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Physicochemical Water Quality Indicators of Groundwater in Ishiagu, Ebonyi State, Nigeria

Luke N. Ukiwe* • Gerald O. Onyedika • Vivien I. Uche • Chinonye I. Iwu

Department of Chemistry, Federal University of Technology, P.M.B 1526, Owerri, Nigeria

Corresponding author: * luggil2002@yahoo.com

ABSTRACT

Physicochemical properties of groundwater in Ishiagu, Ebonyi State, Nigeria were investigated. Results obtained from analysis performed on samples of groundwater collected from boreholes of six sample areas (Amata, Ihie, Amaokwe, Ihetutu, Amaeze, Ngwo-Ngwo) during the raining season of June, July and August, respectively, showed that chloride (Cl^-) concentration ranged from 26.9-49.7 mg/l, while sulphate (SO_4^{2-}) and phosphate (PO_4^{3-}) concentration ranged from 27.8-92.1 mg/l and 0.32-1.02 mg/l respectively. However, trace amounts of the metals Fe, Zn, Pb and Cd ranged from 0.01-0.05 mg/l. These values as well as those of the anions (Cl^-, SO_4^{2-}, PO_4^{3-}) were well below WHO permissible standards.

Keywords: aquifer, environment, hardness, hydrochemical, pollutants, properties, surface waters, turbidity

INTRODUCTION

Fresh water resources are one of the most important resources for life on earth. In Ebonyi State, Nigeria, as well as many other states in the country, fresh water resources are scarce (Adekunle *et al.* 2007) and often the few rivers and streams available have always been a source of strive and conflict rather than a blessing between neighboring states and communities struggling for control over large portions of these resources for agrarian farming, drinking purpose and livestock rearing (Baghvand *et al.* 2006; Dawodu and Ipaiyedu 2007).

Surface and ground waters are important sources of drinking water. Surface water offers economic support for agrarian and industrial activities, while groundwater (GW) is also needed for a large proportion of industrial water demand (Okuo *et al.* 2007). Both surface and ground waters are highly susceptible to contamination (Fasunwon *et al.* 2008). Increased activities by man for socio-economic development have resulted in huge deposits of domestic, industrial and environmental waste which constitute environmental hazards. Waste disposal management is a problem in Nigeria (Ikuponisi 2004). Surface water systems have been the most convenient sewer for domestic, industrial and municipal waste (Edema *et al.* 2001). The bacterial qualities of ground and surface water have been reported to be unsatisfactory with coliform counts exceeding WHO [WHO's guidelines for drinking-water quality, set up in Geneva, are the international reference points for standard setting and drinking-water safety, WHO (2003)] recommendation (Shittu *et al*. 2008).

GWs have unique features which render them suitable for public consumption. These features include; (i) excellent natural quality, (ii) free from pathogens, color, turbidity and (iii) they can be consumed directly without treatment (Alexander 2008). Virtually all GW comes from precipitation that soaks into the soil and passes down to aquifer. A common cause of changes in GW quality is through natural variations within the aquifer and thus the amount and type of dissolved minerals within the aquifer (Nelson 2002). Factors that control the amount and type of dissolved minerals in GW include; the types of minerals that make up the aquifer, the length of time that the water is in contact with the minerals and, the chemical state of the GW (Nelson 2002). In the first factor, different rocks, such as, sandstones, limestone, and basalt all have different minerals and therefore, GW in contact with these materials will have different composition. However, the second factor is described as the residence time of the GW in the aquifer. The longer the GW is in contact with the minerals, the greater the extent of its reaction with those minerals and the higher will be the content of dissolved minerals. The chemical state of GW makes up third factor which is defined in terms of the pH, tempera-

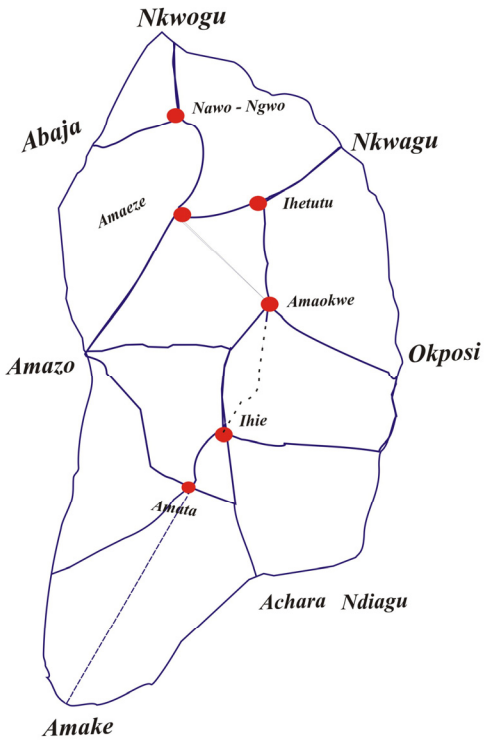

Fig. 1 Sample sites.

