

GEOCHEMICAL ANALYSIS OF GROUNDWATER QUALITY IN AGBARA AND ENVIRONS

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Abstract. This study examines the geochemical compositions of groundwater from three communities viz: Agbara, Igbesa and Lusada to determine their suitability for human consumption. A total of seventeen (17) boreholes were sampled and analyzed using standard procedures. The parameters determined include: pH, temperature, electrical conductivity (EC), redox potential (RP), biochemical oxygen demand (BOD), anions (Cl^- , PO_4^{3-} , NO_3^- , SO_4^{2-} , HCO_3^- and metals (As^{2+} , Ca^{2+} , Mg^{2+} , K^+ , Na^+ , Mn^{2+} and Cd^{2+}). Results showed variations in the values of water quality parameters from one community to another. pH of water samples from Agbara and Igbesa were acidic (4.1 - 5.8) and generally fell below World Health Organization (WHO) limit of 6.5 – 8.5 while that of Lusada was within the WHO range. Chloride, phosphate, bicarbonate and BOD values were generally high in all the three study areas greater than the acceptable limits in drinking water. Metal concentrations in all the sampled groundwater were very low while cadmium and arsenic were not detected in Igbesa and Lusada samples. Since most of the parameters with abnormal values have no (WHO) health-based guidelines, groundwater in these study areas may be suitable for direct consumption.

Keyword: groundwater resource, geochemistry, parameters, consumption, Agbara

Introduction

Groundwater exploitation - for the purpose of supplying good quality drinking water is widely practiced in many developing nations of the world. This is achieved by well sinking, which could be shallow (hand dug or tube wells), or deep as in the case of boreholes. Well sinking is not a new phenomenon but an ancient craft that had been in practice for thousands of years (Todd, 1980). It is an essential resource that supplies drinking water to a large number of people in Nigeria in the urban and rural areas. The study of geochemical compositions of groundwater is therefore, important due to the attached significance for potable water-supply. Besides, it is an alternative against the epileptic supply of pipe-borne water by the water authority. However, the quality of any groundwater resource in terms of physical, chemical and biological compositions determines its fitness for human consumption and diverse usage. These qualities, in turn, are functions of groundwater ionic species like Na^+ , K^+ , Ca^{2+} , Mg^{2+} , HCO_3^- , NO_3^- , SO_4^{2-} , and Cl^- (Sadashivaiah et al., 2008). Human activities such as sewage disposal, industrial waste products, agriculture are as well capable of altering groundwater quality (Adekunle et al., 2007). The influence of water ions on groundwater chemistry depends on their concentrations in the aquifer. Groundwater quality also relies on the

compositions of water recharged into the ground, the interaction between it and media of the aquifer; the reactions that take place in the aquifer and the overlying soil (Rahaman, 1976). International standards have been set as criteria for drinking water quality by relevant bodies such as World Health Organization (WHO), European Community, (EC) and United State Environmental Protection Agency (USEPA). The essence of this is to safeguard the public health against waterborne diseases. However, there are no water standard guidelines for drinking water in Nigeria. The defunct Federal Environmental Protection Agency, FEPA (1991) had only successfully set guidelines for effluents discharge into Nigeria's waterways, in which compliance was at the moment at zero level. It is therefore, necessary to assess the quality of some of these aquifers and compared it with the international standards. This will however, create a public awareness on the possible health risks attached to abnormal geochemical values of the groundwater especially in the study communities.

Many works have been done on the groundwater quality from the southwestern Nigeria. Adekunle et al. (2007) had analyzed groundwater quality of hand-dug wells from Igbora in Oyo state. Results showed pollutions of wells located close to dumping sites. High water parameters such as nitrate, BOD, Cd, Pb and Coliforms were recorded higher than WHO standard indicating organic pollution. Groundwater resource from Lagos state has been studied by Yusuf (2007) and Longe and Balogun (2009). Gbadebo et al. (2010) had also observed high nitrate concentrations in groundwater aquifer from Sango and Abeokuta in Ogun state. Taiwo et al. (2011) had reported the physico-chemical characteristics of groundwater quality of wells sampled in Abeokuta. The metal contents of boreholes sampled in Sango has been studied by Ayedun et al (2011), while a comprehensive geochemical analysis of groundwater aquifers in Sango had been carried out by Gbadebo and Taiwo (2011). The major concern of groundwater in southwestern Nigeria is the issue of high nitrate concentration. High nitrate concentrations in these groundwater aquifers might be connected to seepage of leachates from septic tanks, dumping sites and agricultural activities. Nitrate value greater than permissible standard in drinking water could pose a health problem to infants less than 6 months of age for blue baby syndrome (Taiwo, 2010). Faecal pollution of the groundwater in southwestern Nigeria has also been documented (Adekunle et al., 2007, Orebiyi et al., 2009).

