

Research Article

Groundwater Quality Assessment in Akungba Akoko, Ondo State, Nigeria

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Abstract: Twenty water samples were obtained in Akungba Akoko, Ondo State, Nigeria in order to determine the groundwater quality in the area. Thirteen samples were obtained from hand-dug wells, two samples were obtained from a spring while the remaining five samples were collected from boreholes. These samples were subjected to both physical and chemical analyses with a view to comparing the results obtained with the World Health Organization's (WHO) standard for quality drinking water. The results of the physical parameters measured shows that the colour ranges from 5°H to 50°H, turbidity ranges from 2NTU to 40NTU and the electrical conductivity ranges from 2.2×10^2 mho/cm to 1.4×10^3 mho/cm. Chemical analysis results on the other hand show that all the samples have pH within the weakly acidic range except for sample HDW 3 that falls within the weakly alkaline range. Furthermore, the Total Dissolved Solids (TDS) range from 154 to 980 mg/L while the Total Hardness of the water samples range from 24 to 280 mg/L. Ionic studies show that the Ca^{2+} , Na^+ , K^+ and Mg^{2+} occur in order of decreasing abundance in the samples with the concentrations ranging from 10 to 160 mg/L, 20 to 90 mg/L, 10 to 90 mg/L and 14 to 150 mg/L, respectively. The anions present in the water samples in order of decreasing abundance are HCO_3^- , Cl^- , SO_4^{2-} and NO_3^- with their concentrations ranging from 44 to 292 mg/L, 10 to 77 mg/L, 0.01 to 50 mg/L and 0.01 to 4.0 mg/L, respectively. It has been shown that anthropogenic inputs can continually ruin the suitability of the water for safe drinking purpose. Therefore, the ability to quickly control the anthropogenic inputs to the groundwater system in Akungba Akoko area will assist in keeping the quality of groundwater in Akungba Akoko to be maintained.

Keywords: Electrical conductivity, groundwater, Total Dissolved Solids (TDS), turbidity

INTRODUCTION

Underground and surface water usually constitute the main sources of water in many hydrological setting. Underground water is held within the pore spaces, fractures and weathered regoliths of rocks. It is believed that this kind of water is protected from contamination primarily because the movement of groundwater through the pore spaces offer a natural sieving mechanism which significantly reduces the quantity of pollutants that the water can carry. Shallow underground water is the principal source of water in rural and developing communities, such as Akungba Akoko, because of the relatively cheap cost of exploitation. Despite the general assumption that groundwater is free from contamination relative to surface water, the ever increasing population of Akungba Akoko and the associated anthropogenic inputs on the groundwater system demands quality assessment of the underground water sources in the area based on physicochemical criteria in order to ascertain that the water is safe for consumption.

Akungba Akoko is a rapidly developing university town in the northern part of Ondo State, Nigeria. It lies

between Latitudes 07°27'N and 07°30'N and Longitudes 005°42'E and 005°45'E (Fig. 1). The area is situated in the tropical rain forest region of Nigeria with a mean annual rainfall of 150 cm, mean temperature of 24°C and mean humidity of 80% (Taiwo, 2008).

The area is characterized by wet and dry seasonal variations. It is underlain by the rocks of the basement complex of South-western Nigeria. The rocks in the study area are migmatitic with the most predominant components being the granite-gneiss and grey gneiss. These rocks are covered by regoliths with thickness variation across the town. The wells in many parts of Akungba are shallow reflecting the extent of the weathered profile in the study area. Structural features in the rocks are those typically found in metamorphic rocks. Faults and fractures are also present in the rocks.

MATERIALS AND METHODS

Twenty water samples were obtained from various sources. Thirteen of the samples are from hand-dug wells, five of the samples are from a borehole and the remaining two samples are from a spring source. Water

