Hydrology for Disaster Management

Special Publication of the Nigerian Association of Hydrological Sciences, 2012

http://www.unaab.edu.ng

Assessment of Shallow Groundwater Quality for Irrigation Purposes in Basement Complex Terrain of Southwestern Nigeria

[1]Oke, S. A. and [2]Aladejana J. A.

[1]Department of Chemical and Geological Sciences, Al-Hikmah University Ilorin, Nigeria
[2]Department of Geology, Achievers University, Owo, Nigeria

Correspondng author: Email - sedoeko@yahoo.com

Abstract

This research attempts the investigation of shallow groundwater quality for suitability in agriculture (irrigation) and other uses. Samples were investigated for sodium adsorption ratio, magnesium hazard, Kelley's ratio, residual sodium bicarbonate, and alkalinity hazard and permeability index. The methodology involves sampling of hand dug wells <30m for laboratory analyses. ICP-MS was used in determining the major metals present in the water samples while titrimetric method was employed for anions determinations. Physico-chemical results revealed a midly acidic pH of mean value 6.3, TDS of 329mg/l, E.C of 427uS/cm, Ca of 25mg/l, Mg of 8.5mg/l, and Na of 42.5mg/l. Calculated indices such as MAR, RSBC, PI indicate that majority of the water are suitable for irrigation. Kelley's ratio shows that 31% of the water samples are above permissible limit of good irrigation waters while 69% fall within. Calculated SAR and EC classify 69% of the samples into medium salinity to low sodium hazard (C2S1), 25% within low salinity and low sodium hazard (C1S1) and 3% each within the high salinity and low hazard (C3S1) and medium salinity and medium hazard (C2S2) respectively. The groundwater qualities satisfy the condition for use in industry and livestock farming.

Keywords: SAR, Irrigation, Salinity, Alkalinity and Electrical Conductivity

Introduction

Generally, groundwater has been alternative option that is rely on for the provision of water for adequate use among most inhabitant of Africa. Importance of groundwater resources for human consumption, agricultural and industrial uses as well as its quality has been widely researched (Sayyed and Wagh, 2011; Adekunle et.al., 2007; Olabisi et.al., 2008). Increased knowledge of processes that controls chemical compositions of groundwater can improve the understanding of their usability status. Groundwater usability in irrigation farming is very important and its quality can be related to food security. Undulating topography as well as unreliable rainfall creates moisture limitation for the soil, which affects plants performance and food production.

To alleviate the challenges of food insecurity in the country, irrigation farming must be given serious attention. Irrigation practices has been known to enhance food security, promote economic growth and sustainable development, create employment opportunity, improve living conditions of small scale farmers, and recharge subsurface water level. The characteristics of an irrigation water that seem to be most important in determining its quality are (1) total concentration of soluble salts, (2) relative proportion of sodium to other cations (magnesium, calcium, and potassium), (3) concentration of boron or other elements that may be toxic, and (4) under some conditions, the bicarbonate concentration as related to the concentration of calcium plus magnesium (Raghunath, 1987; Raihan and Alan, 2008).

In addition, urbanization and rural-urban drift in most developing countries has placed a strain on food security and groundwater resources. Many Nigerian urban settlements continue to witness increased population growth. This overpopulation trend posed a lot of challenges on the nation's food security and groundwater management in most of the urban settlement. Therefore, this paper focuses on the investigation of the quality status of the shallow groundwater resources for agricultural use (irrigation farming on one hand and industrial use on the other hand). It should be noted that water quality definition depends on the desired use of water. Therefore different uses required different criteria of water quality as well as standard methods for reporting and comparing results of its analysis (Babiker, 2007).

Previous studies includes the work of Sarkar and Hasan (2006) who investigated the water quality of a groundwater basin in Bangladesh for irrigation use. From their analytical result, the authors observed that the compositions of the groundwater samples were within the permissible range of irrigation use, except increased Cl^- values, which are responsible for toxicity problem. Olabisi et al. (2008) reported bacteria pollution of shallow wells in Abeokuta area and they attributed the cause to anthropogenic sources. Reduced pH of water samples where noted by Adekunle et.al (2007) from wells closer to the defecation sites relative to residential areas of Abeokuta metropolis. The authors attributed this low pH to sulphur and amino acid compounds from human and animal excreta.