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ture, and oxidation-reduction potential. These parameters control and are influenced by chemical reactions. Seasonally changes in temperatures of the water table affect the chemical state and composition of GW. Much of the natural and seasonal water quality variations are due to huge changes in the chemical state of GW. Hence, sufficed to say that chemical state of GW, is governed by three parameters: temperature, pH, and oxidation-reduction potential. It has been suggested that these parameters are often influenced by chemical reactions between the GW and aquifer materials (Nelson 2002).

Contaminants can also find their way into GW through activities like industrial discharges, seepage of municipal landfills, septic tank effluents, etc. A considerable amount of domestic and industrial waste generated and dumped within the city provide pollutants ranging from Cl^- through nitrogen (N) species and metals to organics associated with putrescible materials (Schlegel 2003; Adedayo 2007). Other authors who have examined different issues on the effects of waste dumpsites on GW quality include Akudo *et al.* (2010). They assessed the effects of waste dumpsites located in Warri, Nigeria on GW resources. Emoyan *et al*. (2006) studied the activities of industries and extent of contamination of water resources in Ijana, Ekpan, and Warri in Delta State, Nigeria, while Norbert (2010) also investigated radionuclide contents and physicochemical water quality indicators in streams, well and borehole water sources in high radiation area of Abeokuta, Nigeria.

Studies on physicochemical properties of GW in cities around Nigeria have been reported extensively by Aremu *et al.* (2010), Obijole *et al.* (2010), Tsafe *et al.* (2010), and Egereonu *et al.* (2010). Elsewhere, Sadashivaiah *et al*. (2008) studied hydrochemical analysis and evaluation of GW quality in Tumkur Taluk, Karnataka State, India.

The aim of the present study was to evaluate physicochemical parameters of GW in Ishiagu, an urban city in Eastern Nigeria noted for its large deposit of minerals such as zinc (Zn) and lead (Pb) (Offor 1997).

MATERIALS AND METHODS

Study area

The sample sites (Amata, Ihie, Amaokwe, Ihetutu, Amaeze, and Ngwo-Ngwo) are shown in **Fig. 1**. These are districts located in Ishiagu, Ebonyi State, Nigeria. These districts are known for high deposits of minerals (Offor 1997).

Sample collection, preservation and storage

Samples were collected randomly from the sample areas. At Amata sample site, three replicate samples per day, three times in a month were collected. The samples were collected during the raining season in the month of June, July, and August. The samples were collected from boreholes of depth 620-650 m below the surface. In June, on the first sampling day, samples for nitrates analysis and other anionic parameters were collected in three separate 750 ml clean plastic containers previously washed in 10% reagent-grade nitric acid (HNO_3), purchased from BDH Laboratory, Poole, England, rinsed with deionised water, obtained from a deionizer (Pure-Aqua Inc, Santa-Ana, CA, USA.) and further preserved with 2 ml reagent-grade concentrated H_2SO_4, purchased from May & Baker Ltd., Dagenham, UK, sealed and stored frozen at 4°C. For trace metal analysis, samples were collected in three 750 ml plastic bottles previously soaked in 10% HNO_3 for two days and thoroughly rinsed with deionised water. A few drops (about 2 ml conc. HNO_3) were added to each sample holder bottle, sealed and stored in a refrigerator until required for analysis. This procedure stabilizes the sample, maintain the oxidation state of the element, and prevent adhering of the metals to the walls of the container. pH was immediately determined at the point of collection of samples.

At Amata sampling site for each sampling day, samples for determination of physicochemical parameters were collected in three separate 750 ml clean plastic containers previously washed and rinsed with deionised water. Three treatments were made on the samples on the first sampling day. However, for the first, second, and third sampling days, nine treatments were made for each parameter determined. This procedure was replicated in July and August for first, second and third sampling days respectively. This procedure was also repeated for Ihie, Amaokwe, Ihetutu, Amaeze and Ngwo-Ngwo sampling sites, respectively.