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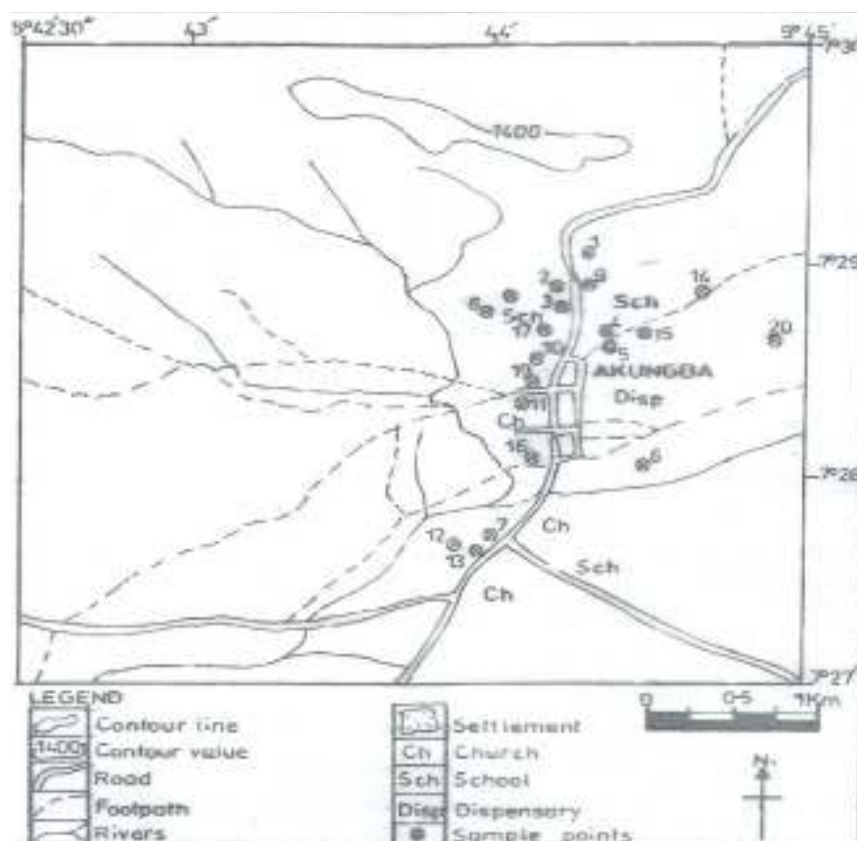


Fig. 1: Drainage Map of Akungba Akoko showing the sampling locations

sampler, rinsed with water from a sample location, was used to collect the samples at each location. All necessary precautionary measures were taken in order to avoid sample mix-ups and contamination. The samples were transported, immediately after collection in the field, to the Ondo State Water Corporation Central Laboratory where both physical and chemical analyses were carried out on the samples.

The Atomic Absorption Spectrophotometer (AAS 5100 PC Perkins) was used in the determination of the elemental composition (cations and anions) of the samples. The conductivity meter bridge was used to determine the conductivity and the pH meter was used to determine the pH of each of the samples. Table 1 shows a summary of the observations and response from consultation noted at each of the sampling locations.

RESULTS AND DISCUSSION

The discussion of the results will be categorized under the parameters measured either physical or chemical parameters.

Physical parameters: The observations and measurements made with respect to the physical parameters of the samples measured are shown in Table

2. The appearance of the water samples varied from being clear through milky to being coloured. 5% of the samples exhibited a milky appearance while 5% of the samples tend to be coloured. Another 5% of the samples are slightly coloured while the remaining 85% of the samples are clear. Colour in the water samples range from 5°H to 50°H. The range of colouration is highest in the hand dug wells (5°H to 50°H). Colouration in the borehole samples range from 5°H to 7°H while the range in spring water is from 5°H to 8°H. Although all the samples exhibit colouration properties within the World Health Organization (WHO) permissible limit, only 5 of the samples meet the WHO regulations (highest desirable limit) for colouration in water.

Turbidity in most of the water samples is low indicating that most of the samples have low silty, clayey and colloidal content. 10 of the 13 samples from the hand dug wells, 1 of the 2 spring samples and 4 of the 5 borehole samples meet the WHO (2006) guidelines. The WHO (2006) permissible limit for turbidity in water sample is not met by sample from HDW 3.

The electrical conductivity in all the samples range from 2.4×10^2 mho/cm- 1.4×10^3 mho/cm. The samples from the hand-dug wells show a conductivity range from 2.4×10^2 mho/cm- 1.4×10^3 mho/cm. The

Table 1: Summary of sample locations and general information obtained in the field

