Assessment of Water Quality in A Typical Industrial Area of Southwestern, Nigeria.

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Abstract
The surface and groundwater in Agbara commercial and industrial areas were evaluated, with a view of ascertaining the impact of industrial activities on water character and suitability for domestic and other usages. Sixteen pairs of water samples were collected in air-tight bottles for laboratory analysis. Physical parameters such as Total Dissolved Solids (TDS), Electrical Conductivity (EC), temperature and pH were conducted in-situ while concentrations of major ions and heavy metals were analysed using Inductively Coupled Plasma Optical Emission Spectrometry (ICP-OES) at the Activation Laboratories, Ancaster, Canada. The results of physical parameters vary from 5.09-6.71, 70.4-8.13 mg/l, 110-1270µS/cm and 29.7-30^{0}C respectively for pH, TDS, EC and temperature while Schoeller's plot showed that the water type in the area falls into NaCl, Mixed $CaNaHCO_3$, $NaHCO_3$ and $CaHCO_3$ while the dominant ions are Na^+ + K^+, Cl^- and HCO_3^- respectively. Wilcox's diagram and Magnesium Hazard Ratio indicated that the water is suitable for irrigation. The plot of Sodium Adsorption Ratio against salinity hazard however revealed that some of the water samples have high salt concentration which will limit their applicability to only plants that have tolerance for salt. The Gibb's diagram revealed that the source of the ions in the water sample is primarily as a result rock weathering. The results of the heavy metal analyses showed that a significant percentage of the water samples have high concentrations of Manganese, Arsenic, Cadmium, Lead, Chromium, Nickel and Iron which are inimical to human's health. It is therefore recommended that industries in the area adopt global best practices in their operations and disposal of wastes. In addition, appropriate water bodies and stakeholders should take definitive measures to monitor their operations for the benefit of man and environment.

Keywords Hydrochemical analyses, irrigation, relevant standards, Wilcox diagram, industrial events

INTRODUCTION

The need for potable water in both rural and urban areas of the world cannot be overemphasized. Ajibade *et al.,* (2011) noted that increased growth in urban population, industrial activities, commercial activities and agricultural evolution are major factors that affect the search and use of potable water. Surface and groundwater are susceptible to contamination and could endanger the lives of living organisms when their quality is adversely affected. The quality of water resource is determined by physical, chemical and biological properties which in turn determine its fitness for human consumption and diverse usage, Harter (2000). Groundwater, under most conditions is safer and more reliable for use than surface water due to the fact that surface water is more readily exposed to pollutants. Groundwater quality relies on the compositions of water recharged into the ground, the interaction between it and media of the aquifer, as well as the reactions that take place between the aquifer and the overlying soil (Rahaman,1976). However, human activities such as sewage disposal, industrial waste products, and agriculture are as well capable of altering groundwater quality. Naturally, Groundwater contains ions and trace elements as well as organic materials in varying amounts which have been dissolved from rocks, sediments and soil particles as they travel along the pore spaces and fractures of the unsaturated zones and the aquifer. These are known as dissolved solids. Some dissolved solids may have originated in the precipitation water or river that recharged the aquifer. The influence of chemical ions on groundwater chemistry depends on their concentrations in the aquifer. Groundwater chemistry is an important factor in determining the water quality for domestic, irrigation and industrial purposes. The geochemical evaluation of groundwater is therefore important due to the attached significance for potable water-supply **(**Gbadebo and Taiwo, 2011). It is most frequently used through reference to a set of standards such as World Health Organization (WHO) against which compliance can be assessed. Several attempts have been made by researchers to study water quality in different parts of Nigeria, especially in the southwestern part (Oloruntola *et al.,* 2018; Ige *et al.,* 2017; Tijani *et al.,* 2014; Ige and Korode 2014; Aladejana and Talabi 2013; Bayode *et al.,* 2012; Oyedele and Olayinka 2012; Edet *et al.,* 2011; Ige and Olasehinde 2011; Ajibade *et al.,* 2011; Gbadebo and Taiwo 2011; Taiwo *et al.,* 2011; Adekunle *et al*., 2007). Only few studies (Adekunle *et al.,* 2007; Afolabi et al., 2017, Oloruntola *et al.,* 2018) were conducted in the South-western part that examined the impact of heavy metals on water quality. Toxic metals, to a large extent, are dispersed in the environment through industrial effluents, organic wastes, refuse burning, transport and power generation (Mahurpawar, 2015). These metals can adversely affect the environment and living organisms (Järup, 2003). According to Lambert *et al.,* 2000), arsenic, cadmium, chromium, copper, lead, nickel, and zinc are the most commonly found heavy metals in waste water which pose threats to human health and the environment. The study area is an industrial terrain and thus the effluents constantly being discharged into the water bodies from these industries could be potential sources of toxic metals. Therefore, significant emphasis is placed on the most commonly found heavy metal constituents in the evaluation of water quality of the area.

Study Area

The study area is situated in Agbara Industrial Estate, Ogun State, Nigeria and it lies within longitude N6°29'00" to 6°33'00" and latitude E 03°3'00" – 03˚7'00" (Figure 1). Adjoining to this Estate town are Ijako-petedo, Ipenrin, Eedu and Lusada. The study area forms part of Dahomey Basin, a very extensive sedimentary basin on the continental margin of the Gulf of Guinea, which extends from Volta River Delta, South-eastern Ghana in the west, to the Western flank of the Niger Delta (Jones and Hockey, 1964). It is underlain by Coastal Plain Sands and Recent Alluvium. It is made up of poorly sorted sands, which in some places cross-bedded and shows transitional to continental characteristics similar to Ilaro Formation and Abeokuta Group. Its thickness ranges from 10 to 100 m while the age falls within Pleistocene and Oligocene (Jones and Hockey, 1964).