Geological and Hydrogeological Setting

The study area is Abeokuta, SW Nigeria (Figure 1). Abeokuta area covers part of the basement complex terrain of southwestern Nigeria. The area is situated on latitude 07^{o}07' to 07^{o}11' and longitude 003^{o}16' to 003^{o}23'. The study area belongs to the subtropical region of West Africa which is generally characterized by wet and dry season with short harmattan season in between. Air temperature ranges between 33°C during the day and 22°C at night, rainfall ranges between 1200mm to 800mm during the wet season.

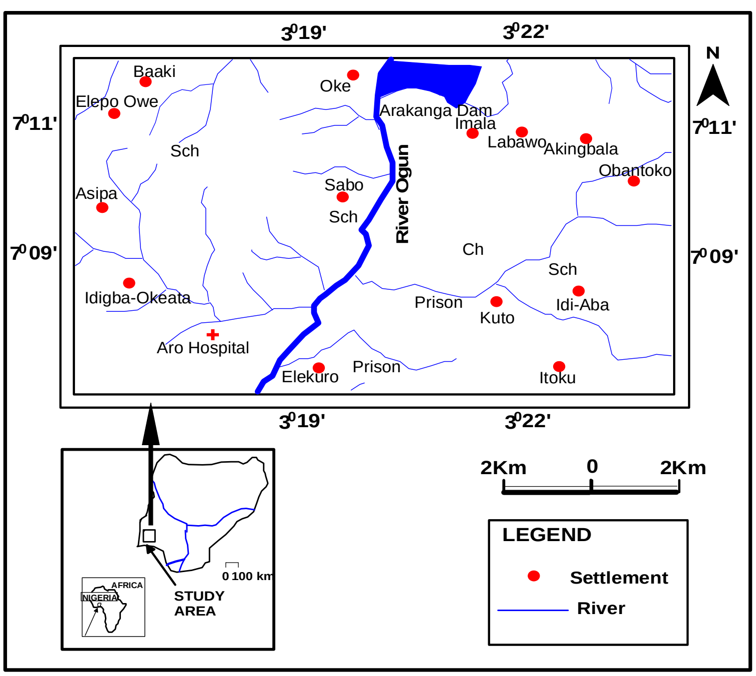

Figure 1: Drainage pattern in the study area

The sedimentary sequence of the study area is mainly represented by the Late Cretaceous Abeokuta formation overlying the basement complex rocks conformably. The basement rocks comprise of the biotite schist, porphyroblastic gneiss, porphyritic granite, biotite granite gneiss and migmatite. The hydrogeological settings of the study area include surface water and groundwater. The surface water is represented by River Ogun, River Oyan and several tributaries. Most of the tributaries are seasonal in flow thereby making them unpredictable for irrigation use. The groundwater system comprises of both shallow unconfined aquifers in weathered sequence overlying the basement rock and deep fracture controlled basement aquifer. The shallow unconfined aquifer which is the target of this paper, are recharge by rainfall. The aquifers are tapped by hand dug wells (< 30m) and varies in depth depending on the overlying formation and topography Olabisi et.al (2008). The thickness of this aquifer as well as its width differs from one locality to another. Groundwater flow in the study area is towards River Ogun (Figure 1). The highest contour lines are at the ridges fringes (105 m) and lowest contour lines are close to the River Ogun (50 m) (Figure 2).

