 2. In the same vein, Figure 4 shows that the pH decreases at the interval where EC increases, and vice-versa.

The pH range (6.30-7.36) is consistent with the results presented by [22]. The latter reported a pH range of 6.7 to 7.6 for a town called Foko in the west Africa city of Ibadan, where the authors observed the same nonchalant wells handling by the occupants, whilst frequent governmental monitoring helps to salvage the situation [23]. Another researcher reported a pH range of 7.65 to 8.48 for 40 selected sites in Abeokuta. Although the sampling did not entirely focus on one site (Abeokuta north), it suggests that the pH of the water in Abeokuta is considered neutral, all things being equal; hence, it further strengthens our data on Abeokuta north. In contrast, [24] reported pH values as low as 4.35 in the Ota region (in the same Ogun State), but it is an industrial area which implies that the surge might be a result of excessive release of acidic effluents into water bodies. So, Abeokuta north seems to be free from undue water pollution. Meanwhile, slightly acidic values are observed in locations such as Sabo Lafenwa, and Ikeredu-Idan which is given for the comparatively higher EC shown in Table 1 and Figure 4. This observation could be because of the presence of refuge sites and abattoirs in these two locations, perhaps trace contamination of the locations is gradually happening. Similarly, [25] reported higher values of TDS (above 500 mg/L) in areas closer to industrial sites compared to the region far-away, in Kakinada city, east coast of India. In a study**,** the researchers reported a pH range between 6.81 and 8.32 for the water quality assessment of Bundelkhand massif, Mahoba in India [26]. The geographical features of the region comprise rainforest and hard rocks, both of which are typical of Abeokuta.

Table 1. The results obtained for the water quality parameters

S/N	X	LAT	LONG	ALT (m)	PH	TDS (mg/L)	EC (µs/cm)	TEMP (‘c)	SWL (m)	TD (m)	H (m)	(Alt - SWL) (m)
1	SABO	3’19’’467	7’09’’455	64	6.53	480	953	26.8	2.41	5.5	1.2	61.59
2		3’19’’416	7’09’’450	64	6.35	394	798	28.5	3.42	3.52	0.46	60.58
3		3’19’’410	7’09’’418	64	6.74	466	932	27.3	1.56	2.94	0.14	62.44
4		3’19’’408	7’9’’422	64	6.76	321	641	27.2	2.17	6.60	0.79	61.83
5		3’19’’423	7’09’’399	64	6.89	499	996	27.2	5.87	7.92	0.71	58.13
6		3’19’’419	7’09’’417	64	6.92	575	1149	27	1.29	2.11	0.18	62.71
7	LAFENWA	3’19’’524	7’09’’183	64	7.08	558	1115	27.3	2.34	3,26	0.5	61.66
8		3’19’’530	7’09’’170	64	7.20	360	722	27.2	0.73	5.43	0.37	63.27
9		3’19’’528	7’09’’148	64	7.15	503	1005	27.8	2.81	4.37	0.72	61.19
10		3’’19’’530	7’09’’144	64	7.10	496	987	28.6	1.12	3.21	0.19	62.88
11		3’19’’520	7’09’’085	64	7.00	472	945	27.4	1.38	4.54	0.75	62.62
12		3’19’’598	7’09’’144	64	7.19	381	757	27.8	3.24	4.31	0.52	60.76
13	TOTORO	3’19’’978	7’09’’272	64	6.86	421	841	27.4	1.8	1.18	0.65	62.20
14		3’19’’923	7’09’’356	64	7.13	333	666	27.4	3.15	4.60	0.67	60.85
15	GBAGURA	3’20’’035	7’’09’’356	64	7.05	430	857	26.8	1.12	2.0	0.18	62.88
16	IKEREDU-IDAN	3’19’’770	7’09’’331	64	6.93	432	866	27.3	2.34	3.45	0.58	61.66
17		3’19’’772	7’09’’348	64	6.87	449	899	28.7	3.14	5.41	1.43	60.86
18	ITA-OSHIN	3’18’’307	7’08’’139	64	7.25	253	504	27.6	1.66	3.44	0.37	62.34
19		3’18’’339	7’08’’083	64	7.36	152	300	26.2	1.52	2.55	0.22	62.48
20		3’18’’358	7’08’’047	64	6.91	202	407	27.4	1.33	3.75	0.64	62.67
21		3’18’’374	7’08’’033	64	6.92	301	596	27.0	1.33	4.07	0.86	62.67
22		3’18’’409	7’08’’008	64	7.13	318	337	28.8	7.25	7.56	0.55	56.75
23		3’18’’355	7’07’’936	64	7.29	140	280	27.4	2.97	13.05	0.61	61.03
24		3’18’’325	7’07’’934	64	7.04	212	425	27.4	0.29	3.31	0.72	63.71
25		3’18’’295	7’07’’935	64	7.21	157	314	27.2	1.64	6.24	0.30	62.36
26	IBEREKODO	3’20’’298	7’11’’031	62	6.95	389	773	26.0	2.74	4.00	0.00	59.26
27		3’20’’438	7’11’’013	60	7.16	379	759	26.4	2.46	4.10	1.04	57.54
28		3’20’’438	7’11’’013	60	7.17	350	696	26.9	2.65	4.28	1.25	57.35
29		3’20’’511	7’11’’110	69	7.12	150	314	28.6	0.32	0.98	0.05	68.68
30		3’20’’508	7’11’’130	63	7.09	242	485	28.4	1.11	2.14	0.82	61.89
31		3’20’’365	7’11’’215	55	7.12	205	412	28.6	2.48	4.10	0.70	52.52
32	AKOMOJE	3’20’’350	7’11’’293	49	7.10	250	506	27.8	2.12	3.25	1.21	46.88
33		3’20’’510	7’10’’826	65	7.08	456	914	29.2	5.00	5,04	1.49	60.00
34	ELEGA	3’20’’800	7’11’’024	94	7.16	340	680	28.7	3.70	4.87	1.00	89.13
35	AGO-ODO	3’20’’284	7’10’’271	57	7.20	364	730	28.5	5.67	7.30	1.00	49.70
36		3’20’’382	7’10’’401	42	7.12	255	450	28.2	2.23	2.51	0.78	39.49
Mean				**7.03**	**352**	**695**	**27.6**	**60.68**				**60.68**
S.D (σ)				**0.20**	**120**	**248**	**0.8**	**7.09**				**7.09**
WQI (%)							**17.20**					

