

## Geochemical Characterization of Phraetic Aquifers in Area of Sango, Southwestern, Nigeria

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**Abstract:** This research work assesses the geochemical characteristics of aquifers in Sango area of Ogun State, Western part of Nigeria with depth ranging from 26.0 to 62.0 m. Water samples were collected from fourteen different boreholes across the town and analyzed for: pH, electrical conductivity (EC), total dissolved solids (TDS), anions (bicarbonate ( $\text{HCO}_3^-$ ), sulphate ( $\text{SO}_4^{2-}$ ), chloride ( $\text{Cl}^-$ ), nitrate ( $\text{NO}_3^-$ ) as nitrogen nitrate) and cations (sodium ( $\text{Na}^+$ ), potassium ( $\text{K}^+$ ), Calcium ( $\text{Ca}^{2+}$ ), zinc ( $\text{Zn}^{2+}$ ), lead ( $\text{Pb}^{2+}$ ), cadmium ( $\text{Cd}^{2+}$ ), iron ( $\text{Fe}^{2+}$ ), chromium ( $\text{Cr}^{2+}$ ), copper ( $\text{Cu}^{2+}$ ), manganese ( $\text{Mn}^{2+}$ ), magnesium ( $\text{Mg}^{2+}$ ) and cobalt ( $\text{Co}^{2+}$ )). Results were compared to World Health Organization (WHO) standards. Pearson correlation coefficient was used to ascertain relationship between some geochemical parameters and depth. Results indicated that parameters such as  $\text{Mn}^{2+}$  (0.05-0.55  $\text{mg L}^{-1}$ ),  $\text{Pb}^{2+}$  (0.00-0.09  $\text{mg L}^{-1}$ ),  $\text{Cd}^{2+}$  (0.009-0.03  $\text{mg L}^{-1}$ ) and  $\text{NO}_3^-$  (8.0-54.0  $\text{mg L}^{-1}$ ) were higher than WHO standards indicating anthropogenic infiltration of pollutants into the aquifers. Pollution of aquifers could be serious and pose threat to public health when water from it is consumed without treatment.

**Key words:** Geochemical • Aquifer • Anthropogenic • Parameters • Health

### INTRODUCTION

Hand-dug wells and deep boreholes have become the major sources of daily water needs in cities, towns and villages in Nigeria due to inadequate supply of pipe-borne water by the appropriate authorities. Public water supply in Sango areas has never been regular for year now. Being close to Lagos state, the former Federal Capital Territory (FCT) of Nigeria, Sango is densely populated and consequently, there's a pressure on groundwater resource as the only water-supply option for both industrial and domestic consumption. All over the globe groundwater remains essential resource that provides billions of people with high quality water supply for industrial, domestic and drinking purposes. However, its quality varies and depends on underlying rocks [1]. The quality of any aquifer water is a function of geochemical, physical and biological characteristics of the water. The chemistry of the groundwater may be determined by mineral enrichment from underlying rocks [2]. In the study of Owen and Blair [3] aquifer is underlain by different rocks and thus determines the groundwater yields. Several studies exist on the relationship between groundwater quality and rock types in many parts of the

world [4-7]. Aquifer can be classified into unconsolidated sand and gravel, carbonate and non-carbonate bedrock. Water from some aquifers may be suitable for direct consumption contrary to the study of Freeze and Cherry [6] that both ground and surface water are not safe when consumed directly without prior treatment. To some extent, this may be true due to mobility of trace metals into groundwater [8]. High concentration of these metals in the underlying or basement rock may further increase metal-load in the aquifers. The overlying soil also plays an important role in the physical filtration and biochemical reaction of underground water quality [9]. However, groundwater obtained from sandy subsoil in a catchments area may be freed from pollutants and hence be of satisfactory quality while water from deep underlying strata rich in mineral matter may be of unsatisfactory quality due to demineralization processes. Sango (located between longitude  $3^\circ 05'$  and  $3^\circ 15' \text{ E}$  and latitude  $6^\circ 55'$  and  $6^\circ 40' \text{ N}$ ) is one of the industrial towns in Ogun State with a population of over 1 million. Both the residents and industries relied mainly on groundwater resource for water supply. The main objective of this study is to examine geochemical characterization of phraetic aquifers in Sango, southwestern part of Nigeria.