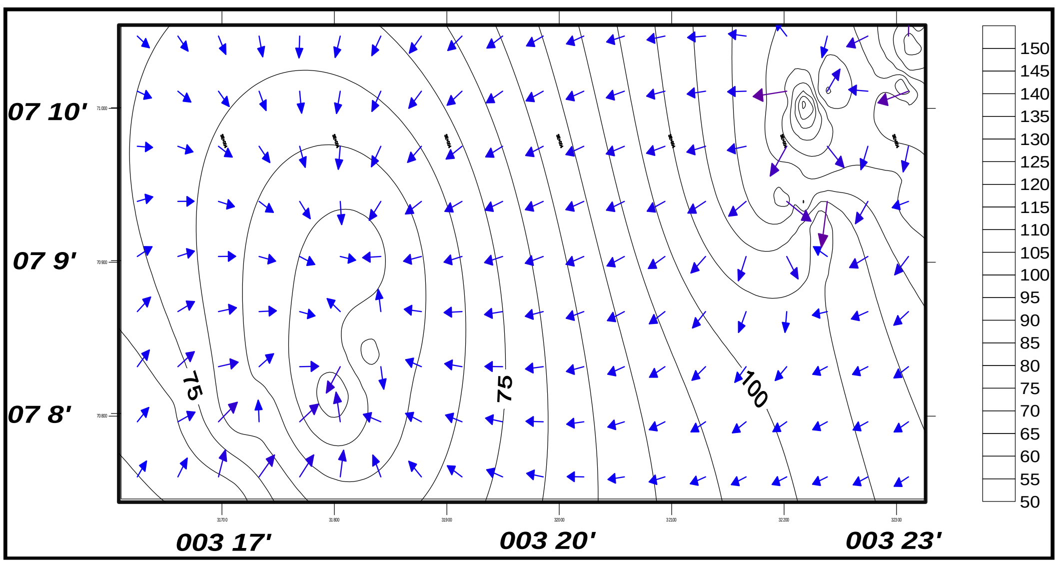

Figure 2: Contour lines and groundwater movement pattern

Materials and Methods

Shallow groundwater samples were obtained for chemical analysis during the dry season from 32 wells in the study area. The samples were collected into two sterillized polyethylene bottles pre-cleaned to remove any traces of previous samples or contaminant for analyses in the laboratory. The bottles were washed many times with deionized water and later washed with the sampling water. All the samples were well cocked and later transported to the laboratory for analyses. Major cations (Na^{+}, K^{+}, Ca^{2+}, Mg^{2+}) were determined by Inductively Coupled Plasma-Mass Spectrometer (ICP-MS) while anions (SO_4^{2-}, Cl^{-}, HCO^{3-}, CO_3^{2-} NO^{3-} and PO_4) were determined by titrimetric methods. pH, temperature and electrical conductivity (EC) were determined on the field using Hanna probe conductivity meters HI 8033. Total dissolve solids (TDS) were computed from the electrical conductivity. The sampling and analysis followed APHA (1995) standard procedure.

Water Quality Indices

Sodium Absorption Ratio (SAR): This is a useful index to classify the suitability of groundwater for irrigation purposes. Salinity and Toxicity problems of irrigation water are attributed to SAR (Raihan and Alan, 2008). The SAR was calculated by the following equation given by Richards (1954) as:

$$SAR = \frac{Na}{\sqrt{\frac{(Ca+Mg)}{2}}}$$

Permeability Index (PI): This is the rate of water infiltration into soil which may arise from salinity of water and its sodium content relative to calcium and magnesium. PI was calculated according to Doneen (1962) by the following equation:

$$PI = \frac{\left(Na + \sqrt{HCO_3}\right)*100}{Ca + Mg + Na}$$

Total Hardness (TH) was calculated by the following equation (Raghunath, 1987):

$$TH = \left(Ca + Mg\right)*50$$

Where, TH is expressed in meq/l (ppm).

The Residual Sodium Bi-carbonate (RSBC) was calculated according to proposed formula by Gupta and Gupta (1987): RSBC = HCO_3 - Ca

Magnesium Adsorption Ratio (MAR): The presence of magnesium in groundwater to a great extent will reduce the overbearing effect of sodium in groundwater. The MAR was calculated by the equation of Raghunath (1987) as:

$$MAR = \frac{Ma*100}{Ca + Mg}$$

Where, all the ionic concentrations are expressed in meq/L.

The Kelly's Ratio was calculated using the equation of Kelly's (1963) as:

$$KR = \frac{Na}{Ca + Mg}$$

Results and Disscussion

Groundwater Composition

The composition of the shallow groundwater show variations in the chemical properties of the analysed water samples. The variations are due to water - rock interraction, groundwater sources, weathering and leaching of soil minerals. Table 1 contains summarized results of the physico-chemical parameters and caculated indices for the study area.

pH

The pH is a measurement of the relative acidity or basicity of water. The pH in the study area ranges from 5.1 to 7.3 with average value of 6.3. This make the water midly acidic to slightly alkaline water. The majority of the shallow aquifer waters in the study area are neutral. The acidic waters are localised to the overpopulated region. This indicate anthropogenic effects on the water system. Water suitable for irrigation must have pH range of 6.5-8.4 (Bauder et al., 2010). pH characteristics (acidity or alkalinity) has a significance influence on reactions_in soil and water (SAI,2010) thereby affecting the performance of plants.