Materials and methods

Study areas

The study areas, which include Agbara, Igbesa and Lusada is situated within longitude 3°04' and 3°10' E, and latitude 6°31' and 6°34' N in Ado Odo/ Ota Local Government, Ogun state (*Fig. 1*), Nigeria. Agbara is noted for industrial activities in Ogun state while the Igbesa and Lusada are civil communities characterized by peasant farming with little or no viable industrial activities. *Table 1* shows the sampling locations and their coordinates.



Figure 1. The map of Ogun State showing the Local Government Areas (red arrow pointing to the study areas)

Table 1. Description of the groundwater locations

Borehole Serial number	Location	Latitude N	Longitudes E
1	Joak Block	06° 34' 319"	003° 04' 897"
2	Omiata Block	06° 33' 701"	003° 04' 758"
3	Car Wash	06° 31' 951"	003° 04' 537"
4	Dive Primary School	06° 31' 545"	003° 04' 566"
5	Opic estate1	06° 31' 431"	003° 04' 493"
6	Baptist church	06° 31' 042"	003° 04' 737"
7	Opic estate 2	06° 31' 090"	003° 04' 769"
8	Crawford University1	06° 30' 553"	003° 04' 690"
9	Crawford University2	06° 30' 682"	003° 04' 708"
10	Crawford University3	06° 30' 731"	003° 04' 605"
11	Ketu-Adie Owe1	06° 30' 853"	003° 04' 424"
12	Ketu-Adie Owe2	06° 30' 935"	003° 04' 164"
13	Crawform Guest house	06° 30' 688"	003° 04' 599"
14	GRA Igbesa	06° 30' 561"	003° 04' 733"
15	Lusada1	06° 35' 176"	003° 04' 892"
16	Grace court hotel	06° 35' 010"	003° 04' 123"
17	Lusada2	06° 35' 009"	003° 04' 055"

Geology of the study area

The study areas (Agbara, Lusada and Igbesa) form part of Dahomey basin, a very extensive sedimentary basin on the continental margin on the Gulf of Guinea, which extends from Volta River Delta, Southeastern Ghana in the west, to the Western flank of the Niger Delta (Jones and Hockey, 1964). This Formation known as Coastal Plain Sand is made up of poorly sorted sands, which are in parts cross-bedded and shows transitional to continental characteristics like Ilaro and Abeokuta Formations. The thickness of coastal plain sand ranges from 10m to 100m while the age falls under Pleistocene and Oligocene (Jones and Hockey, 1964).

Methodology

To determine the chemical constituent of the groundwater, a total of 17 borehole water samples were analyzed in this study in for physico-chemical parameters using standard procedures (APHA, 1989). The parameters evaluated were pH, temperature, electrical conductivity (EC), redox potential (RP), biochemical oxygen demand (BOD), chloride, phosphate, nitrate, sulphate, bicarbonate and metals (arsenic, calcium, magnesium, potassium, sodium, manganese and cadmium). Parameters like pH, temperature, EC and RP were measured in-situ using probe methods while BOD was determined by dilution method. However, chloride, sulphate and bicarbonate were determined in the laboratory by titrimetric method while phosphate and nitrate were assayed using spectrophotometric method. Analysis of metals was carried out by Atomic Absorption Spectrophotometry (AAS) except sodium and potassium which were determined by flame photometric method.