These procedures were repeated in the second and third sampling days, and also the entire procedures were repeated in July and August at the Amata sample site and also repeated for Ihie, Amaokwe, Ihetutu, Amaeze and Ngwo-Ngwo sample sites, respectively.

Physicochemical analysis

pH was determined using pH meter (PHS 25, Nanjing T-Bota Scietech Instruments & Equipment Co., Ltd, Jiangsu, China), while conductivity was determined using Hanna conductivity meter (EC 215, Hanna Instruments, Bedfordshire, UK). Total dissolved solid (TDS) was measured by gravimetry as described by Ademorati (1996), as alkalinity was determined by titration with HCL (general purpose reagent-grade, purchased from BDH Laboratory, Poole, England) (APHA 1992). However, Cl^-, SO_4^{2-}, PO_4^{3-} as well as Mg^{2+} and Ca^{2+} content were determined as described by APHA (1992). Fe, Zn, Pb, and Cd concentrations were determined using atomic absorption spectrophotometer (ALFA 4, Talbot Scientific Ltd, Cheshire, UK) according to the method described by Ukiwe and Oguzie (2008).

Statistical analysis

Arithmetic mean and standard deviation were used to present data. The one-way Analysis of variance (ANOVA) was used to determine statistical difference in calcium hardness between sample stations. Data were analyzed using Microsoft Excel 2000 (Version 9). The *F*-test was used to estimate significance in calcium hardness between sample stations.

RESULTS AND DISCUSSION

It is commonly believed that the composition of GW does not change naturally (Nelson 2002). However, GW may vary in composition from one well to another as a result of the respective GWs being in contact with different aquifer materials, or having been in contact with the aquifer minerals for significantly different periods of time. Seasonal variations in the compositions of GW from a single well may generally results in a change in the chemical state of GW (Nelson 2002).

Tide can bring about remarkable over height of coastal GW level thus affecting its quality. Wu and Zhuang (2010) have shown that tidal fluctuations with increase in on-shore distance affects coastal GW table and quality. Nevertheless, understanding the hydrological functioning of tidally influenced floodplain on GW is hindered by complex interactions between GW and heterogenous soils and topography. Hence, dynamic factor analysis (DFA) was applied to model water table elevation in the floodplain. It was found that altered watershed hydrology led to changing hydroperiod and salinity regimes of GW (Kaplan *et al.* 2010a), thus, regional GW circulation and surfacewater (SW) elevations were found to be the main factors explaining GW profiles (Kaplan *et al.* 2010a). Floodplain forests provide unique ecological structure and function, which are often degraded when watershed hydrology is modified. Restoration of damaged ecosystems requires a clear understanding of GW quality. Soil moisture complemented by GW quantifies the spatial variability and temporal dynamics of vadose zone hydrology (region of aeration above the GW table) (Kaplan *et al.* 2010b). This provides an explanation for observed changes in GW quality and offers a methodological framework for floodplain monitoring in locations where restoration of GW depend on vadose zone hydrology (Kaplan and Muñoz 2011). Other studies on the influence of soil moisture and surface evaporation on GW quality have been investigated by Chen and Hu (2004). Their study noted that

Table 1 Mean values of physiochemical properties of groundwater samples of Amata sample station.