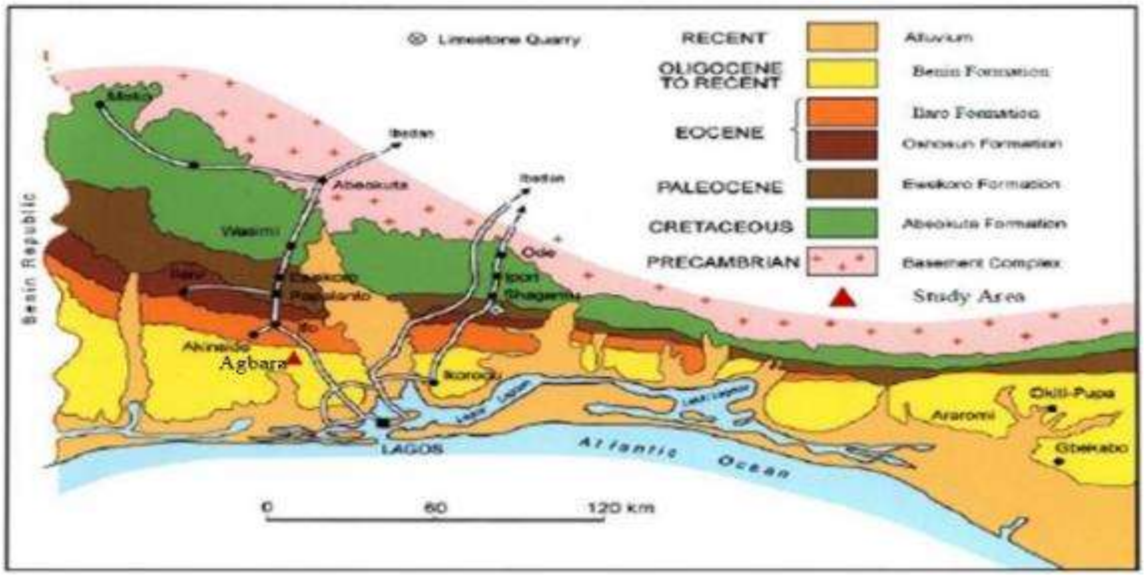

Figure 1: Geological Map of Dahomey Basin Showing the Study Area (Modified after Omatsola and Adegoke, 1981)

The study area is characterized by low to moderate relief (150 – 350 m) above sea level (Ajibade and Wright, 1988). The drainage is sub-dendritic as a result of proliferations of river channels. The study area is well drained with major rivers such as River Ijuri which flows in NE-SW direction where it joins the Atlantic Ocean. It flows in North to South direction. The volume of water noticeably reduces during the dry season, this may cause the tributaries to dry up for a few weeks as a result fluctuation in the groundwater level in the studied area. The climatic condition is tropical as expressed in alternation of wet and dry seasons. These two regimes of tropical climate show a fairly wide seasonal and diurnal variation in temperature ranging between 35^0C during dry season and 25^0C during wet season (Ikhane *et al*., 2012)**.**

METHODOLOGY

Water samples (16 each for anion and cation analyses) were collected from stream and wells. Sampling points were geo-located with the use of a Global Positioning System (GPS). The bottles that were used for sampling were first cleaned with distilled water. At the point of sampling, the bottles were rinsed with the sampling media at each sampling point and samples were collected into the airtight bottles. Physical parameters such as pH, temperature, total dissolved solids (TDS) and electrical conductivity (EC) were obtained in-situ using the MARTINI Mi 861 Portable pH meter. Two water samples each were collected at sampling site and one pair of samples was acidified with a drop of concentrated trioxonitrate (iv) (HNO_3) acid to prevent the molecules of water from adhering to the walls of the sample bottles. The acidified samples were analysed for cations while the other set of samples were tested for anions. Cations such as sodium, potassium, calcium, magnesium were determined while anions include chloride, sulphate, silica, phosphate, nitrate and bicarbonate/carbonate. The anion was analysed using ion chromatography (IC), Heavy metals such as Cobalt (Co), Manganese (Mn), Arsenic (As), Cadmium (Cd), Copper (Cu), Lead (Pb), Barium (Ba), Zinc (Zn), Chromium (Cr), Nickel (Ni), Iron (Fe), Silver (Ag) and Titanium (Ti) were analysed using Inductively Coupled Plasma Optical Emission Spectrometry (ICP-OES) at the Activation Laboratories, Ancaster, Canada. The results of the water analyses were evaluated using statistical analyses and compared with various water standards such as Standard Organization of Nigerian (SON) and World Health Organization (WHO).

Calculation of plotted parameters

Conversion of parameter from milligram per litre to milli-equivalent per litre values and percentage.

Milli-equivalent per litre value is the ratio of product of milligram per litre value and valency to the molecular weight of the ions as shown below;

$$Meg/L = \frac{\mathrm{mg/L} * \mathrm{valency}}{\mathrm{Molecular\ weight}}$$

$$\mathrm{Percent} = \frac{\mathrm{Meq/L\ value\ of\ each\ ion}}{\mathrm{Total\ Meq/L\ value\ of\ all\ ions}} \times 100\%$$

This is calculated for cation and the anions separately.

Wilcox diagram

This is a plot of the percentage of sodium (Na^+) against the electrical conductivity.

$$\mathrm{Percentage\ (\%) of\ Na^+}$$

$$\% = \frac{\mathrm{Na}}{\mathrm{Na+\ +K+\ +Ca2+\ +Mg2+}} * 100\%$$

(Na^+ + K^+ + Ca^{2+} +Mg^{2+}) Vs Electrical Conductivity (EC)

Gibb's Ratio

This is a ratio of sodium and potassium to sodium, potassium and calcium plotted against the Total dissolved solid for cations and for anion, the ratio of chloride to chloride and bicarbonate also plotted against TDS: (Na^+ + K^+) **/** (Na^+ + K^+ + Ca^{2+}) Vs TDS and Cl^-**/**Cl + HCO_3^- Vs TDS

Sodium absorption ratio (SAR)

Sodium Absorption Ratio is the ratio of concentration of sodium in Meq/L and half the square root of the concentration of both calcium and magnesium in Meq/L as show below;

$SAR = Na^+ / \{(Ca^{2+} + Mg^{2+})/2\}^{1/2}$

Magnesium Hazard Ratio (MHR): This is given by: Mg ∕ (Ca + Mg)

RESULTS AND DISCUSSIONS

Table 1 shows the summary result of the physico-chemical parameters of the water samples.