Electrical conductivity

The most significant water quality guideline on crop productivity is the water salinity hazard as measured by electrical conductivity Johnson and Zhang (1990). The EC observed in the study area contain between 102 uS/cm as minimum value and 1133 uS/cm as maximum value while average value of 427.38 uS/cm was recorded. The primary effect of EC has observed by Naseem et.al (2010) is the inability of plant to compete with ions in the soil.

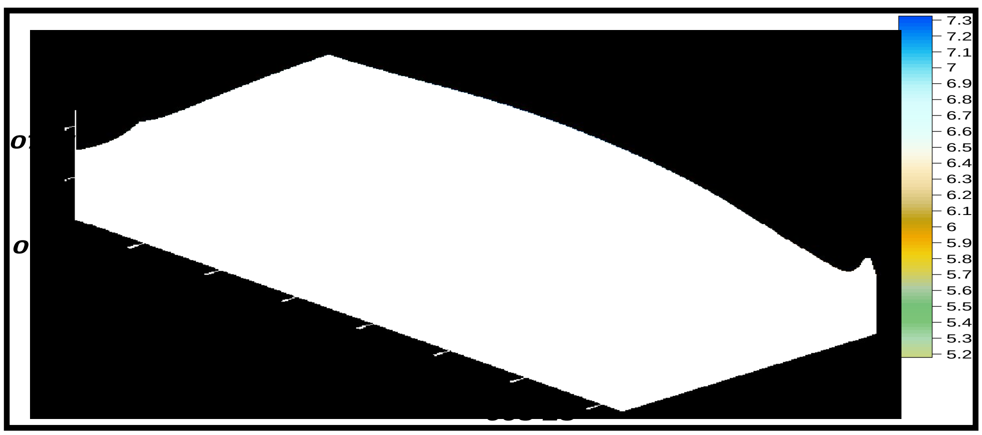

Figure 3: pH distribution level in Abeokuta, Nigeria

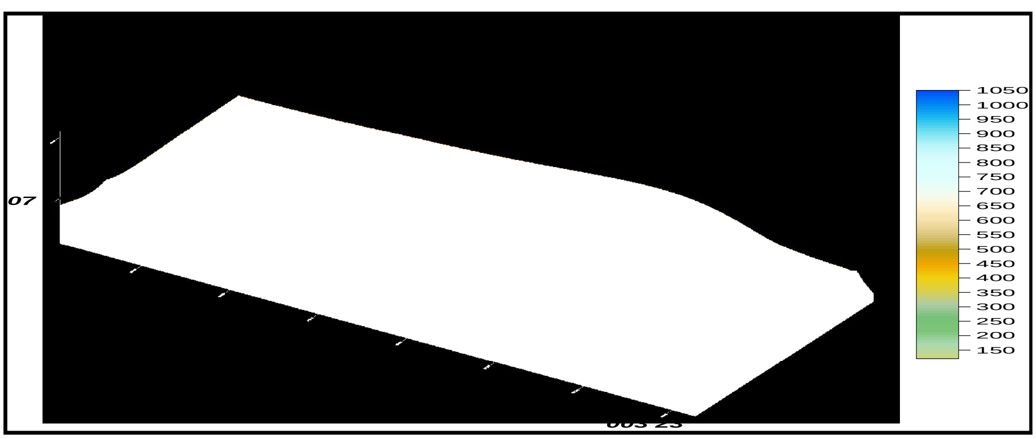

Figure 4: Electrical Conductivity distribution in Abeokuta, Nigeria

Total Hardness

The predominant class of total hardness in the study area according to Sawyer and McCarthy (1967) ranged between 34% very hard to 38% moderately hard water and 28% soft water (Table 2). This result show the concentration of alkali earth metals presence in groundwater samples, which poses minimal impact on plant.