Table 1: Geochemical parameters and methods of determination

Parameters	Methods of Analysis
pH	pH meter (Combo HI 98130, Hanna, USA)
TDS	TDS meter (Combo HI 98130, Hanna, USA)
EC	EC meter (Combo HI 98130, Hanna, USA)
SO <sub>4</sub> <sup>2-</sup>	Turbidimetry [12]
HCO <sub>3</sub> <sup>-</sup>	Titration
Cl <sup>-</sup>	Silver-nitrate method [12]
NO <sub>3</sub> <sup>-</sup>	Sodium Salycate [13]
Metals	Atomic Absorption Spectrophotometry (Perkin A Analyst 200)
	Flame Photometry for Na <sup>+</sup> and K <sup>+</sup> (Model PFP 7, Jenway, UK)

## MATERIALS AND METHODS

**Geological Setting:** Sango falls into coastal plain sands which is the youngest stratigraphic sequence in the Eastern Dahomey Basin. It is also known as Benin Formation [10] and consists of poorly sorted sands with lenses of clays and rare thin lignites. The sands are in parts cross-bedded and shows transitional to continental characteristics similar to Ilaro and Abeokuta Formations. The coastal plain sand is not really fossiliferous and falls within Pleistocene and Oligocene age [10].

**Methodology:** A total number of fourteen boreholes were sampled. Water analysis was carried out using standard procedures [11] and the following parameters were determined: pH, EC and TDS were determined in situ. The anions (chloride, sulphate, bicarbonate and nitrate were determined within the seven day of collection). Metals determination was carried out using acidified water samples, which was digested by addition of 10 mL concentrated HCl for about 30 minutes to dissolve the metals. After cooling, samples were filtered and made up to 100 mL. Digested samples were taken to Obafemi Awolowo University central laboratory for metals analysis. However, Na<sup>+</sup> and K<sup>+</sup> were read at department of Environmental Management and Toxicology, University of Agriculture, Abeokuta using flame photometer (MODEL PFP 7, JENWAY, UK). All analysis was carried out in duplicates.

## RESULTS AND DISCUSSIONS

Results of the geochemical analysis of the groundwater are presented in Table 2. The pH of the sampled aquifers ranges from 6.5 to 8.5, which is within the WHO [8] standard for drinking water. The pH of the groundwater is within the neutral range.

Table 2: The values of depth, pH, TDS and EC of the sampled boreholes

No of wells	Depth (m)	pH	TDS	EC
			(mg L <sup>-1</sup> )	(µS/cm)
1	54.90	7.30	6.60	12.0
2	52.0	7.10	8.0	16.0
3	25.0	7.20	5.0	10.0
4	30.0	7.10	17.0	34.0
5	54.90	6.50	6.0	12.0
6	54.90	7.10	17.0	32.0
7	28.0	6.90	7.0	14.0
8	45.70	6.80	21.0	40.0
9	53.0	6.60	14.0	28.0
10	51.0	6.60	15.0	30.0
11	62.0	8.40	6.0	11.50
12	51.0	8.50	5.0	10.0
13	28.0	8.30	7.0	14.0
14	26.0	8.10	6.0	12.0
Mean ±SD	44.09±13.36	7.32±0.7	10.04±5.49	19.68±10.58
WHO		6.5-8.5	500	

Table 3: Concentrations values of the groundwater anions

No of Boreholes	SO <sub>4</sub> <sup>2-</sup> (mg L <sup>-1</sup> )	Cl <sup>-</sup> (mg L <sup>-1</sup> )	HCO <sub>3</sub> <sup>-</sup> (mg L <sup>-1</sup> )
1	2.21	39.57	32
2	1.47	57.67	28
3	0.86	50.89	19
4	2.64	47.49	41.1
5	1.64	52.02	47.6
6	1.32	50.89	54.7
7	1.67	39.57	24.5
8	1.83	40.71	42.3
9	0.32	53.15	28.6
10	2.48	45.23	20.1
11	0.86	50.89	20
12	1.3	52.02	24
13	2.23	94.99	19
14	1.64	49.76	28
Mean±SD	1.61±0.66	51.78±13.57	0.64±11.47
WHO	500	200	