Table 1: Result of Physico-chemical Parameters of the Water Samples

Sample	Temp (^{0}C)	pH	EC (µS/cm)	TDS (mg/l)	Ca^{2+} (mg/l)	Mg^{2+} (mg/l)	Na^+ (mg/l)	K^+ (mg/l)	HCO_3^- (mg/l)	Cl^- (mg/l)	SO_4^{2-} (mg/l)	MHR
S1	29.8	5.09	110	70.4	7.7	2	7.2	3.1	36	13.95	2	30
S2	29.7	6.26	800	512	36.2	4.9	109	30.3	272	81.68	38	18
S3	29.9	5.33	170	109	4.7	<1	34.8	1.6	32	13.95	6	26
S4	29.8	5.87	950	608	51.5	14.7	108	55.6	296	149.42	48	32
S5	29.9	6.01	920	589	68.2	16.6	123	28.3	392	115.55	48	28
S6	30.2	5.24	940	601	3.5	0.6	20.8	1.8	64	11.96	4	22
S7	29.9	5.91	190	122	4	0.4	30.3	1.1	108	27.89	3	14
S8	29.9	5.96	140	89.6	61	16.9	136	40.9	224	223.14	66	32
S9	29.8	5.91	1270	813	71.2	17.1	141	46.8	232	181.3	60	29
S10	29.9	5.73	1080	691	37.4	12.2	89.2	27.9	248	115.55	40	35
S11	29.8	6.1	760	486	74.7	13.2	177	34.5	364	199.23	66	23
S12	29.7	6.05	1110	710	53.5	11.1	96.1	25.5	168	113.86	60	26
S13	29.8	5.26	780	499	40.8	11.6	99.9	30.4	116	143.45	62	32
S14	29.8	5.62	810	518	59.7	17.8	148	53.7	164	195.25	64	33
S15	29.9	5.66	1170	749	58.1	16.7	108	52.5	156	163.37	60	32
S16	29.9	6.71	740	473	3.2	2.2	36.9	4.6	8	5.98	2	53
MEAN	29.86	5.79	746.25	477.50	39.71	10.53	91.58	27.41	180.00	109.72	39.31	29.06
STD DEV	0.11	0.41	373.24	238.80	25.90	6.40	49.32	19.16	113.45	72.95	25.55	8.35
SON		6.5-8		500	Nil	0.2	200	Nil	Nil	250	500	
WHO	35-40	6.5-8	1200	1000	Nil	50	200	55		200	500	

Physical Parameters

The knowledge of the quality of water aids in determining its suitability for various purposes Subramani *et al*. (2005). The temperature (°C) of the water samples ranged from 29.7 - 30.2 with an average of 29. 85. These range of values are well below the maximum permissible limit proposed by WHO (2011) as shown in Table 1. Electrical Conductivity (EC) and Total Dissolved Solids (TDS) values of the samples ranged from (110 – 1270) µS/cm with an average of 792.6 µS/cm and 70.4 – 813 mg/L with an average of 792 mg/l respectively. About 25% of the water samples have EC values above the maximum permissible limit while all have TDS values within the permissible limits of WHO (2011), although, only 44% of the water samples had their values within the permissible limit of SON for potable water. The investigated waters can be classified as freshwater according to Freeze and

Cherry (1979) High TDS may not be palatable, however, no health-based regulation has been established for TDS (WHO, 2017). pH is a quantitative measure of the acidity or basicity of aqueous or other liquid solutions. It indicates whether water is likely to be either corrosive or scale forming. According to USEPA (1985) standard, the pH value of acceptable water must be 7.0 – 8.5, while according to WHO standard and SON (2007) any water below 6.5 and higher than 8.0 are considered to be detrimental. The pH values range from 5.01 to 6.26 which indicate slightly acidic water. A comparison with the aforementioned standards for drinking water points out that all the water samples are not potable.

Anions

The concentrations of sulphate, chloride and carbonate in the water samples ranged (mg/l) from 2.0 – 66.0 mg/l, 5.96 – 223.1 mg/l and 8.0 – 392.0 mg/l with average of 39.31 mg/l, 109.72 mg/l and 180.0 mg/l respectively and are therefore within the WHO permissible limits. The concentration of bicarbonate in the water samples range from 8.0 – 392.0 mg/l and is therefore within 500 mg/l maximum permissible limit specified by WHO (2011). Excessively dissolved bicarbonate in ingested water could affect level of body metabolism, cause seizures, severe muscle spasms and contractions and can also worsening congestive heart failure (Arumugam and Elangovan, 2009). Chloride concentration in water above 250 mg/l is likely detectable by taste, although on health-based regulation is proposed for chloride by WHO (2017).

Cations

The concentrations of Calcium (Ca), Magnesium (Mg), Sodium (Na) and Potassium (K) in the water samples range between 3.2 – 74.7 mg/l, 0.4 – 17.8 mg/l, 7.2 – 177 mg/l and 1.1 – 55.6mg/l with average values of 39.71 mg/l, 10.53 mg/l, 91.58 mg/l and 27.41 mg/l respectively. Excessive concentration of Ca^{2+} in water could lead to scale formation (WHO 2017). While all the samples have Mg^{2+} and Na^{+} concentrations within recommended limit (WHO 2017), only 1 sample out of 16 has K^{+} concentration that is marginally above the recommended limit. Excess magnesium could cause hardness and gastrointestinal irritation. Excess sodium ion dissolved in water has the same consequence with excess bicarbonate on plants and agricultural soil (Arumugam and Elangovan, 2009) while Excess K^{+} could impact bitter taste on water (WHO, 2006).