Alkali Hazard

The alkali or sodium hazard can be calculated from the dominance metals relative to the other metals. The sodium hazard can be calculated from sodium adsorption ratio (SAR) which is a simple method to evaluate the danger of high sodium water (Nata et.al 2011). Sodium level in water determines the alkali hazard level. If sodium proportion is high, the alkali hazard is high but if calcium and magnessium predominate the water, the hazard is less. Calcium and Magnessium content ranges from 5.9 mg/l to 62 mg/l and 0.9mg/l to 21 mg/l with mean of 25mg/l and 8.5mg/l respectively while Sodium and Potassium ranges from 11.8mg/l to 125mg/l and 0.7mg/l to 55mg/l with mean value of 8.6 respectively (Figure 5 and 6). This clearly shows the dominace of sodium above other metals. Figure 7b show the dominant metals in the water samples. 25% of the samples plot in the range of Ca^2+Mg^2 dominace while 75% plot in the Na^++K^+dominace.

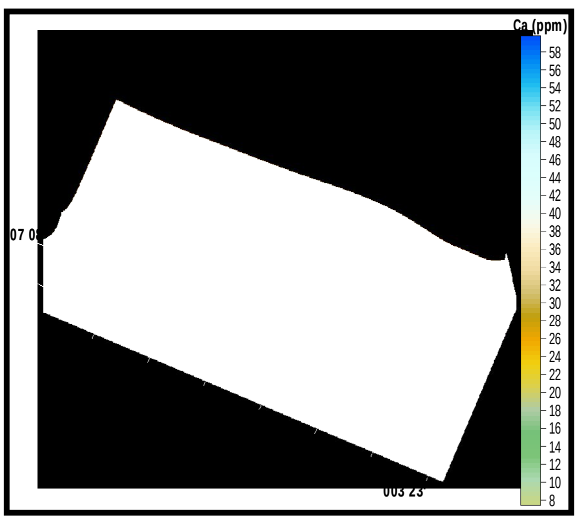

Figure 5:Ca distribution map in the study area

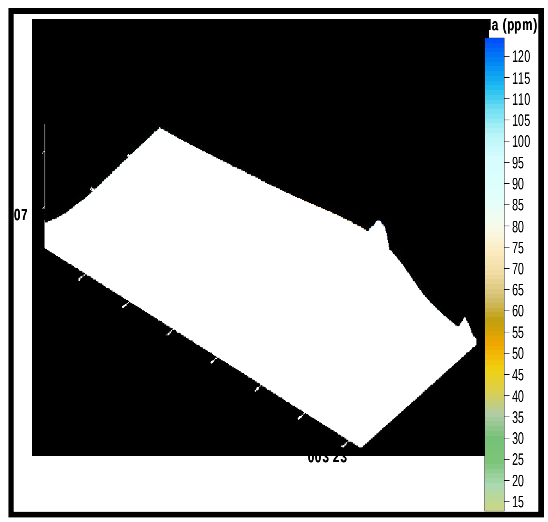

Figure 6:Na distribution map in the study area

The plot point to the excess of alkali metals (sodium) over alkali earth metals particularly Calcium. But the calcium goes into reaction more with bicarbonate than sodium (Figure 7a). This correlation is seen more in Figure 7c where samples of Ca^{2+}+Mg^{2+}vs HCO^{3-} is shown. The correlation is a proof of rock-water interaction where silicate weathering dominate the bicarbonate. Minor representations is also noted in the bicarbonate zone due to reactions of feldsparthic minerals with carbonic acid in the presence of excess water, which produces HCO_3 (Elango et.al., 2003). Also, excess bicarbonate can also be derived from a CO_2 charge rainstorm which produces weak carbonic acid that later dissociate into hydrogen ions and bicarbonate ions in the water (Tijani et.al., 2003). However, plot of Na^+/HCO_3 vs Ca^{2+}/HCO_3 indicate the possibility of cation exchange between the alkali metal (Na^+) ions and alkali earth Metals (Ca^+) ions. The dominant sodium reacts with excess bicarbonate ions (Figure 7a). It should be noted that majority of the sodium ions react with the chloride than the bicarbonate, but where bicarbonate ions dominate chloride ions in the groundwater, the sodium ions goes into reaction with the bicarbonate. This is shown with the few samples of Na^+/HCO_3 (Figure7d).