Location No	Sample No	Location (Lat. and Long.)	Altitude (m)	W.C	W.D (m)
1	HDW 1	07° 29.014'N 005° 44.283'E	373.07	M	0.98
2	HDW 2	07° 28.883'N 005° 44.232'E	371.55	M	0.72
3	HDW 3	07° 28.849'N 005° 44.253'E	360.88	N.C	0.83
4	HDW 4	07° 28.705'N 005° 44.389'E	360.57	N.C	0.70
5	HDW 5	07° 28.630'N 005° 44.328'E	353.56	M	0.69
6	HDW 6	07° 28.111'N 005° 44.477'E	334.97	W	1.10
7	HDW 7	07° 27.703'N 005° 43.957'E	335.58	M	1.20
8	HDW 8	07° 28.758'N 005° 43.977'E	328.87	M	0.96
9	HDW 9	07° 28.880'N 005° 44.262'E	361.49	W	0.65
10	HDW 10	07° 28.507'N 005° 44.119'E	354.48	W	1.10
11	HDW 11	07° 28.285'N 005° 44.025'E	342.59	W	1.00
12	HDW 12	07° 27.556'N 005° 43.904'E	330.35	W	1.10
13	HDW 13	07° 27.537'N 005° 43.905'E	326.44	W	0.70
14	SP 1	07° 28.821'N 005° 44.700'E	368.50	-	-
15	SP 2	07° 28.630'N 005° 44.470'E	356.92	-	-
16	BH 1	07° 28.050'N 005° 44.193'E	329.48	-	-
17	BH 2	07° 28.619'N 005° 44.241'E	349.30	-	-
18	BH 3	07° 28.783'N 005° 44.105'E	328.87	-	-
19	BH 4	07° 28.391'N 005° 44.129'E	338.93	-	-
20	BH 5	07° 27.596'N 005° 44.978'E	323.39	-	-

Location No	Depth (m)	C.D	N.R	Purpose
1	7.2	2003	12	Drinking
2	4.8	1985	8	Drinking
3	2.2	2006	-	Drinking
4	3.6	2005	6	Drinking
5	4.2	2002	7	Drinking
6	3.6	1994	-	Drinking
7	2.2	1960	-	Drinking
8	7.1	2006	12	Drinking
9	4.4	2008	-	Drinking
10	3.2	1979	-	Drinking
11	3.4	1981	-	Drinking
12	2.8	1960	-	Drinking
13	5.4	2006	9	Drinking
14	-	-	-	Drinking
15	-	-	-	Drinking
16	-	1999	-	Drinking
17	-	1999	-	Drinking
18	-	1999	-	Drinking
19	-	2002	-	Drinking
20	-	1999	-	Drinking

Key: W.C-Well Cover [(W-Wooden); (M-Metal) and (N.C-Not Covered)]; W.D-Well Diameter; C.D-Completion Date; N.R-Number of Rings; HDW-Hand-dug Well; SP-Spring; BH-Borehol.

Table 2: Summary of results of measured physical parameters

Location No	Sample No	Appearance	Colour (°H)	Turbidity (NTU)	Conductivity (mho/cm)	Temp. (°C)
1	HDW 1	Clear	10	3	2.4×10 ²	25.0
2	HDW 2	Clear	10	2	3.6×10 ²	25.6
3	HDW 3	Coloured	50	40	4.0×10 ²	25.6
4	HDW 4	Clear	15	5	4.8×10 ²	25.0
5	HDW 5	Clear	5	2	3.1×10 ²	25.0
6	HDW 6	Clear	6	3	6.6×10 ²	25.0
7	HDW 7	Clear	8	4	1.3×10 ³	25.0
8	HDW 8	Clear	5	3	2.3×10 ²	25.0
9	HDW 9	Milky	12	18	2.2×10 ²	25.0
10	HDW 10	Clear	5	4	1.4×10 ³	25.0
11	HDW 11	Clear	6	4	1.4×10 ³	25.0
12	HDW 12	Clear	7	5	8.8×10 ²	25.0
13	HDW 13	Clear	10	8	4.8×10 ²	25.0
14	SP 1	Slightly coloured	8	10	4.1×10 ²	25.0
15	SP 2	Clear	5	5	8.6×10 ²	25.0
16	BH 1	Clear	7	3	8.8×10 ²	25.0
17	BH 2	Clear	10	5	3.4×10 ²	25.0
18	BH 3	Clear	10	5	8.6×10 ²	25.0
19	BH 4	Clear	5	3	4.5×10 ²	25.0
20	BH 5	Clear	8	6	9.6×10 ²	25.0