Hydrochemical Facies

The hydrochemical facies of the water samples have been classified based on the dominant ions in the facies using Piper's (1944) trilinear diagram. This divides water into six facies (Figure 2). The plot of the water samples showed that 56.25%, 25%, 12.5% and 6.25% of the water samples fall within Na-Cl, Mixed Ca-(Na)-HCO_3, Na-HCO_3 and Ca-HCO_3 water type respectively. Thus Na-Cl is the dominant water type in the study area. Schoeller's plot (Figure 3) showed that the dominant major cations were Na^{+}+K^{+} while the dominant anions are Cl^{-} and HCO_3^{-} which confirm the result of Piper's trilinear diagram.

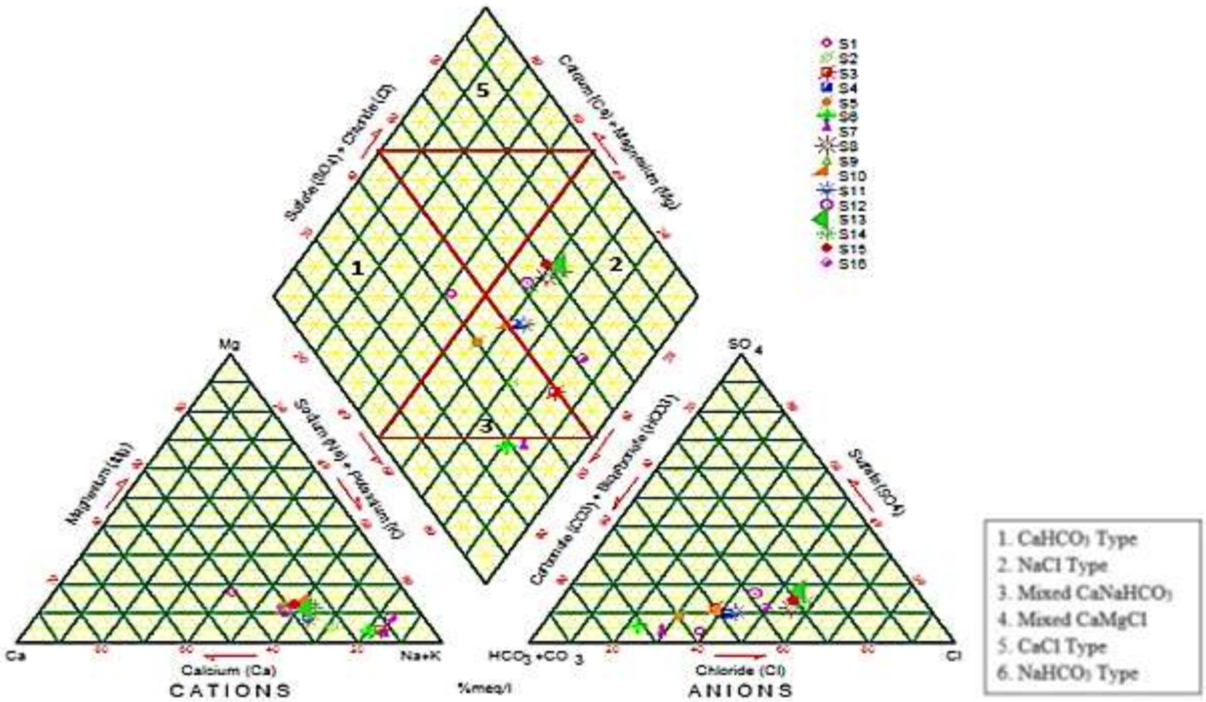

Figure 2: Plot of Water Samples on Piper Trilinear Diagram

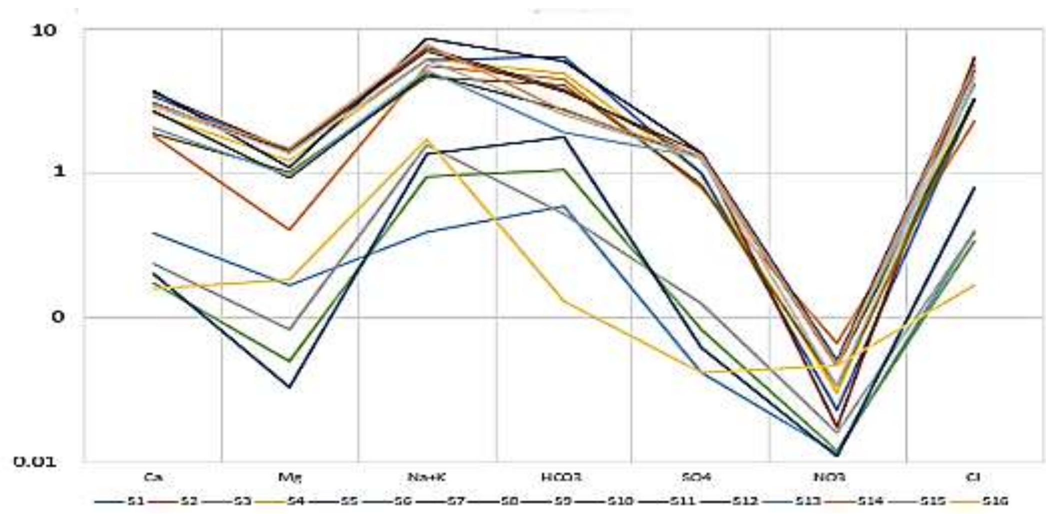

Figure 3: Shoeller's Plot for the Water Samples

Stiff pattern

Stiff patterns (Stiff, 1951) are useful in making rapid visual comparison between water from different sources and the larger the area of the polygonal shape, the greater the concentrations of the various ions (Fetter, 2001). Except for samples 1, 3, 6, 7 and 16, all the water samples have similar and high concentrations of dissolved ions (Figure 4)