X= Location; Lat= Latitude; Long= Longitude; Alt= Altitude; TDS: Total Dissolved Solid; EC= Electrical Conductivity; SWL= Shallow Depth Length; TD= Total Depth; (Alt-SWL) = Hydraulic head; H= Height of Apron; S.D= Standard Deviation. WQI= water Quality Index.

Table 2. Pearson correlation coefficient of water quality parameters (n=36); p<0.01

	EC	TDS	PH	HD
EC	1			
TDS	0.9794	1		
PH	-0.4254	-0.4173	1	
HD	0.1080	0.0719	-0.0385	1

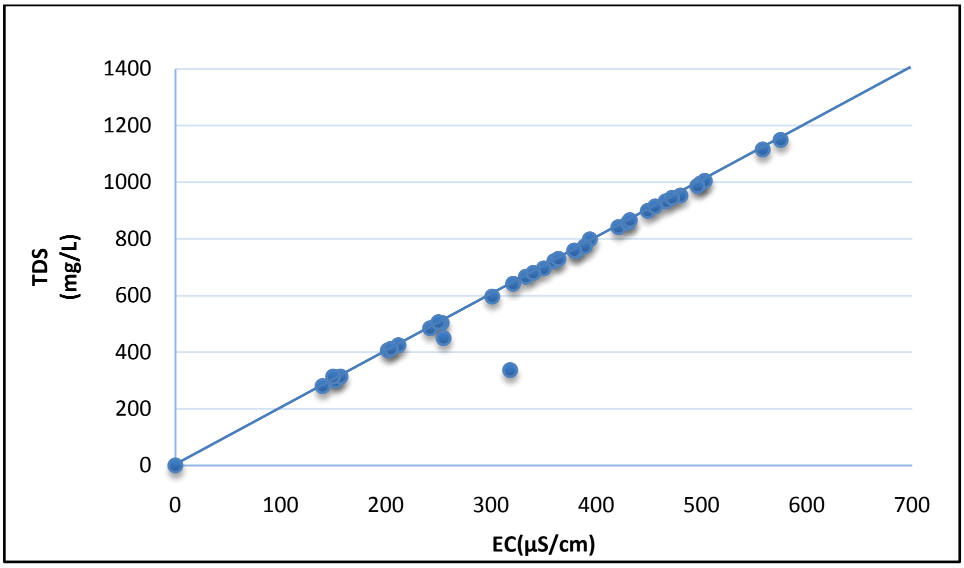

Figure 3. Graph of the TDS vs EC for all locations.