Sample location / Parameters	June	July	August	WHO standards
	Mean ± SD	Mean ± SD	Mean ± SD	
pH	6.87 ± 0.2	6.87 ± 0.7	6.90 ± 0.3	6.5 – 8.5
Temperature (°C)	28.0 ± 0.5	28.0 ± 0.5	28.0 ± 0.1	30 – 32
Conductivity (µs/cm)	406.0 ± 0.1	405.0 ± 0.3	406.0 ± 0.2	400
Alkalinity (mg/l)	186.0 ± 0.1	185.0 ± 0.2	180.0 ± 0.1	500
Total dissolved solid (mg/l)	312.0 ± 0.1	310.0 ± 0.2	300.0 ± 0.9	500
Total hardness (mg/l)	175.0 ± 0.1	170.0 ± 0.8	168.0 ± 0.6	500
Calcium hardness (mg/l)	65.0 ± 0.7	65.0 ± 0.1	62.0 ± 0.8	75
Magnesium hardness (mg/l)	3.4 ± 1.0	3.6 ± 0.8	3.0 ± 0.4	50
Chloride (mg/l)	51.5 ± 0.2	51.0 ± 0.1	51.5 ± 0.1	600
Sulphate (mg/l)	58.1 ± 0.4	58.4 ± 0.7	59.0 ± 0.2	400
Phosphate (mg/l)	0.42 ± 0.1	0.45 ± 0.2	0.50 ± 0.4	0.1
Iron (mg/l)	0.01 ± 0.0	0.05 ± 0.0	0.02 ± 0.0	0.30
Zinc (mg/l)	0.02 ± 0.0	0.03 ± 0.0	0.03 ± 0.0	5.00
Lead (mg/l)	0.01 ± 0.0	0.01 ± 0.0	0.01 ± 0.0	0.01
Cadmium (mg/l)	ND	ND	ND	0.05

ND = Not Detected

Table 2 Mean values of physiochemical properties of groundwater samples of Ihie sample station.

Sample location / Parameters	June	July	August	WHO standards
	Mean ± SD	Mean ± SD	Mean ± SD	
pH	6.30 ± 0.1	6.72 ± 0.2	6.50 ± 0.1	6.5 – 8.5
Temperature (°C)	27.8 ± 0.1	28.0 ± 0.4	28.0 ± 0.1	30 – 32
Conductivity (µs/cm)	406.0 ± 0.3	406.0 ± 0.2	404.0 ± 0.1	400
Alkalinity (mg/l)	184.0 ± 0.8	182.0 ± 0.1	183.0 ± 0.6	500
Total dissolved solid (mg/l)	231.0 ± 0.2	230.0 ± 0.5	225.0 ± 1.0	500
Total hardness (mg/l)	176.0 ± 0.2	176.5 ± 0.1	180.2 ± 0.8	500
Calcium hardness (mg/l)	66.2 ± 0.9	66.4 ± 0.1	66.0 ± 0.2	75
Magnesium hardness (mg/l)	2.5 ± 0.1	2.4 ± 0.1	2.5 ± 0.2	50
Chloride (mg/l)	31.5 ± 0.3	31.0 ± 1.2	31.2 ± 1.4	600
Sulphate (mg/l)	52.8 ± 0.9	52.0 ± 0.1	53.0 ± 0.3	400
Phosphate (mg/l)	0.93 ± 0.4	1.02 ± 0.3	0.90 ± 0.1	0.1
Iron (mg/l)	0.04 ± 0.0	0.05 ± 0.0	0.05 ± 0.0	0.30
Zinc (mg/l)	0.02 ± 0.0	0.03 ± 0.0	0.03 ± 0.0	5.00
Lead (mg/l)	0.01 ± 0.0	0.01 ± 0.0	0.01 ± 0.0	0.01
Cadmium (mg/l)	ND	ND	ND	0.05

ND = Not Detected

Table 3 Mean values of physiochemical properties of groundwater samples of Amaokwe sample station.

Sample location / Parameters	June	July	August	WHO standards
	Mean ± SD	Mean ± SD	Mean ± SD	
pH	6.83 ± 0.2	6.80 ± 0.1	6.80 ± 0.4	6.5 – 8.5
Temperature (°C)	29.0 ± 0.1	29.2 ± 1.3	29.2 ± 0.2	30 – 32
Conductivity (µs/cm)	501.0 ± 0.2	500.0 ± 0.4	505.0 ± 0.1	400
Alkalinity (mg/l)	316.0 ± 0.1	312.0 ± 0.1	310.0 ± 0.1	500
Total dissolved solid (mg/l)	374.0 ± 0.2	370.0 ± 0.1	366.0 ± 0.1	500
Total hardness (mg/l)	100.0 ± 1.2	105.0 ± 1.1	108.0 ± 1.0	500
Calcium hardness (mg/l)	35.0 ± 0.1	35.6 ± 0.9	35.0 ± 0.1	75
Magnesium hardness (mg/l)	1.0 ± 0.0	1.6 ± 0.1	1.0 ± 0.1	50
Chloride (mg/l)	49.0 ± 0.3	47.0 ± 0.8	49.7 ± 0.6	600
Sulphate (mg/l)	28.1 ± 0.2	27.8 ± 0.4	28.4 ± 0.6	400
Phosphate (mg/l)	0.43 ± 0.0	0.45 ± 0.0	0.48 ± 0.1	0.1
Iron (mg/l)	0.02 ± 0.0	0.02 ± 0.0	0.03 ± 0.0	0.30
Zinc (mg/l)	ND	ND	ND	5.00
Lead (mg/l)	ND	ND	ND	0.01
Cadmium (mg/l)	ND	ND	ND	0.05