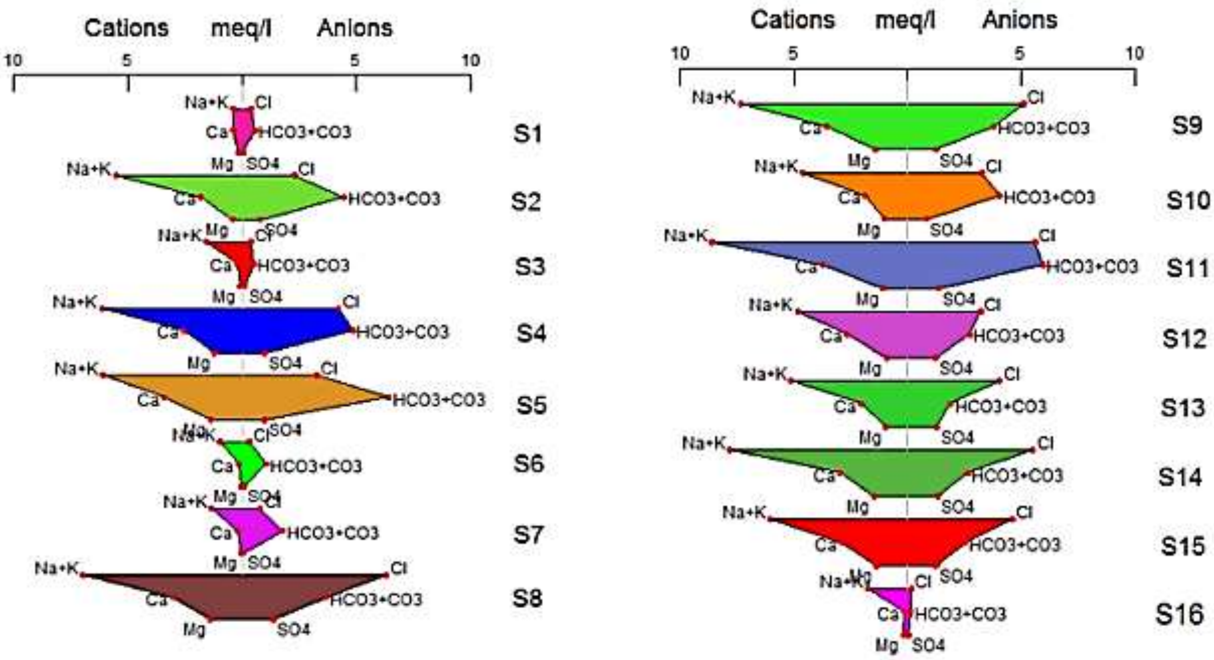

Figure 4: Stiff Pattern for the Water Samples

Wilcox Diagram

Wilcox diagram helps to predict the suitability of water for irrigation purpose. The Wilcox diagram (Figure 5) reveals that 87.5% of the water samples are within the area of excellent to good and good to permissible area, while 12.5% fall within permissible to doubtful area. Generally, the water samples can be used for irrigation.

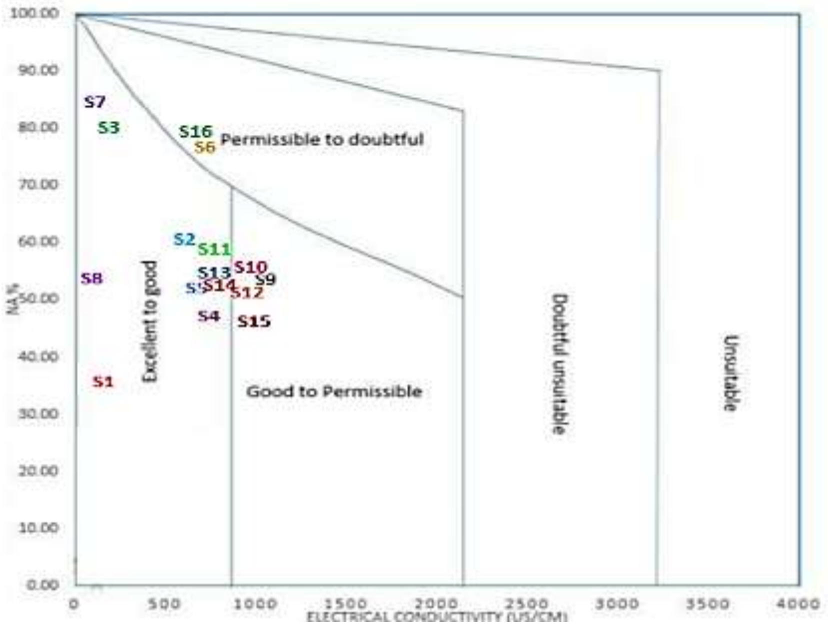

Figure 5: Plot of the Water Samples on Wilcox Diagram

In order to evaluate the suitability of water for irrigation, SAR and specific conductance are most commonly used by the United States Salinity Laboratory (Figure 6). The SAR is related to the sodium hazard; the specific conductance is related to the salinity hazard. From the Wilcox plot above, 25 % of water samples are located in C1-S1 class with low salinity and low sodium hazard; 50% plot in the C2-S1 class with medium salinity and low sodium hazard, while 25% of the water samples fall in the C3-S1 class with high salinity and low sodium hazard. It is advisable that plants that have some levels of salt tolerance should be selected.