SD-standard deviation

According to Taylor [14] pH classification, the sampled groundwater is free from organic and inorganic acid and none of the sample is saturated with free CO<sub>2</sub>. The TDS range of between 6.0 -21.0 mg L<sup>-1</sup> indicates low dissolved substance and high filtration capacity of underlain rocks [15]. Electrical conductivity, which is a measure of the ions or salinity [15], has a range of 10.5 –28.75 µS/cm thereby signifying a reflection of low dissolved solids. Both TDS and EC are within the international limit for drinking water of 500 mg L<sup>-1</sup> WHO [8] and 400-1250 µS/cm Mento [16] standards respectively.

**Anions:** Results of the anions are presented in Table 3. Chloride, bicarbonate and nitrate are the major anion found in the sampled aquifers with sulphate having

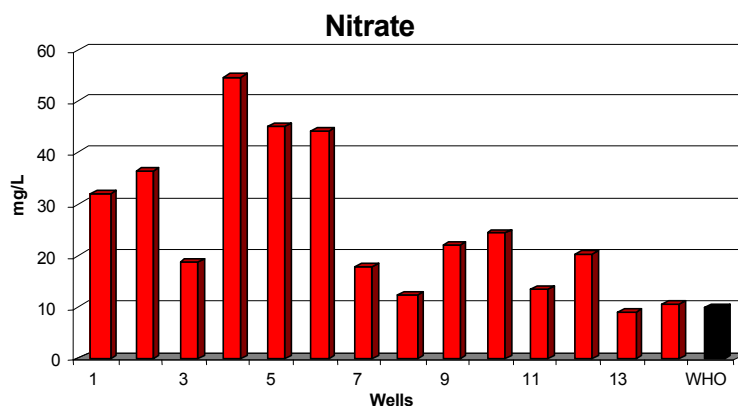


Fig. 1: Nitrate concentrations in Sango groundwater compared to WHO standard

Table 4: Concentration values of cations/metals in the sampled boreholes

No of Boreholes	Na <sup>+</sup> (mg L <sup>-1</sup> )	K <sup>+</sup> (mg L <sup>-1</sup> )	Ca <sup>2+</sup> (mg L <sup>-1</sup> )	Mg <sup>2+</sup> (mg L <sup>-1</sup> )	Co <sup>2+</sup> (mg L <sup>-1</sup> )	Zn <sup>2+</sup> (mg L <sup>-1</sup> )	Fe <sup>2+</sup> (mg L <sup>-1</sup> )	Cr <sup>3+</sup> (mg L <sup>-1</sup> )	Cu <sup>2+</sup> (mg L <sup>-1</sup> )
1	5.0	45	4.8	0.73	ND	0.44	0.19	0.01	0.09
2	ND	79.5	4.4	0.94	ND	0.34	0.19	0.01	0.12
3	25.0	75.5	5.0	0.49	ND	0.43	0.15	0.01	0.15
4	5.0	60.5	4.2	0.52	0.001	0.26	0.23	0.01	0.07
5	10.0	60	6.2	0.82	ND	0.28	0.09	0.01	0.09
6	5.0	50.5	5.4	0.44	0.003	0.25	0.15	ND	0.1
7	15.0	53	5.2	0.58	ND	0.4	0.14	ND	0.14
8	5.0	45.5	4.9	0.63	0.001	0.32	0.17	0.01	0.08
9	5.0	45	5.8	0.5	ND	0.18	0.2	0.01	0.05
10	5.0	47	6.2	0.7	ND	0.16	0.13	0.01	0.06
11	5.0	28.5	3.9	0.79	ND	0.19	0.06	ND	0.07
12	5.0	45.5	5.8	0.81	ND	0.38	0.11	ND	0.15
13	15	79.5	5.0	0.54	ND	0.14	0.1	ND	0.07
14	ND	35.5	6.6	0.46	ND	0.25	0.08	ND	0.08
Mean ±SD	6.25±6.72	53.61±15.69	0.49± 0.15	0.64 ± 0.16	0.002± 0.001	0.29±0.10	0.14± 0.05	0.01± 0.01	0.09± 0.03
WHO	200					3	0.3	0.05	2