Table 2. Summary of analytical data of groundwater from Agbara

Parameters	Mean $\pm$ SD	Range	WHO (2008)
Temperature ($^{\circ}\text{C}$)	29.2 $\pm$ 17.2	27.7-32.2	
pH	4.34 $\pm$ 0.54	4.10-4.81	6.5-8.5
Electrical conductivity ($\mu\text{S cm}^{-1}$)	349 $\pm$ 9.74	195-721	
Redox Potential (RP) (mV)	350.4 $\pm$ 18.51	346-380	
BOD (mg L^{-1})	11.14 $\pm$ 18.51	10.43-12.67	
Chloride (mg L^{-1})	937.5 $\pm$ 569.40	531.5-1455.5	200-300
Phosphate (mg L^{-1})	7.83 $\pm$ 0.32	7.03-9.43	
Sulphate (mg L^{-1})	15.7 $\pm$ 0.89	14.0-18.05	< 250
Nitrate (mg L^{-1})	0.01 $\pm$ 0.00	0.01-0.02	50
Bicarbonate (mg L^{-1})	1804 $\pm$ 250.24	1022-2628	
Arsenic (mg L^{-1})	0.01 $\pm$ 0.00	0.01-0.02	0.01
Calcium (mg L^{-1})	15.0 $\pm$ 0.04	10.0-23.0	100-200
Potassium (mg L^{-1})	3.0 $\pm$ 0.04	2.0-4.0	
Sodium (mg L^{-1})	15.0 $\pm$ 0.04	14.0-16.0	200
Magnesium (mg L^{-1})	3.0 $\pm$ 0.01	2.0-13.0	250
Iron (mg L^{-1})	0.96 $\pm$ 0.39	0.00-2.00	0.30
Manganese (mg L^{-1})	0.01 $\pm$ 0.05	0.00-0.10	0.40
Cadmium (mg L^{-1})	ND		0.003

SD- Standard Deviation, ND-Not Detected, BOD-Biological Oxygen Demand

Results

Geochemical values of groundwater samples in Agbara, Igbesa and Lusada were shown in Table 2-4 respectively. Results of geochemical parameters follow similar trends in the three communities with results range: temperature (27.7-33.2 °C), pH (4.10-7.77), EC (195-721 $\mu\text{S cm}^{-1}$), RP (344-390 mV), BOD (9.47-15.3 mg L^{-1}), chloride (531.5-3088.5 mg L^{-1}), phosphate (6.94-9.43 mg L^{-1}), sulphate (10.75-18.05 mg L^{-1}), nitrate (0.01-0.02 mg L^{-1}), bicarbonate (1022-2628 mg L^{-1}), As (ND-0.02 mg L^{-1}), Ca (2.0-120.0 mg L^{-1}), K (1.0-20 mg L^{-1}), Na (14.0-38.0 mg L^{-1}), Mg (1.0-13.0 mg L^{-1}), Fe (0.0-2.0 mg L^{-1}), Mn (0.0-0.30 mg L^{-1}) and Cd (ND-0.02 mg L^{-1}).

Table 3. Summary of analytical data of groundwater from Igbesa

Parameters	Mean $\pm$ SD	Range	WHO (2008)
Temperature (°C)	30.32 $\pm$ 1.72	28.1-33.2	6.5-8.5
pH	4.78 $\pm$ 5.04	4.28-5.84	
Electrical conductivity ($\mu\text{S cm}^{-1}$)	377.5 $\pm$ 9.74	345-410	
Redox Potential (RP) (mV)	350.86 $\pm$ 18.51	344-385	200-300
BOD (mg L^{-1})	11.41 $\pm$ 19.82	9.47-15.3	
Chloride (mg L^{-1})	1887.64 $\pm$ 569.40	1132-3088.5	
Phosphate (mg L^{-1})	7.55 $\pm$ 0.32	6.94-8.05	< 250
Sulphate (mg L^{-1})	13.27 $\pm$ 0.89	11.93-14.4	
Nitrate (mg L^{-1})	0.01 $\pm$ 0.00	0.01-0.02	
Bicarbonate (mg L^{-1})	1585.1 $\pm$ 250.24	1153-1826	50
Arsenic (mg L^{-1})	0.01 $\pm$ 0.00	0.01-0.02	
Calcium (mg L^{-1})	30.0 $\pm$ 5.04	20-120	
Potassium (mg L^{-1})	3.0 $\pm$ 1.50	1.0-10.0	100-200
Sodium (mg L^{-1})	21.0 $\pm$ 2.04	15.0-26.0	
Magnesium (mg L^{-1})	2.0 $\pm$ 1.01	1.0-4.0	
Iron (mg L^{-1})	0.46 $\pm$ 0.39	0.00-1.10	0.30
Manganese (mg L^{-1})	0.06 $\pm$ 0.05	0.00-0.20	0.40
Cadmium (mg L^{-1})	0.01 $\pm$ 0.02	0.0-0.02	0.003