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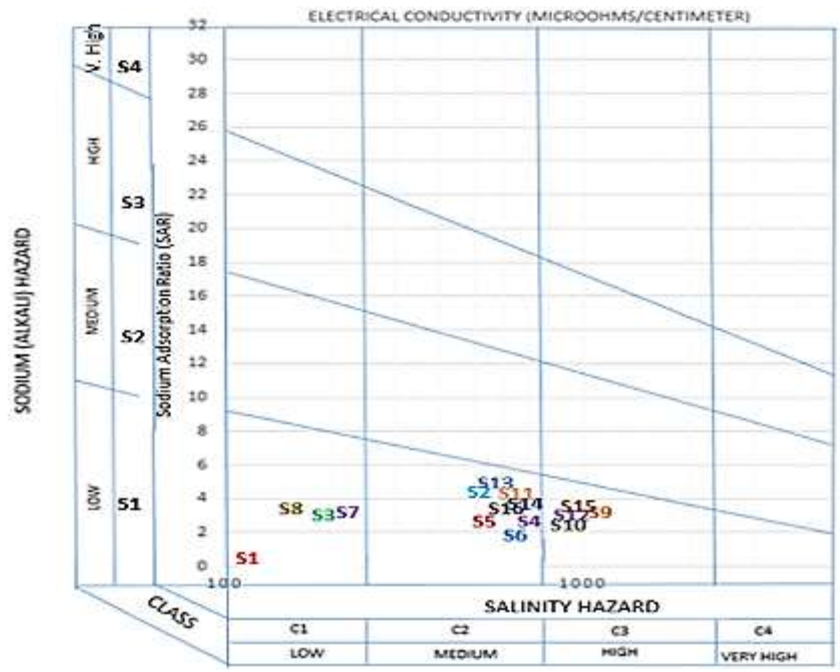

Figure 6: Plot of Water Samples in U.S. Lab. Classification of Irrigation Water (Richard, 1954 and Wilcox, 1955)

Gibb's Diagram

The source of the dissolved ions in water can be studied using the Gibb's diagram. The Gibb's diagram (Fig. 7) showed that rock weathering accounts for the dissolution of the ions in 87.5% of the water samples, while precipitation is responsible for the remaining 12.5%.

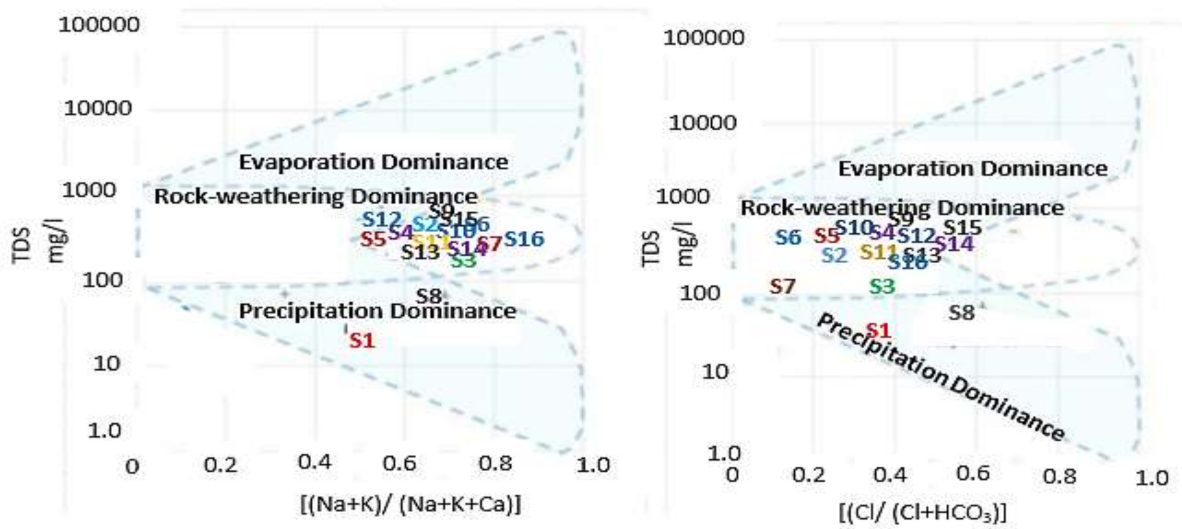

Figure 7: Plot of the water samples on Gibb's diagram

Heavy Metals

Heavy metals are commonly found in the environment and diet, they are required for maintaining good health in small amounts but toxic or dangerous when in larger quantity**.** Table 2 presents the summary of the analysed heavy metal constituents in the water samples.

Only 12.5% of the analysed samples have concentration of manganese beyond the maximum permissible limit of SON. Excess Manganesse could affect the nervous system thereby causing Central and Peripheral Neuropathies (Mahurpawar, 2015). 25, 37.5, 62.5 and 68. 75 % of the samples respectively have Chromium, Iron, Nickel and Lead concentrations in excess. According to WHO (2003), excess chromium has carcinogenic effect on the respiratory system could cause severe acute effects such as gastrointestinal disorders, haemorrhagic diathesis and convulsion or even cause death from cardiovascular shock (Janus and Kranjnc, 1990). Excess iron could cause stain to laundry and sanitary wares (WHO, 2011). Higher concentrations of Nickel in water could affect the pulmonary system and skin and can lead to cancer and dramatis (Mahurpawar, 2015). Lead is an extremely toxic heavy metal that disturbs various plant physiological processes. According to Najeeb *et al.,* 2014 cited in Jaishankar *et al*., (2014) a plant with high lead concentration fastens the production of reactive oxygen species (ROS), causing lipid membrane damage that ultimately leads to damage of chlorophyll and photosynthetic processes and suppresses the overall growth of the plant.Chronic exposure of lead can result in mental retardation, birth defects, psychosis, autism, allergies, dyslexia, weight loss, hyperactivity, paralysis, muscular weakness, brain damage, kidney damage and may even cause death (Martin and Griswold, 2009).All the samples however have Arsenic and Cadmium concentrations beyond the permissible limit. According to Smith *et al*., (2000) cited in Jaishankar *et al*., (2014), lower levels of arsenic exposure can cause nausea and vomiting, reduced production of erythrocytes and leukocytes, abnormal heart beat, pricking sensation in hands and legs, and damage to blood vessels.