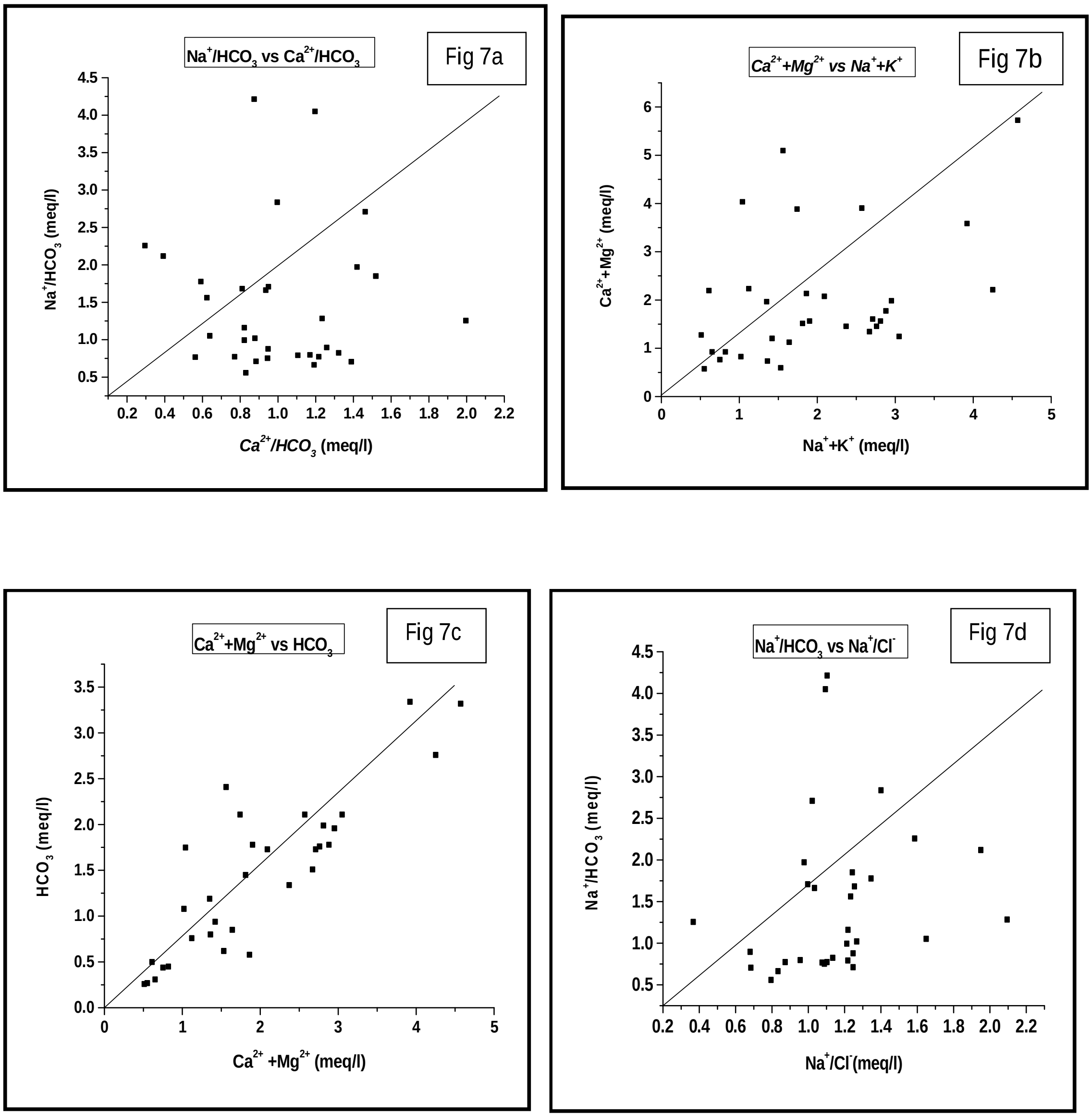

Figure 7: Correlation of anions and cations

Residual Sodium Bicarbonate

Residual sodium bicarbonate (RSBC) exists in irrigation water when the bicarbonate (HCO3) content exceeds the calcium (Ca) content of the water. Where the water RSBC is high (>2.5meq/l), extended use of that water for irrigation will lead to an accumulation of sodium (Na) in the soil. This may results in (1) Direct toxicity to crops, (2) Excess soil salinity (EC) and associated poor plant performance, and (3) Where appreciable clay or silt is present in the soil, loss of soil structure occur through clogging of pore spaces thereby hindering air and water movement (SAI, 2010; Naseem et.al., 2010). The RSBC value of the study area is between -0.5 to 1.45, indicating good quality for irrigation purpose.