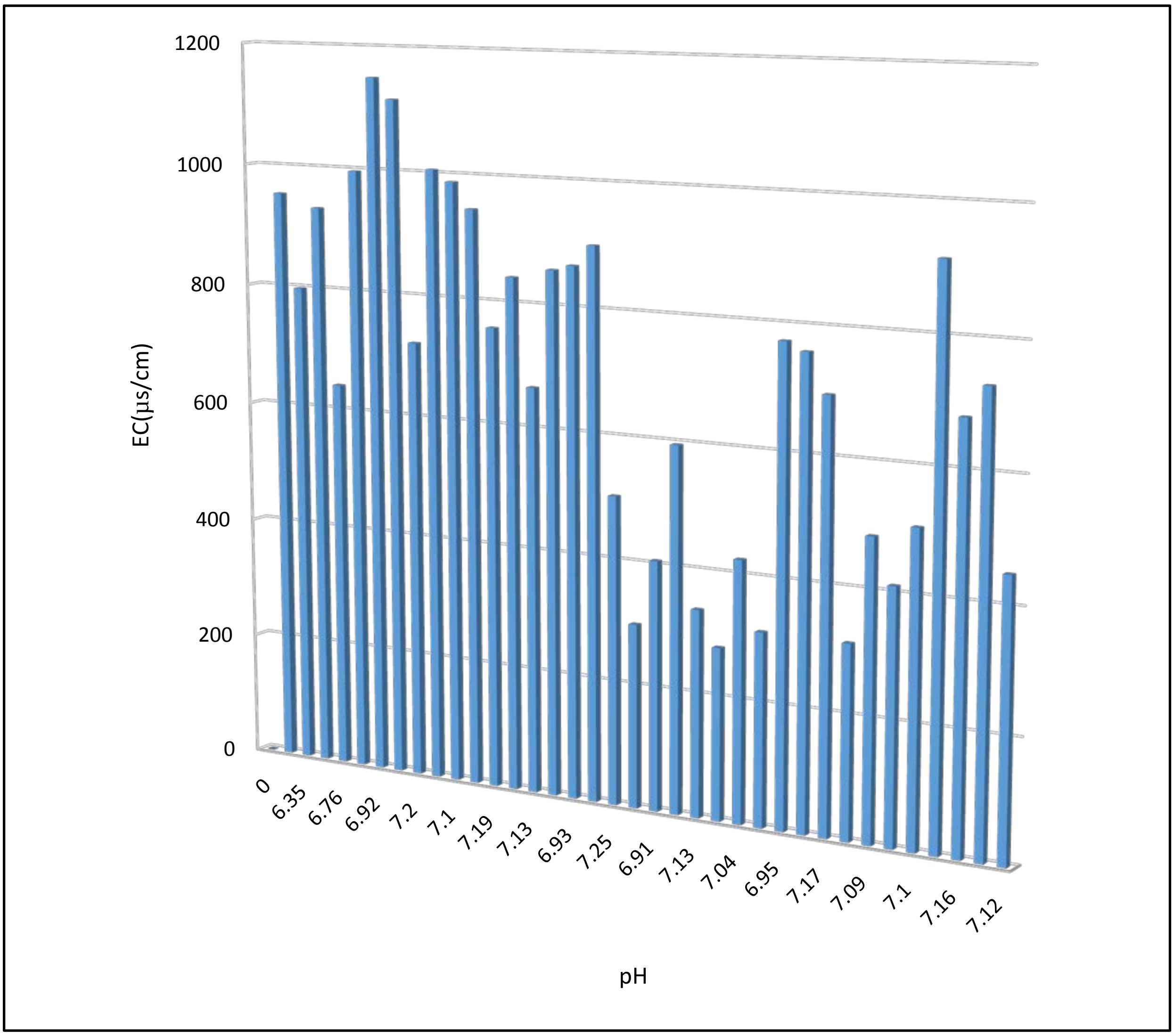

Figure 4. A cluster column chart that relates EC and pH of all the sites

The moderately low hydraulic head value shown in Table 1 is an indication that solid suspension due to pressure in water is not associated with these sites, which further affirms the purity of groundwater in the study area. Also, WQI calculated using the four stepwise equations shown above gave a value of 17.20 %. The result agrees with the findings of [26]. This implies that the water quality is excellent as represented in Table 3. Therefore, the water is good for both human and animal consumption.