Table 2: Heavy Metals in the Water Samples and Comparison with SON Limits

Heavy Metals	Conc Range (mg/l)	SON limit	Samples exceeding limit	Percentage (%) exceeding limit
Cobalt	0.002-0.004	N/S	-	-
Manganese	0.01-0.26	0.2	SS2, WS5	12.5
Arsenic	0.003-0.4	0.01	All	100
Cadmium	0.02-0.4	0.003	All	100
Copper	0.002-0.01	1	Nil	0
Lead	0.01-0.2	0.01	WS1, SS2,SS3,WS5,SS6,WS8,WS10,WS12,WS13,WS14,BH 1*	68.75
Barium	0.02-0.4	0.7	Nil	0
Zinc	0.006-0.06	3	Nil	0
Chromium	0.04-0.4	0.05	SS3,WS5,WS12,WS13	25
Nickel	0.005-0.1	0.02	WS1 SS3,WS4,WS5,SS7,WS9,WS11,WS12,WS13,WS15	62.5
Iron	0.16-3.68	0.3	SS2, SS3,WS5,SS7,WS11,BH1*	37.5
Silver	0.005-0.03	N/S	-	-
Titanium	0.011-0.1	N/S	-	-

Long-term exposure can lead to the formation of skin lesions, internal cancers, neurological problems, pulmonary disease, peripheral vascular disease, hypertension and cardiovascular disease and diabetes mellitus. Chronic arsenic osis results in many irreversible changes in the vital organs and the mortality rate is higher. In spite of the magnitude of this potentially lethal toxicity, there is no effective treatment for this disease (Mazumder, 2008). Cadmium in the environment is toxic to plants and animals and many micro-organisms. Cadmium does not degrade in the environment to less toxic products which contributes to its bioaccumulation in the kidneys and liver of vertebrates and invertebrates. Excess Cadmium could cause damage to kidney, liver, lung and bones (Mahurpawar, 2015). The rest of the tested heavy metals have no excess concentration beyond the acceptable limits in any of the water sample.

CONCLUSION

Water quality study has been carried out in a typical industrial estate in Agbara for the purpose of evaluating the suitability of the water for drinking and irrigation purposes. Although the levels of concentration of the major ions in the water sample, when compared to WHO standard generally fall within their acceptable limit, the concentration of the heavy metals suggests underlying hazards which could be traced to contamination by effluents from industrial activities. It is therefore paramount that the industries adopt best practices in sewage disposal and that appropriate water bodies and stakeholders take strict measures to govern the operation and activities of the industries for the overall benefit of man and her environment.

The heavy metal concentration when compared with SON limit showed concentration beyond permissible limit in samples SS2 and WS5 for manganese, while all samples tested for arsenic and cadmium showed concentrations beyond permissible limit. Samples tested for copper, barium and zinc showed concentrations below the SON permissible limit. 68.75% of the samples observed for Lead showed concentrations higher than the permissible limit, 62.5% were higher for nickel test, while percentage of samples higher than the SON iron concentration limit is 37.5.

These results, when further paralleled with SON permissible limits does not fall with the maximum acceptable limits, suggesting that the source of water of the study is not portable. Continuous intake of this water could lead to nervous system damage, gastrointestinal disorders, disturbed pulmonary systems, muscular weakness and also brain damage.

References

Adekunle I. M., Adetunji M. T., Gbadebo A. M and Banjoko O. B. (2007). Assessment of Ground water quality in a typical rural settlement in southwest, Nigeria. – International Journal of Environmental Public Health 4(4): 307-318.

Ajibade O. M., Omosanya K. O., and Odunsi G. O. (2011). Ground water portability and flow direction of urban aquifer, Ibadan, Southwestern Nigeria. Water Resources Journal of Nigerian Association of Hydrogeologists. 21, 38-56.

Ajibade A. C. and Wright, J. B. (1988). Structural Relationship in the Schist Belts of North Western Nigeria in P. O Oluyide et al (Eds). Precambrian geology of Nigeria. A publication of Geological Survey, 103-109.

Aladejana, J. A and Talabi, A. O. (2013). Assessment of Groundwater Quality in Abeokuta Southwestern, Nigeria. International Journal of Engineering and Science, 2(6): 21 – 31.

Arumugan, K. and Elangovan, K. (2009). Hydrochemical Characteristics and Groundwater Quality Assessment in Tirupur Region, Coimbatore District, Tamil Nadu, India. Environ Geol., 58: 1509-1520

Bayode, S; Olorunfemi, O. and Ojo, J (2012). Assessment of Impact Some Waste Dumpsites on the Groundwater Quality in Parts of Akure Metropolis, Southwestern Nigeria. The Pacific Journal of Science and Technology, 13(2): 528-536.

Davis, S.N and DeWiest, R.J. (1966). Hydrogeology, Wiley, New York.

Edet, A., Nganje, T.N., Ukpong, A.J. and Ekwere, A.S. (2011). Groundwater chemistry and quality of Nigeria: A status review. African Journal of Environmental Science and Technology, 5(13): 1152-1169.

Fetter, C. W. (2001). Applied hydrogeology. 4th ed. Prentice-Hall, Inc, 615p

Freeze, R.A. and Cherry, J.A. (1979). Groundwater, Printice-Hall, New Jersey.

Gbadebo A. M., and Taiwo A. M., (2011). Geochemical characterization of Phreatic aquifers in Sango area, Southwestern Nigeria. World Applied Science Journal. 12, 815-821.

Harter T.A., (2000). Groundwater quality and assessment. 2nd Edition pp 432.