Table 3: Summary of results of analyzed chemical parameters

Sample No	Total dissolved solids	Total hardness	pH	Ca ²⁺ (mg/L)	Mg ²⁺ (mg/L)	K ⁺ (mg/L)
HDW 1	168.00	40.00	6.20	24.00	16.00	70.00
HDW 2	252.00	70.00	6.20	30.00	40.00	82.00
HDW 3	280.00	82.00	7.40	50.00	32.00	50.00
HDW 4	336.00	48.00	6.40	20.00	28.00	70.00
HDW 5	217.00	50.00	6.20	30.00	20.00	30.00
HDW 6	462.00	104.00	6.00	90.00	14.00	70.00
HDW 7	910.00	140.00	6.20	88.00	52.00	60.00
HDW 8	161.00	24.00	6.00	10.00	14.00	10.00
HDW 9	154.00	242.00	6.00	160.00	82.00	80.00
HDW 10	980.00	164.00	6.20	120.00	46.00	60.00
HDW 11	980.00	164.00	6.00	140.00	24.00	70.00
HDW 12	616.00	280.00	6.40	130.00	150.00	70.00
HDW 13	336.00	60.00	6.00	40.00	20.00	10.00
SP 1	287.00	98.00	6.80	54.00	44.00	60.00
SP 2	602.00	196.00	6.60	80.00	16.00	40.00
BH 1	616.00	160.00	6.40	92.00	68.00	90.00
BH 2	238.00	70.00	6.40	46.00	24.00	20.00
BH 3	602.00	140.00	6.00	90.00	50.00	80.00
BH 4	315.00	170.00	6.00	104.00	66.00	50.00
BH 5	672.00	160.00	6.20	130.00	30.00	74.00
Sample No	Na ⁺ (mg/L)	Cl ⁻ (mg/L)	SO ₄ ²⁻ (mg/L)	NO ₃ ⁻ (mg/L)	HCO ₃ ⁻ (mg/L)	
HDW 1	80.00	20.00	1.00	1.20	62.00	
HDW 2	90.00	26.00	1.50	1.00	80.00	
HDW 3	60.00	15.00	0.01	1.50	94.00	
HDW 4	60.00	29.00	5.00	0.40	50.00	
HDW 5	40.00	20.00	0.04	0.01	80.00	
HDW 6	75.00	31.00	20.00	4.00	140.00	
HDW 7	70.00	77.00	10.00	3.00	180.00	
HDW 8	20.00	15.00	0.08	0.01	44.00	
HDW 9	90.00	50.00	30.00	4.00	292.00	
HDW 10	82.00	12.00	40.00	2.50	218.00	
HDW 11	84.00	15.00	35.00	1.80	220.00	
HDW 12	78.00	26.00	20.00	1.50	204.00	
HDW 13	20.00	32.00	0.02	0.01	82.00	
SP 1	70.00	45.00	0.05	2.00	120.00	
SP 2	50.00	62.00	15.00	3.50	220.00	
BH 1	80.00	10.00	15.00	0.04	210.00	
BH 2	30.00	27.00	7.00	1.00	94.00	
BH 3	70.00	66.00	20.00	3.00	190.00	
BH 4	70.00	39.00	25.00	2.20	230.00	
BH 5	78.00	34.00	50.00	1.00	198.00	

conductivity in the borehole samples range from 3.4×10^2 mho/cm- 9.6×10^2 mho/cm while conductivity in the spring samples range from 4.1×10^2 mho/cm- 8.6×10^2 mho/cm.

Chemical parameters: The measurements recorded in the laboratory with respect to the analysis of the chemical parameters of the samples are shown in Table 3. The hydrogen ion concentration (pH) of the water samples range from 6.0-7.4 with an average pH value of 6.28; implying that the samples range from being slightly acidic to slightly alkaline. All the samples have pH within the weak acidity range (6.0-6.8) except for HDW 3 which has pH within the weak alkaline (7.4) range. Water exhibiting this kind of characteristics is generally good for drinking and for other domestic uses based on the WHO (2008) guidelines. The approximately neutral behaviour of the water samples reduces the tendency of increased rate of reaction by the fluid.

The Total Dissolved Solids (TDS) range from 154 to 980 mg/L. The TDS values of the samples show that

all the samples exhibit properties within the permissible limit of the WHO (2006) guidelines. The correlation co-efficient between the Electrical Conductivity (EC) and the Total Dissolved Solids (TDS) of the samples is 1. This implies that the TDS is basically responsible for the electrical conductivity measured in the water samples (Hagan *et al.*, 2011). MacCutcheon *et al.* (1983) posited that water samples with TDS level of 600 mg/L and less are suitable for drinking while increasing TDS levels are associated with increasing non-potability of the water. Based on MacCutcheon *et al.* (1983) position, the samples analyzed become increasingly unpotable for drinking in the order SP 2, BH 3, HDW 12, BH 1, BH 5, HDW 7, HDW 10 and HDW 11.