Table 3. Water quality rating

Rating Class	WQI
>100	Unsuitable
76-100	Very Poor
51-75	Poor
26-50	Good
0-25	Excellent

5. Conclusion

The values of each parameter obtained from the sampled wells (in the study area) do not differ significantly among themselves. This might be because the samples were taken in the same geographical locations and are prone to similar human activities and environmental conditions. The graph plotted shows a vivid relationship between the EC and TDS, and then pH, backed up with a statistical correlation analysis which shows a positive correlation between EC and TDS, and a slightly inverse relationship between EC and pH. Moreover, they are within the recommendation of the World Health Organization's standards for water quality, even as proven by the water quality (WQI) calculation. This can be interpreted to mean that groundwater sources (wells) in Abeokuta North Local Government are good for drinking.

Significance Statement

This study discovered the quality of the groundwater sources in Abeokuta North, Ogun, Nigeria. We imply that the groundwater in the study area is good for drinking. It would serve as a piece of background information, perhaps researchers opt to conduct further assessments in this region. In addition, this novel research could be beneficial in the future in a situation where an outbreak of waterborne illness occurs in the area; hence, this report would serve as a guide to backdate the time when and when not, contaminants that dent the quality of the water might have been introduced. In this light, we encourage the residents to improve and maintain the usage of the groundwater sources.

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Competing Interest

The authors declare no competing interest

References

[1] Murray CJ, Lauer JA, Hutubessy RC, Niessen L, Tomijima N, Rodgers A, et al. Effectiveness and costs of interventions to lower systolic blood pressure and cholesterol: a global and regional analysis on reduction of cardiovascular-disease risk. Lancet; 2003. 361(9359): 717-725.

[2] Adekunle A.A., Badejo A.O., and Oyerinde A.O. 2013. Ion studies on Groundwater Contamination: Water Quality of Abeokuta, Ogun State, southwest Nigeria. Journal of Environment and Earth Science www.iiste.org ISSN 2224-3216 (paper) ISSN 2225 0948 (online) vol. 3, No.5, 2013.

[3] Saeed, T.U and D. Khan. 2014. Assessment and conservation of groundwater quality: A challenge for agriculture. Br.J. Applied Sci. Technol. 4: 1256-1272.

[4] Mahananda H.B, Mahananda M.R, and B.P. Mohanty. 2005. Studies on the Physico-chemical and Biological Parameters of a Fresh Water Pond Ecosystem as an Indicator of Water Pollution. Ecol. Env & Cons. 11(3-4), pp 537-541.

[5] Frik Schutte. 2006. Development of a handbook for the operation of water treatment works. The water research commission; the water institute of southern Africa. ISBN: 1770054286.

[6] Annan K.A. 2003. Message on World Environment Day "Water: Two Billion People Are Dying for It!" — highlights the centrality of water to human survival and sustainable development. World Health Organization secretary-general of the united nations. Press Release SG/SM/8707; OBV/348.

[7] Damla, N., Cevik, U., Karahan, G., and Kobya, A.I. Gross alpha and beta activities in tap water in eastern black sea region of turkey. 2006. Chemosphere vol. 62(37). p957-960. 2nd edition. Butterworth Publishers, PP. 55-65.

[8] Jimmy, D.H., Sundufu, A.J., Malanoski, A.P. et al. Water quality associated public health risk in Bo, Sierra Leone. Environ Monit Assess 185, 241-251 (2013).

[9] Webber JS, Covey JR, King MV. Asbestos in drinking water supplied through grossly deteriorated A-C pipe. Journal of the American Water Works Association, 1989. 81(2):80-85.

[10] Margherita Ferrante, Salvatore S.S, Santina L.F, Alfina Grasso, Angela Dimartino, Chiara Copat. 2017. Groundwater-based water wells characterization from Guinea Bissau (Western Africa): A risk evaluation for the local population. Elsevier: Sciencedirect.

[11] Bhatia, S. C. Environmental Pollution and Control in the chemical process industries. 2006. ISBN13: 9788174091062.

[12] Mohammad Aljaradin, Kenneth M. Persson. Municipal Landfilling Practice and Its Impact on the Water Resources - Jordan, *World Environment*, 2014. Vol. 4 No. 5, pp. 213-218.