Salinity Hazard

This is a useful index to classify the suitability of groundwater for irrigation purposes. Salinity and Toxicity problems of irrigation water are attributed to SAR (Raihan and Alan, 2008). The SAR is defined by US Salinity Laboratory Staff (1954), as Sodium rich water which may cause deterioration of the physical structure of the soil (pore clogging). Usually SAR less than 3.0 will not be a threat to vegetation while SAR greater than 12.0 is considered Sodic and threatens the survival of vegetation by increasing soil swelling (dispersion) and reducing soil permeability (Kuipers et al., 2004). The compounding effects of discharging water with high SAR is that it produces soils that are unsuitable for agriculture, grazing and it creates hazards such as fugitive dust from wind and increased sediment loading of local streams and rivers from surface runoff and damages the stream channel integrity (Kuipers et al., 2004, Sayyed and Sayadi, 2011). In the study area, nearly majority of the samples fall within the medium salinity to low sodium hazard (C2S1) representing 69% while 25% fall within low salinity and low sodium hazard (C1S1) and 3% each falls within the high salinity and low hazard (C3S1) and medium salinity and medium hazard (C2S2) respectively (Figure 8). Jain *et al*., (2000) warns that water with high salinity and sodic hazard should not be used on soil with restricted drainage.

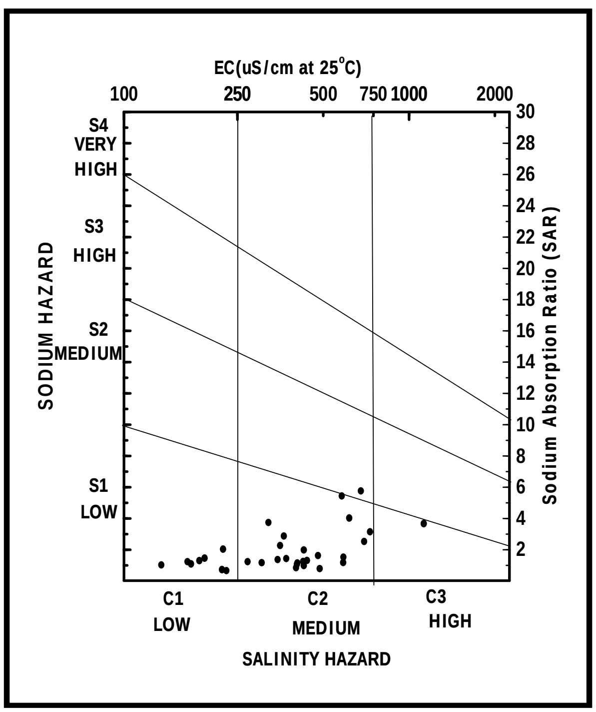

Figure 8: Classification of groundwater according SAR and EC

Alkalinity Hazard

Alkalinity is the addition of bicarbonate and carbonate present in irrigation water. Alkalinity shows ability of water to increase the pH of the soil or growing media and the buffering power of the water itself. Alkalinity also provides index into the nature of the rocks within the aquifer and the degree to which they are weathered to release metals. Medium to alkaline pH water are known to support bicarbonate accumulation in water, this trend is repeated in the shallow groundwater of the study area, where the low alkalinity value of <20 mg/l according to Figure 9 are established around pH of 6.8-7.3. Bicarbonate has been known to be directly toxic to plant species (SAI, 2010). Also, if bicarbonate level exceeds 200ppm in irrigated water, lime deposition will occur which may be undesirable for ornamental plants (SAI, 2010). The alkalinity limit found in the water is between 3mg/l and 33mg/l. This is far below the recommended standard limit suitable for irrigation.