SD- Standard Deviation, ND-Not Detected, BOD-Biological Oxygen Demand

Table 4. Summary of analytical data groundwater from Lusada

Parameters	Mean $\pm$ SD	Range	WHO (2008)
Temperature ($^{\circ}\text{C}$)	29.3 $\pm$ 0.33	28.9-29.4	
pH	6.74 $\pm$ 0.10	6.52-7.77	6.5-8.5
Electrical conductivity ($\mu\text{S cm}^{-1}$)	253.3 $\pm$ 5.19	308-417	
Redox Potential (RP) (mV)	360.67 $\pm$ 5.44	359-390	
BOD (mg L^{-1})	10.31 $\pm$ 6.89	9.40-11.06	
Chloride (mg L^{-1})	1275.59 $\pm$ 51.21	1203.5-1312.25	200-300
Phosphate (mg L^{-1})	6.89 $\pm$ 0.19	6.70-7.03	
Sulphate (mg L^{-1})	11.60 $\pm$ 0.78	10.75-12.63	< 250
Nitrate (mg L^{-1})	0.01 $\pm$ 0.00	0.00-0.01	50
Bicarbonate (mg L^{-1})	1349.40 $\pm$ 185.30	1095-1531	
Arsenic (mg L^{-1})	ND		0.01
Calcium (mg L^{-1})	6.0 $\pm$ 0.06	2.0-15.0	100-200
Potassium (mg L^{-1})	10.0 $\pm$ 2.05	7.0-20.0	
Sodium (mg L^{-1})	28.0 $\pm$ 1.08	21.0-38.0	200
Magnesium (mg L^{-1})	4.0 $\pm$ 0.02	2.0-7.0	250
Iron (mg L^{-1})	1.50 $\pm$ 0.08	1.40-1.60	0.30
Manganese (mg L^{-1})	0.17 $\pm$ 0.09	0.10-0.30	0.40
Cadmium (mg L^{-1})	ND		0.003

SD- Standard Deviation, ND-Not Detected, BOD-Biological Oxygen Demand

Discussions

Water pH values of groundwater samples collected in Agbara and Igbesa were acidic while the pH of Lusada sample was slightly alkaline. Agbara and Igbesa water samples fell below the WHO limit for pH in drinking water given as 6.5 to 8.5 (WHO, 2008). The implication of the low pH may include corrosion, solubility of heavy metals and impartation of bitter and metallic taste in water (USEPA, 2007). However, the water hardness was very high in all the sampled groundwater, and might reduce the dissolution of metals (Adeyeye and Ayejuyo, 2002) against metal toxicity. Similarly, low pH in these boreholes may be attributed to dissociation of carbonic acid in the aquifer due to their unconfined nature (Zhou, 2006). Chemical contaminants from Agbara Industrial Estate seeping into groundwater might also have resulted into low water pH. Similar low pH values have been observed by Efe et al. (2005) in groundwater samples from Niger-Delta of Nigeria.

Redox potential is a measure of a water system's capacity to either release or gain electrons in chemical reactions (Eaton et al., 1995). The essence of RP measurement in

water is to evaluate corrosions of metals in drinking water. The range of RP in this study will not cause corrosion but may be considered in normal range of 350 mV-390 mV (EnviroEquip, 2007). Positive RP in the samples indicated that the boreholes are oxidizing with appreciably high dissolved oxygen.

Owen and Blair (1996) have defined Electrical conductivity as a measure of dissolved ions or salinity in water. EC values obtained in this study could be described as good according to Sadashivaiah, et al. (2008) classification of EC in water (*Table 5*). WHO desirable limit for EC in drinking water is 1000 $\mu\text{S cm}^{-1}$. All the observed mean values of EC fell within this limit. High salinity in groundwater may be associated with alluvial aquifers (Geetha et al., 2008).

Table 5. Salinity Standard (Sadashivaiah, et al., 2008)

EC ($\mu\text{S cm}^{-1}$)	Class
100-250	Excellent
250-750	Good
750-2250	Doubtful
> 2250	Unsuitable

High BOD in groundwater is a signal of organic pollution. The extreme high values of BOD recorded across the borehole in the three communities indicated that the groundwater resources were polluted. Water with BOD greater than 4 mg L^{-1} is considered a rejectable source by Kothandaraman and Ewing (1969) as depicted in Table 6. Environmental Canada (1977) and (1979) has classified water BOD values greater than 10 mg L^{-1} as polluted. Elevated values of BOD in these groundwater samples might probably be from infiltration of leachates from nearby dumpsites and septic tanks into the groundwater resource. Adekunle et al. (2007) reported a high value of BOD (35.0 mg L^{-1}) in groundwater close to defecating sites in Igbora, Nigeria. Abnormal values of BOD in groundwater could harbour pathogenic organisms which may cause water-borne diseases.