[13] Danielle K. Hare, Ashley M. Helton, Zachary C. Johnson, John W. Lane, and Martin A. Briggs. 2021. Continental-scale analysis of shallow and deep groundwater contributions to streams; Open access; nature communications 12, article number: 1450 (2021).

[14] Tyler J.Thompson, Martin A.Briggs, Patrick J.Phillips, Vicki S.Blazer, Kelly L.Smalling, Dana W.Kolpin, Tyler Wagner. 2021. Groundwater discharges as a source of phytoestrogens and other agriculturally derived contaminants to streams. Science direct; science of the total environment; volume 755, part 1: 142873.

[15] Wei Zhi and Li Li. 2021. The Shallow and Deep Hypothesis: Subsurface Vertical Chemical Contrasts Shape Nitrate Export Patterns from Different Land Uses.

[16] MacDonald, A.M. and R.C. Calow. 2009. Developing groundwater for secure rural water supplies in Africa Desalination, 248: 546-556.

[17] Al-Harbi, O.A., G. Hussain, M.M. Khan, M.A. Moallim and I.A. Al-Sagaby. Evaluation of groundwater quality and its recharge by isotopes and solute chemistry in Wadi Malal, Al-Madinah Al-Munawarah, Saudi Arabia. Pak. J. Biol. Sci. 2006, 9: 260-269.

[18] Oyem, H. H., Oyem, I. M., and Ezenweali, D. 2014. Temperature, pH, Electrical Conductivity, Total Dissolved Solids and Chemical Oxygen Demand of Groundwater in Boji-BojiAgbor/Owa Area and Immediate Suburbs. *Research Journal of Environmental Science* ISSN 1819-3412.

[19] Tyagi, Shweta, et al. "Water Quality Assessment in Terms of Water Quality Index." American Journal of Water Resources 1.3 (2013): 34-38.

[20] Jiri Hulcr, Andrew M. Latimer, Jessica B. Henley, Nina R. Rountree, Noah Fierer, Andrea Lucky, et al. "A Jungle in There: Bacteria in Belly Buttons are Highly Diverse but Predictable." PLoS ONE 7 no. 11 (2012): e47712.

[21] Shahidullah, S.M., M.A. Hakim, M.S. Alam and A.T.M. Shamsuddoha. 2000. Assessment of groundwater quality in a selected area of Bangladesh. Pak. J. Biol. Sci.

[22] Ahaneku, I.E. and P.A. Adeoye, 2014. Impact of pit latrines on groundwater quality of Fokoslum, Ibadan, Southwestern Nigeria. Br. J. Applied Sci. Technol., 4: 440-449.

[23] Adewole Michael Gbadebo. 2020. Assessment of quality and health risk of peri-urban groundwater supply from selected areas of Abeokuta, Ogun State, Southwestern Nigeria. Environ Geochem Health. Springer Link.

[24] Ojekunle Olusheyi Zacchaeus, Mujeeb Balogun Adeyemi, Adeyemi Azeem Adedeji, Kayode Adesina Adegoke, Abdulraheem Okehi Anumah, Adewale Matthew Taiwo, et al. Effects of industrialization on groundwater quality in Shagamu and Ota industrial areas of Ogun State, Nigeria. Elsevier; open access. 2020.

[25] Srinivas J, Purushotham A.V and Murali Krishna K.V.S.G. Determination of Water Quality Index in Industrial areas of Kakinada, Andhra Pradesh, INDIA. International Research Journal of Environment Sciences. ISSN 2319–1414 Vol. 2(5), 37-45, May (2013). www.isca.in.

[26] Ram, A., Tiwari, S.K., Pandey, H.K. *et al.* Groundwater quality assessment using water quality index (WQI) under GIS framework. *Appl Water Sci* 11, 46 (2021).

[27] Gbenga J. Oladehinde., Lasun M. Olayiwola., Kehinde O. Popoola. 2018. Land accessibility constraints of migrants in rural border settlements of Ogun State, Nigeria. Environmental and socio-economic studies.

[28] Oladehinde John Gbenga Obafemi., Lasun M. Olayiwola., Kehinde Olayinka Popoola. 2018. Land accessibility constraints of migrants in rural border settlements of Ogun State, Nigeria. Environmental & Socio-economic Studies 6(1): 46-56.

[29] Baloye, D.O. and Palamuleni, L.G. 2016. Modeling a critical infrastructure-driven spatial database for proactive disaster management: A developing country context’, Jàmbá: Journal of Disaster Risk Studies 8(1), a220. 2016.