ND = Not Detected

GW may have a small effect on soil moisture in areas with deep GW table. Moreover, GW can also act as soil water source and have substantial effects in areas where the water table is near or within a model's soil column. Shallow GW table and hydrogeologic conditions indicate that contamination risks of GW quality are high (White *et al.* 2009). However, integration of cover crops into agronomic systems may yield water quality benefits by reducing contaminated inputs to GW (Potter *et al*. 2007). Studies on the effect of shallow GW table on crop water requirement yields and assessment of microbial activity of subsoils and mineralization rates on GW quality have been reported by Kahlown *et al*. (2005) who noted that the contribution of GW in meeting crop (wheat, sugarcane, maize, sorghum, berseem and sunflower) water requirements varied with the water-table depth, and, Beelen *et al*. (2011) who also found that subsoils at the GW table of areas which are in contact with soil air, showed a higher mineralization rate compared with surface soils. However, there was a lower rate of mineralization of subsoils at the GW table of sandy soils.

Knowledge of water quality interactions between agriculture land-use and shallow regional aquifer is critical in quantifying the effects of hydrological factors over local GW quality. It has been shown that fertilization, masked by soil/water/plant-delayed processes has no discernible effect on GW nitrate levels (Ritter *et al*. 2007).

Tables 1-6 present mean values of physicochemical analysis of GW samples from Amata, Ihie, Amaokwe, Ihe-

Table 4 Mean values of physiochemical properties of groundwater samples of Ihetutu sample station.

Sample location / Parameters	June	July	August	WHO standards
	Mean ± SD	Mean ± SD	Mean ± SD	
pH	7.05 ± 0.2	7.14 ± 0.2	7.10 ± 0.2	6.5 – 8.5
Temperature (°C)	29.1 ± 0.2	28.8 ± 0.1	29.0 ± 0.2	30 – 32
Conductivity (µs/cm)	381.0 ± 0.7	380.0 ± 0.9	385.0 ± 1.1	400
Alkalinity (mg/l)	228.0 ± 0.4	220.0 ± 0.1	225.0 ± 0.6	500
Total dissolved solid (mg/l)	282.0 ± 1.1	260.0 ± 0.8	278.0 ± 0.7	500
Total hardness (mg/l)	210.0 ± 0.6	240.0 ± 0.2	220.0 ± 0.2	500
Calcium hardness (mg/l)	78.9 ± 0.6	78.4 ± 0.2	78.0 ± 0.2	75
Magnesium hardness (mg/l)	2.4 ± 0.1	2.9 ± 0.2	2.0 ± 0.2	50
Chloride (mg/l)	39.7 ± 0.6	39.6 ± 0.4	36.0 ± 0.3	600
Sulphate (mg/l)	81.9 ± 0.4	90.0 ± 0.2	81.6 ± 0.2	400
Phosphate (mg/l)	0.34 ± 0.0	0.30 ± 0.0	0.32 ± 0.0	0.1
Iron (mg/l)	0.01 ± 0.0	0.01 ± 0.0	0.01 ± 0.0	0.30
Zinc (mg/l)	ND	ND	ND	5.00
Lead (mg/l)	ND	ND	ND	0.01
Cadmium (mg/l)	ND	ND	ND	0.05

ND = Not Detected

Table 5 Mean values of physiochemical properties of groundwater samples of Amaeze sample station.