N/A-Not Available, ND-Not Detected, SD-Standard Deviation

the lowest value. Sulphate, a non-toxic anions with the values in all the aquifers samples the values are extremely very low (0.32-2.64 mg L<sup>-1</sup>) and will not be harmful to human health. There is no health-based guideline value for sulphate in drinking water. However, ailments like gastrointestinal irritation, catharsis and dehydration have been identified with high sulphate concentrations in water [17]. WHO had suggested that sulphate concentration in drinking water should be below 500 mg L<sup>-1</sup> because above this concentration, the possibility of health problems identified above is feasible. Chloride values of the groundwater have a range of 39.57-94.99 mg L<sup>-1</sup>. This value is low compare to 250 mg L<sup>-1</sup> recommended by WHO in drinking water. Chloride as anion is not harmful at even high concentration. Naturally, Chloride is present in water with varying concentrations, however it is greater

in groundwater than surface water in areas where salts are deposited [18]. High chloride concentration in groundwater may indicate pollutions by sewage, industrial wastes or saline water intrusions [17].

Bicarbonate values range from 19.0 to 54.7 mg L<sup>-1</sup> CaCO<sub>3</sub>, which is within WHO [19] desirable permissible limit of 100 mg L<sup>-1</sup> CaCO<sub>3</sub> in drinking water. However, the groundwater is moderately buffered against sudden change in pH. Both Low and High water pH could disrupt water chemistry. The generally low values of most groundwater anions in this study may be due to relative insolubility of the rock composition as water moves down the aquifer [20].

The high nitrate values (Fig. 1) in all the aquifers sampled are of health-concern especially to growing infants. High nitrate concentration is associated with

methemoglobinemia, a disease characterized by paleness, bluish mucous membranes, digestive and respiratory problems in children under six months [21]. WHO acceptable value for nitrate (nitrogen-nitrate) in drinking water is  $10.0 \text{ mg L}^{-1}$ . In this research work, 93 % of the groundwater sampled has concentration of nitrate above this limit. This nitrate values are risky and calls for public attention. Cancer and spontaneous abortions have also been identified with high nitrate concentration in water [22]. The high concentration of nitrate in Sango aquifers could be as a result anthropogenic sources from industrial plants and septic tank seepage into groundwater. The average value of nitrate obtained from this study is 250 % higher than WHO  $10 \text{ mg L}^{-1} \text{ NO}_3$  permissible level in drinking water in most of the sampled groundwater samples.

Correlation analysis showed that sulphate and chloride have negative correlation with depth of the sampled borehole while bicarbonate and nitrate have weak positive correlation with depth (Table 5). This implies that as depth increases sulphate and chloride decreases while bicarbonate and nitrate increases. The increase in depth with nitrate may be attributed to high solubility of nitrate. High nitrate values have been observed by several authors in the groundwater of southwest Nigeria [23-25]. Negative correlation of sulphate and chloride with depth shows that the high values of these anions in most of the borehole is caused by anthropogenic activities, rather than the natural processes that took place in the groundwater.

**Cations / Metals:** Results of metals/cations are displayed in Table 4. Potassium recorded the greatest values ranging from  $28.5$  to  $79.5 \text{ mg L}^{-1}$  followed by sodium at a distant value. Concentration of  $\text{K}^+$  is normally one-tenth of  $\text{Na}^+$  concentration and is normally less than  $10.0 \text{ mg L}^{-1}$  in potable groundwater [26]. Reverse was the case in this study,  $\text{K}^+$  values were greater than  $\text{Na}^+$  values in all the sampled groundwater. Similar trend of  $\text{Na}^+$  and  $\text{K}^+$  was observed by Ufoegbune *et al.* [27] for groundwater in Abeokuta, but their values were low compared to this study. Tesanva [28] and Ezeala [29] have reported that abundance of  $\text{K}^+$  in groundwater water could be attributed to presence of decomposition of vegetative matter, which releases  $\text{K}^+$  rapidly in the groundwater. But for these boreholes, high  $\text{K}^+$  may be due to the underlying rocks. The values of the cations in the groundwater are generally low relative to anions values (Fig. 5). With the exception of lead, manganese and cadmium (Fig. 2-4), all other metals have values below WHO recommended limits in