Ige O. O., Okunola, N., Obasaju, D. O. and Omorinoye, O. A. (2017). Hydrochemical Evaluation of Water Sources in Iwo Southwestern Nigeria. Ethiopian Journal of Environmental Studies & Management 10(7): 958-967

Ige, O. O. and Korode, I. A. (2014). Effects of Seasonal Variations on Groundwater Facies Classification in Otte, Southwestern Nigeria. Ilorin Journal of Science, 1(1): 61.

Ige O. and Olasehinde P. I. (2011). Preliminary assessment of water quality in Ayede–Ekiti, Southwestern Nigeria. Journal of Geology and Mining Research 3(6), 147 – 152.

Ikhane P. R., Akintola A. I., Ola-Buraimo A. O., Oyebolu O. O., Akintola G. O. and Adesanwo B. T. (2012). Palynology and Paleoenvironmental Reconstruction of the Early Maastrichtian Afowo Formation, Dahomey Basin, Southwestern Nigeria. Science Journal of Environmental Engineering Research. (Nigeria). 2 (20), 1-8.

Jaishankar, M. Tseten T., Anbalagan N., Mathew B., and Beeregowda K. (2014). Toxicity, mechanism and health effects of some heavy metals. Interdiscip Toxicol. 7(2): 60–72

Janus, J. A and Kranjnc, E. I (1990). Integrated Criteria Document Chromium: effects. Appendix. Bilthoven, Netherlands, National Institute of Public Health and Environmental Protection.

Järup L. (2003). Hazards of heavy metal contamination. Br Med Bull 68(1): 167–182.

Jones and Hockey R.D., (1964). Geology of some parts of SouthWestern Nigeria, Geological Survey of Nigeria, 31, 1-101.

Lambert M, Leven B. A, Green R. M. (2000). New methods of cleaning up heavy metal in soils and water. Environmental science and technology briefs for citizens. Kansas State University, Manhattan, KS.

Mahurpawar M. (2015). Effects of Heavy Metals on Human Health.

International Journal of Research – Granthaalayah. Social issues and environmental problems. 1-7

Martin S, Griswold W. (2009). Human health effects of heavy metals. Environmental Science and Technology Briefs for Citizens (15): 1–6

Mazumder G. (2008). Chronic arsenic toxicity & human health. Indian J Med Res 128(4): 436–447.

Mosby C. V, Glanze W. D, Anderson K. N. (1996). Mosby Medical Encyclopedia, The Signet: Revised Edition. St. Louis.

Najeeb U, Ahmad W, Zia M. H, Malik Z and Zhou W. (2014). Enhancing the lead phytostabilization in wetland plant Juncus effusus L. through somaclonal manipulation and EDTA enrichment. Arabian Journal of Chemistry (2014), http://dx.doi.org/10.1016/j.arabjc.2014.01.009

Oloruntola, M. O, Obasaju, D. O and Yusuf M. A (2018): Hydrochemical, Microbiological and Biochemical Assessments of Groundwater Quality in some parts of Lagos Metropolis, Southwestern Nigeria Ethiopian Journal of Environmental Studies and Management. 11(1): 58 – 72

Omatsola M. E., and Adegoke O. S., (1981). Tectonic evolution and cretaceous stratigraphy of the Dahomey basin. Journal of Min. Sci. 18, 130-137

Oyedele, E and Olayinka, A. (2012). Statistical Evaluation of Groundwater Potential of Ado –Ekiti, Southwest, Nigeria. Transnational Journal of Science and Technology, 2(6): 110 – 127.

Piper A. M (1944) A graphical interpretation of water—analysis. Trans Am Geophys Union 25:914–928

Rahaman, M. A., (1976). Review of the basement geology of southwestern Nigeria. In Kogbe, C.A. (ed) Geology of Nigeria. Elizabethan Pub. Co. Lagos, 45-48.

Rajmohan, N. and Elango, L. (2005). Nutrient chemistry of groundwater in an intensively irrigated region of Southern India. Environ. Geol., 47: 820-830.

Richards, L. A. (US Salinity Laboratory) (1954). Diagnosis and improvement of saline and alkaline soils. US Department of Agriculture hand book 60p.

Smith A. H, Lingas EO, Rahman M. (2000). Contamination of drinking-water by arsenic in Bangladesh: a public health emergency. Bull World Health Organ 78(9): 1093–1103.

SON (2007). Nigerian Standard for Drinking Water Quality, Abuja, Nigeria. 554, 30p.

Stiff, H. A., (1951). The interpretation of chemical water analysis by means of patterns. Journal of petroleum technology 3:15-17.

Subramani, T. Elango, L. Damodarasamy, S. R (2005). Groundwater Quality and its Suitability for Drinking and Agricultural Use, Chithar River Basin, Tamil Nadu, India. Environ Geol., 47: 1099-1110.

Taiwo, A. M., Adeogun, A. O., Olatunde, K. A., Adegbite, K. I. (2011). Analysis of groundwater quality of hand-dug wells in peri-urban area of Obantoko, Abeokuta, Nigeria for selected physic-chemical parameters. – The Pacific Journal of Science and Technology 12(1): 527-534.

Tijani, M. N., Olatunji, A.S., Sangogbade, O. O and Chuckwurah, B. N. (2005). Hydrochemical Evaluation of Seawater Influence on Water Quality in Metropolitan Lagos, Nigeria, 225-239

Tijani, M. N., Oke, S. A. and Olowookere, A. T. (2014). Hydrogeochemical characterization of shallow groundwater system in the weathered basement aquifer of Ilesha area, southwestern Nigeria. 475 – 480.

United States Environmental and Pollution Agency (1985). Water quality control. 3rd Edition. 378p

WHO (1993). Guidelines for drinking water quality, vol 1, recommendations, 2nd edn. WHO, Geneva, 130p

WHO (2011). Guidelines for Drinking Water Quality. Fourth ed. World Health Organization.

Wilcox, L. V. (1955). Classification and use of irrigation waters USDA Circular No. 969. 19 pp.