Sample location / Parameters	June	July	August	WHO standards
	Mean ± SD	Mean ± SD	Mean ± SD	
pH	7.05 ± 0.1	6.46 ± 0.1	7.10 ± 0.1	6.5 – 8.5
Temperature (°C)	29.0 ± 0.2	28.0 ± 0.6	28.5 ± 0.6	30 – 32
Conductivity (µs/cm)	349.0 ± 0.2	350.0 ± 0.4	348.0 ± 0.9	400
Alkalinity (mg/l)	208.0 ± 0.1	206.0 ± 0.2	208.0 ± 0.1	500
Total dissolved solid (mg/l)	261.0 ± 0.3	256.0 ± 0.4	260.0 ± 0.7	500
Total hardness (mg/l)	206.0 ± 0.2	206.0 ± 0.2	205.0 ± 0.6	500
Calcium hardness (mg/l)	78.0 ± 0.2	76.0 ± 0.9	78.8 ± 0.1	75
Magnesium hardness (mg/l)	3.6 ± 0.1	3.2 ± 0.1	3.4 ± 0.3	50
Chloride (mg/l)	26.9 ± 0.2	27.0 ± 0.2	26.8 ± 0.5	600
Sulphate (mg/l)	54.0 ± 1.0	54.6 ± 0.8	55.0 ± 1.1	400
Phosphate (mg/l)	0.41 ± 0.1	0.40 ± 0.2	0.41 ± 0.1	0.1
Iron (mg/l)	0.03 ± 0.0	0.04 ± 0.0	0.04 ± 0.0	0.30
Zinc (mg/l)	ND	ND	ND	5.00
Lead (mg/l)	ND	ND	ND	0.01
Cadmium (mg/l)	ND	ND	ND	0.05

ND = Not Detected

Table 6 Mean values of physiochemical properties of groundwater samples of Ngwo-Ngwo sample station.

Sample location / Parameters	June	July	August	WHO standards
	Mean ± SD	Mean ± SD	Mean ± SD	
pH	6.44 ± 0.2	6.50 ± 0.1	6.40 ± 0.4	6.5 – 8.5
Temperature (°C)	28.0 ± 0.5	28.6 ± 0.2	29.0 ± 0.1	30 – 32
Conductivity (µs/cm)	294.0 ± 0.2	290.0 ± 0.6	291.0 ± 0.1	400
Alkalinity (mg/l)	250.0 ± 0.4	255.0 ± 0.3	248.0 ± 0.1	500
Total dissolved solid (mg/l)	254.0 ± 0.2	250.0 ± 0.2	245.0 ± 0.5	500
Total hardness (mg/l)	130.0 ± 0.7	135.0 ± 1.0	128.0 ± 0.2	500
Calcium hardness (mg/l)	72.0 ± 0.3	72.0 ± 0.1	70.3 ± 0.1	75
Magnesium hardness (mg/l)	7.1 ± 1.1	7.4 ± 1.0	7.0 ± 0.9	50
Chloride (mg/l)	30.8 ± 0.2	31.2 ± 0.2	33.6 ± 0.1	600
Sulphate (mg/l)	91.0 ± 0.2	90.0 ± 0.2	92.1 ± 0.1	400
Phosphate (mg/l)	0.41 ± 0.1	0.40 ± 0.1	0.43 ± 0.2	0.1
Iron (mg/l)	0.06 ± 0.0	0.01 ± 0.0	0.04 ± 0.0	0.30
Zinc (mg/l)	0.05 ± 0.0	0.05 ± 0.0	0.02 ± 0.0	5.00
Lead (mg/l)	0.01 ± 0.0	0.01 ± 0.0	0.01 ± 0.0	0.01
Cadmium (mg/l)	0.01 ± 0.0	0.01 ± 0.0	0.01 ± 0.0	0.05

ND = Not Detected

tutu, Amaeze, and Ngwo-Ngwo sample stations. The mean pH value of Ihie sample station in June was the lowest recorded and it fell just below WHO permissible limit, indicating slight acidity. This was also observed by Okoli *et al.* (2005). The slight increase in acidity could be as a result of run-off from domestic and agrarian waste disposal activities, since June in that part of Nigeria coincides with the period of high agricultural activities. The mean temperature also ranged from 27.8-29.2°C. This figure exceeds what Amoo and Akinbida (2007) reported in their study on physicochemical analysis of well waters in Minna, and its environs in Niger State, Nigeria. Also, Nkolika and Onianwa (2011) reported similar figures when they investigated the impact of poor waste management on the physicochemical properties of GW in some areas of Ibadan, Nigeria. Amaokwe sample station recorded the highest temperature averaging 25.8°C in the three months investigated.