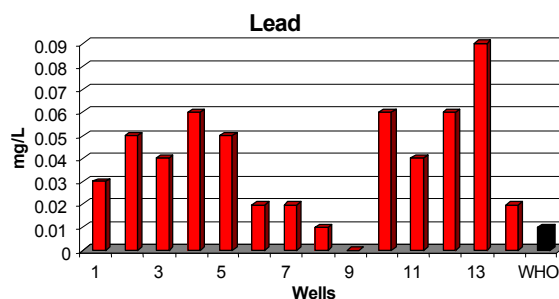


Fig. 2: Groundwater lead concentrations and WHO standard

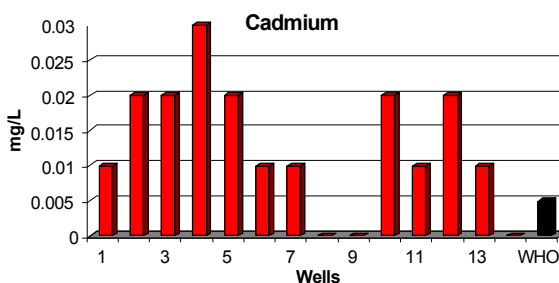


Fig. 3: The groundwater Cadmium values and WHO standard

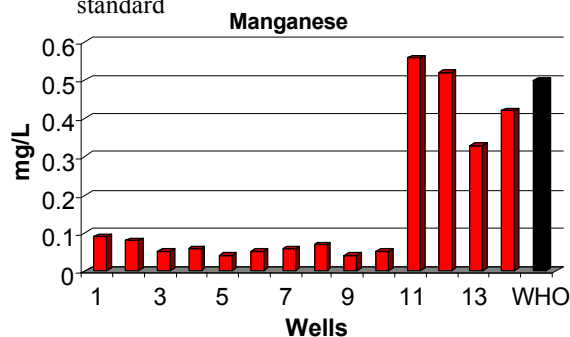


Fig. 4: Manganese concentrations in the groundwater in relation to WHO standard.

water. Over 70 % of the sampled aquifers have lead and cadmium values greater than permissible standards. The high level of  $\text{Pb}^{2+}$  and  $\text{Cd}^{2+}$  observed in our study was also similar to that of Ufoegbune *et al.* [27]. Cobalt, sodium and chromium values of some groundwater samples were below detectable limits as shown in Table 4. This scenario is possible in groundwater of unweathered bedrock or saprock [30].

High-observed values of lead and cadmium in the aquifers in Sango areas are an indication of anthropogenic pollution. Lead and cadmium are non-essential metals of no benefit to humans [31]. Elevated level of these metals greater than WHO standard is risky to public health. EPA [32] documented that cadmium level above  $0.005 \text{ mg L}^{-1}$