Table 6. BOD Standard for Raw Water: (Source: Kothandaraman and Ewing, 1969)

Average BOD value (mg L^{-1})	Class
0.25 – 1.5	Excellent source
1.5 – 2.5	Good source
2.5 – 4.0	Porous source
Greater than 4.0	Rejectable source

Sulphate and nitrate values were generally low in the groundwater samples with very slim possibility of initiating any health problems when the water is consumed. However, the mean values of phosphate in the groundwater was high, and could be attributed to weathering of underlain phosphate rocks in the aquifers and from other point sources. High phosphate values have been reported in groundwater near landfill site (Longe and Balogun, 2009). The greatest threats to groundwater quality and quantity include nutrient loading from agricultural fields, urban run-off, industrial effluents (and other contaminants that could infiltrate the groundwater systems), climate change, and high groundwater use (Danielopol *et al.*, 2003).

Mean values of chloride in this study exceeded WHO recommended maximum limit of 250 mg L^{-1} in drinking water. High chloride and electrical conductivity in

groundwater might be attributed to the intrusions of saline water from the coastal water (Department of National Health and Welfare (Canada), 1978). The studied areas fall under coastal plain Formation (Jones and Hockey, 1964). The chloride concentration of these study areas was very high with possible effect on health (Wesson, 1969) and impairment of water taste. Other environmental considerations of high chloride concentration are increases pitting corrosion of metal pipes, elevation of metals in drinking water and galvanic corrosion (Gregory, 1990).

Bicarbonate values of the groundwater samples are generally high, which may due to the underlain sedimentary rock. Groundwater samples in the study areas follow the geochemical trend in terms of abundance of ions as follows: Agbara ($\text{HCO}_3^- > \text{Cl}^- > \text{SO}_4^{2-} > \text{Na}^+ / \text{Ca}^{2+} > \text{K}^+ > \text{NO}_3^-$); Igbesa ($\text{Cl}^- > \text{HCO}_3^- > \text{Ca}^{2+} > \text{Na}^+ > \text{SO}_4^{2-} > \text{K}^+ > \text{NO}_3^-$) and Lusada ($\text{HCO}_3^- > \text{Cl}^- > \text{Na}^+ > \text{SO}_4^{2-} > \text{Na}^+ > \text{K}^+ > \text{Ca}^{2+} > \text{NO}_3^-$). The rock types of these aquifers were mainly bicarbonate and chloride types.

All the metals data collected from Agbara and Lusada groundwater samples except iron were low and met the permissible standards in drinking water (WHO, 2008). In Igbesa water samples, only the values of Fe and Cd were higher than the WHO permissible limits. Cadmium toxicity may include cancer (JECFA, 2000), hypertension, renal failure (Krajnc et al., 1987), proteinuria and itai-itai disease (WHO, 2008; JECFA, 1989). Iron has no health effect on healthy individual as it is required by the body as essential trace metal (Finch, 1972). However, it could impart taste and offensive odour in water at concentration greater than 0.3 mg L^{-1} . (Lemley et al., 1999). Iron and Manganese in the samples from Lusada were higher than WHO standard. Manganese has similar effects as iron in drinking water. Ayedun et al. (2011) and Gbadebo and Taiwo (2011) had previously reported high concentrations of Fe, Mn and Cd in boreholes sampled in Sango, which is about 10 km away from the study areas.

Conclusion

The geochemical compositions of the groundwater of the study areas showed that the water quality was poor in terms of chloride concentration and this would definitely affect the taste of the water. The higher values of iron, greater than WHO standard in the groundwater from the study areas could also affect the taste of the water. The presence of considerable value of cadmium in Igbesa groundwater samples is a major concern to public health. However, other parameters were within the permissible standard. In terms of abundance of ions, the predominant ions in the aquifers are: bicarbonate, chloride, sulphate, calcium, sodium, potassium while nitrate level was very low. Chloride removal from the groundwater samples in the study areas could be expensive since it cannot be done by ordinary filtration or boiling. However, the visible method of its removal could be achieved by reverse osmosis, deionization and distillation. This paper recommends proper and routine monitoring of groundwater resources in Agbara and environs.

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