Total hardness of the samples range from 24 to 280 mg/L in the hand-dug wells, the range is from 70 to 170 mg/L in the borehole samples while the range is from 98 to 196 mg/L in the spring water samples. 7 of the 13 hand-dug well samples are compliant with the WHO (2006) standard, 1 of the 2 spring water samples and 1

of the 5 borehole samples meet the WHO (2006) standard. However, all the samples fall within the permissible range of hardness for drinking water according to the WHO (2006) regulation. The interactions of other physico-chemical parameters (such as pH) along with the hardness of water samples may result in scale deposition in pipes when the total hardness is above 200 mg/L. However, soft water with less than 100 mg/L hardness concentration is corrosive for water pipes (WHO, 2008). Provided the other physico-chemical parameters permit, water from HDW 9 and HDW 12 will cause scale deposition while water from HDW 1, HDW 2, HDW 3, HDW 4, HDW 5, HDW 8, HDW 13, SP 1 and BH 2 will cause water pipe corrosion.

In ionic studies, water participates in chemical reactions and also plays a role in transporting weathered materials resulting in leaching. These characters make groundwater assessment based on ionic studies possible (Malomo *et al.*, 1993; Boboye, 2008). The most abundant cations in the water samples are Ca^{2+} , Na^+ and K^+ . The result shows that the concentration of Ca^{2+} ranges from 10 to 160 mg/L. Although Ca^{2+} and Mg^{2+} ions exhibit similar characteristics, Ca^{2+} in most cases are generally found in higher concentrations than the Mg^{2+} . The concentration of Mg^{2+} range from 14 to 150 mg/L. The possible source of the Mg^{2+} in the water could be from the chemical weathering of mafic and other related minerals constituting the basement complex rocks common in the area.

The concentration of Na^+ in the water samples range from 20 to 90 mg/L while the concentration of K^+ ranged from 10 to 90 mg/L. The Na^+ must have entered the groundwater system by natural means; possibly through the weathering of sodium-rich feldspars and leaching of clay minerals (Spears and Reeves, 1975; Todd, 1980). However, the K^+ may be sourced from orthoclase or microcline feldspars, micas and clay minerals. The K^+ may also have entered the groundwater system through the leaching of fertilizers such as NPK. Todd (1980) indicated that a concentration of Na^+ or K^+ in excess of 50 mg/L can lead to accelerated scale formation in boilers. Therefore, only samples HDW 5, HDW 8, HDW 13, SP 2 and BH 2 will not rapidly form scales in boilers of treatment plants if located in Akungba Akoko.

The most abundant anion in the sample is HCO_3^- . The abundance of this ion is presumed to have an effect on the pH values, by reducing the acidity level, of the samples. However, it does not necessarily imply that the pH value must fall within the alkalinity range; it will reduce the acidity of the samples (Taylor, 1958). The concentration of HCO_3^- ranges from 44-292 mg/L.

Another abundant anion in the samples is Cl^- . The concentration ranges from 10 to 77 mg/L. The geological nature of the environment does not allow evaporite formation; which could be a major source of chlorine. However, the concentration of mineral salts

by evapo-transpiration may be an important source of Cl^- in the area (Egbunike, 2007). Anthropogenic sources are assumed to be the major source of Cl^- for instance Cl^- contribution from the use of bleach in laundry and chlorination attempt by the locals in order to treat their wells.

The concentration of NO_3^- ranges from 0.01 to 4.0 mg/L. The concentration in all the samples falls within the acceptable range by WHO (2006) standards. The possible sources of NO_3^- in this case are likely to be both anthropogenic (improper sewage disposal near water sources) or by natural means of nitrogen fixation or from leguminous plants. Sources from agricultural practices (NPK fertilizers) cannot also be discounted. The SO_4^{2-} in the samples analyzed range from 0.01 to 50 mg/L. The concentration of the SO_4^{2-} is within the limits of the WHO (2006) standard for drinking water.

CONCLUSION

The study has provided information about the groundwater quality status in Akungba Akoko. At current levels, all the results of physico-chemical parameters show that the underground water in Akungba Akoko falls within the highest desirable as well as maximum permissible limit of the WHO (2006, 2008) standards. Assessments of the controls of the water chemistry indicate a possible influence from the underlying geology of the area (basement bedrock and weathered products), the infiltrated precipitated water and anthropogenic factors. Very limited control can be exercised on the geology and groundwater recharge system in the area. Therefore in order to keep the groundwater in Akungba Akoko within safe limits for consumption, adequate measures must be taken to significantly reduce anthropogenic inputs into the groundwater contamination, because the population growth in Akungba Akoko is increasing at a geometric rate.

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