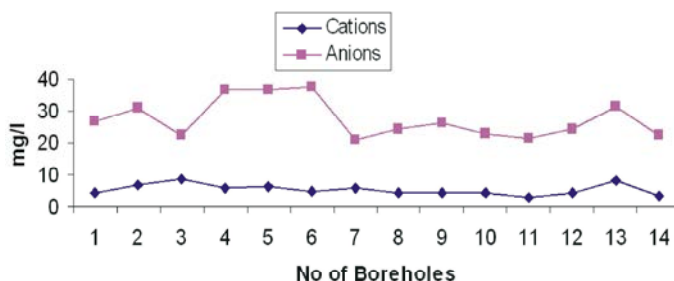


Fig. 5: Ratio of sum of anions to sum of cations of the groundwater

Table 5: Pearson Correlation between the major cations and boreholes depth

	Depth	Na <sup>+</sup>	K <sup>+</sup>	Ca <sup>2+</sup>	Mg <sup>2+</sup>
Depth	1	-0.511	-0.399	0.293	0.599*
pH	-0.128	-0.061	-0.169	-0.050	0.059
TDS	0.134	-0.316	-0.134	0.171	-0.330
EC	0.113	-0.312	-0.118	0.176	-0.331
SO <sub>4</sub> <sup>2-</sup>	-0.262	-0.128	0.175	0.238	0.043
Cl <sup>-</sup>	-0.230	0.231	0.548	-0.015	-0.080
HCO <sub>3</sub> <sup>-</sup>	0.270	-0.299	-0.071	0.271	-0.132
NO <sub>3</sub> <sup>-</sup>	0.255	-0.213	0.233	0.040	0.129
Na <sup>+</sup>	-0.511	1		0.642*	-0.308
K <sup>+</sup>	-0.399	0.499	1		0.034
Ca <sup>2+</sup>	0.293	-0.642*	-0.435	1	
Mg <sup>2+</sup>	0.599*	-0.308	0.034	0.110	1
Mn <sup>2+</sup>	0.044	-0.204	-0.397	0.129	0.183
Co <sup>2+</sup>	0.139	-0.170	-0.61	0.042	-0.418
Zn <sup>2+</sup>	-0.138	0.273	0.148	-0.410	0.195
Pb <sup>2+</sup>	-0.158	0.200	0.518	-0.088	0.314
Cd <sup>2+</sup>	-0.044	0.188	0.472	-0.307	0.346
Fe <sup>2+</sup>	-0.040	-0.108	0.289	-0.214	-0.148
Cr <sup>3+</sup>	0.160	0.000	0.278	-0.236	0.203
Cu <sup>2+</sup>	-0.232	0.431	0.324	-0.410	0.180

\* Significant at p&lt;0.05

in drinking water could lead to kidney, liver, bones and blood health related problems while lead (Pb) could lead to central and peripheral nervous system damage, kidney diseases and pediatric toxicity and teratogenicity. Cadmium is a known carcinogen capable of inducing cancer in human [33]. In groundwater calcium value below 10 mg L<sup>-1</sup> is considered low and value greater than 18.0 mg L<sup>-1</sup> is considered high [5]. Calcium is an essential part of human diet for strong bone. Hence its presence in water may not be detrimental to human health. Copper ingested in high doses could be dangerous to infants and people with certain metabolic disorders, stomach and intestinal disorder, anemia, kidney and liver ailments etc [32]. Iron, cobalt and manganese are essential trace metals for body metabolism. The WHO limit for iron in drinking water is 0.3 mg L<sup>-1</sup>. The values of iron in the sampled boreholes are within this permissible limit. Manganese values are also within the WHO standards for drinking

water except for boreholes 11 and 12 while WHO has no standard for cobalt. Neurological toxicity has been reported in persons exposed to high values of manganese in drinking water [34]. Magnesium range in potable groundwater is between 1.0 to 40 mg L<sup>-1</sup> [26], however, the values of magnesium in the sampled boreholes are extremely low. Low Mg is an indication of natural softening undergone in the groundwater by cation exchange.

Prolonged high doses of zinc can result in some health complications like fatigue, dizziness and neutropenia [35]. Pearson correlation of the metals versus depth of the boreholes revealed that only magnesium has a significant positive correlation with the depth at p<0.05 (Table 5). Calcium also possesses positive relationship with depth but not significant while Na<sup>+</sup>, Zn<sup>2+</sup>, Pb<sup>2+</sup>, Cd<sup>2+</sup>, Fe<sup>2+</sup> and Cu<sup>2+</sup> bear negative correlation with depth (Table 5). Negative correlations of these cations with depth suggest anthropogenic influence.

There's a positive correlation between chloride, Na and K (Table 5). It could be inferred that NaCl and KCl are the major salts present in the aquifer and this may be responsible for slight alkaline nature of the water with pH varying from 6.5 to 8.5.

The bicarbonate present in the aquifer may result from Ca and Mg salts since they bear positive correlation with each other with tendency of increasing water hardness. However, the concentration of magnesium in the groundwater was low (Table 4). From this study, the sum of anions present in the aquifer is far higher than the cations as shown in Figure 5. The alkaline nature of the near-by stream might have been responsible for the low cation values of the boreholes. At low pH metals tend to go into solution [36].

## CONCLUSION

This study has revealed the geochemical compositions of some aquifers sampled in Sango, Southwestern Nigeria with high public health concern for

anions such as nitrate, which values are extremely high. Study also highlighted elevated values of cations like lead and cadmium in the groundwater: these metals are dangerous and toxic to human organs. Moreover, the activities of the industries in this area should be checked for toxic wastes disposals. The wells and boreholes in the study area need regular and periodic monitoring.

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