The conductivity in the study ranged from 290-505 µs/cm. The highest conductivity value (505 µs/cm) was recorded at the Amaokwe sample station in August, while the lowest (290 µs/cm) was obtained in July at Ngwo-Ngwo sample station. The high conductivity values obtained from all the sample areas suggest the presence of dissolved mineral matter in the samples, since Ishiagu is a mineralized area.

The result of alkalinity, total dissolved solids, and total hardness ranged from 182-316, 230-374, and 100-206 mg/l, respectively. These values all fall within the range stipulated by WHO (2003). Calcium hardness concentration was

highest in June (78.8 mg/l) at Ihetutu sample station and lowest (35.0 mg/l) in June and August at Amaokwe sample stations. Calcium mineral causes hardness of water. The level of hardness of water is related to the amount of dissolved mineral in the water. Calcium hardness has been associated with several economic problems with regard to water usage (Nkolika and Onianwa 2011).

Chloride, sulphate and phosphate concentrations ranged from 31.2-31.5, 52.8-53.0, 0.90-0.93 mg/l, respectively in June through August. Generally, through the three months, chloride, sulphate and phosphate concentrations ranged from 26.9-49.7, 27.8-92.1, and 0.32-1.02 mg/l, respectively. It was observed that chloride and sulphate concentrations fell below WHO permissible limit; however, phosphate concentration exceeded this limit.

Tables 1-6 also show mean values and standard deviation of the parameters including trace metals analyzed during the three months research period in all six sample stations. While Zn, Pb, and Cd were largely undetected in Amaokwe, Ihetutu, and Amaeze sample stations, Ngwo-Ngwo sample station has relative values for these elements.

The high calcium hardness content value didn't differ significantly between sample stations. The *F*-test of calcium hardness between Amata and Ihie, Amaokwe and Ihetutu, Amaeze and Ngwo-Ngwo sample stations are 1.7, 1.2 and 1.40, respectively (2 and 2 degrees of freedom, $P < 0.01$).

It appears the GW from the six sample station is potable not withstanding the fact that the sample areas are locations of high mineral deposits. One reason might be ascribed to this phenomenon. GW water moves very slowly through sediments with low permeability, but faster with high permeable minerals such as sand and minerals with high particle size. For minerals with high permeability, there is less time for minerals to dissolve and thus the GW usually contains lower levels of dissolved minerals, hence, the portable nature of the GW. There is also a difference in dissolved solids between GW in recharged zones and water in discharged zones. Recharged zones are uplands areas where precipitation readily enters the ground through permeable, sandier sediments. Generally, water in recharge zones has a low level of mineralization. Discharge areas are low areas where GW flow eventually makes its way back to (or near) the ground surface. GW found in such areas can be extremely high in minerals. It has been suggested that Ishiagu is an upland area hosting permeable sediments (Offor 1997). Thus there would be less mixing of water and minerals.

GW pollution works differently from surface water pollution, although they have many sources in common, such as fertilizers, pesticides, and animal waste. Extensive research on GW pollution have been studied by Assubaie (2004) and Al-Salamah and Nassar (2009).

However, recent studies on SW and GW pollution include the works of Edimeh *et al.* (2011), who studied physicochemical parameters and some heavy metals content of rivers in Idah, Nigeria. Aremu *et al.* (2011) also studied physicochemical characteristics of stream, well and borehole water sources in Eggon, Nigeria, while Kolawole *et al.* (2011) examined water quality in Asa river, Nigeria and concluded that the quality of any body of SW or GW is a function of either or both natural influences and human activities. Nevertheless, Imoobe and Koye (2011) investigated the impact of effluent from a soft-drink processing factory on the physicochemical parameters of Eruvbi stream in Benin City, Nigeira. These authors are of the opinion that the main pollution sources of SW and GW systems include municipal wastewater, storm water runoffs, and irrigation farms with chemical fertilizers. Elsewhere, in their separate studies, Bhuiyan *et al*. (2011), Memon *et al.* (2011), and Abdelrahman and EI-Tahir (2011) had investigated the possible sources of heavy metal contamination in lagoon and canal water in Dakar, Bangladesh and drinking water quality assessment in Southern Sindh (Pakistan), as well as bacteriological quality of drinking water in Nyala, South Darfur, Sudan. These studies, however, provide evidence that effluents discharge from urban sewage system and sewage infiltration through leakage points are the main sources of pollution of SW and GW systems.

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