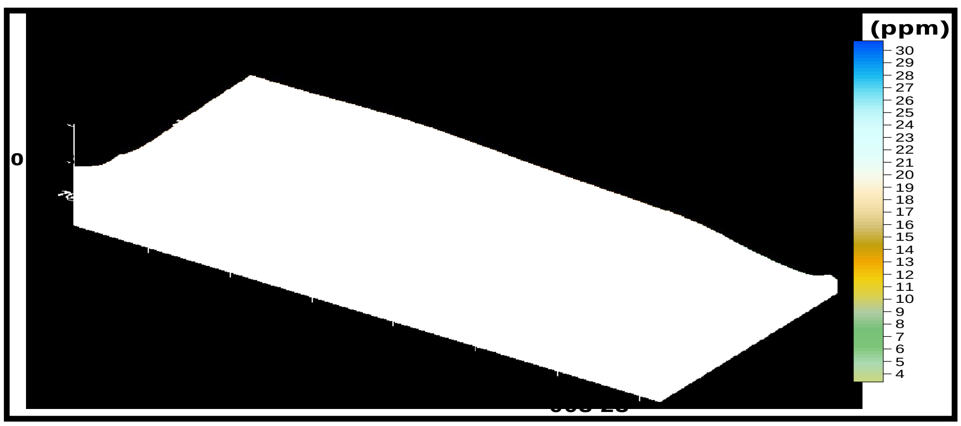

Figure 9: Alkalinity distribution in shallow groundwater of Abeokuta, Nigeria

Magnesium Hazard

In the study area, three water samples well No. 13(50.3), well 21(60.4) and well 28 of magnesium hazard value (50.3) contains magnesium absorption ratio (MAR) values exceeding 50, which is the restricted limit to cause harmful effect to the soil. This water is less suitable for irrigation. Apart from these three well waters, the groundwater can be classified as suitable for irrigation. It was also reported that soils containing high levels of exchangeable magnesium causes infiltration problem (Ayers and Westcot, 1985).

Permeability index (PI) problem occurs when the rate of infilteration in soil is reduced appreciably due to salinity of water and its sodium content relative to calcium and magnisium. Highly saline water decreases the infilteration rate.

Kelley's Ratio (KR)

This is an important parameter formulated by Kelley (1963) based on the level of Na against Ca and Mg. He suggested that good irrigation water based on this ratio should not exceed 1.0. The KR value of the investigated shallow groundwater has about 31% of it samples above the permissible limit and 69% suitable for the irrigation.

Groundwater Usability

Water quality requirements for different purposes differ; hence standards have been developed to appraise water usability for various purposes. Tijani (1994) suggested that water quality is subjective and depends on its usage. Therefore, water standard differ for various uses such as domestic (drinking), agricultural / irrigation and industries.

Domestic Use

For drinking purposes, Davies and De-weist, (1966), proposed two main criteria to be

1) The absence of objectionable tastes, odour and colour.
2) The absence of substance with adverse physiological effects.

From the field observations, the water are colourless, odourless and tasteless, in fact most of the habitant are using the water directly without treatment. The suitability of the groundwater in the study area for drinking purposes as disscussed by Olabisi et.al (2008), Adekunle et.al (2007), Oke and Tijani (2012) permit domestic use of the water provided hygenic and other conditions such as the treatment of iron and aluminium enrichment are improved. Results also show that the water type found in the study area tend towards sodium bicarbonate and calcium bicarbonate water believed to be common in the basement complex and water with such qualities are generally acceptable in industries if the TDS is low (Offodile, 1992).

Agricultural use

Water usability in agricultural fields is in two ways; namely, livestock feeding and irrigation. The suitability of the shallow groundwater for irrigation has been qualified according to most irrigation indices (SAR, EC, RSBC, KR, PI, MAR and SSP). The groundwater quality criteria for livestock feeding is the same as that of domestic uses, which the groundwater satisfied. This implies that the Abeokuta groundwater type is a good water source for irrigation and other agricultural uses.

Industrial Use

The American Water Works Association (1971) proposes a guideline for water use in the industry: Non-low taste and odour, TDS (500-1500mg/l), Hardness as TH (0-250meq/l), pH (6.5-8.3), chlorides (20-250mg/l), iron (0.1-1.0mg/l) and manganese (0-0.5). Result of the analysed water sample as presented in Table 1 revealed mean pH value of 6.38, TDS of 329mg/l, TH of 100.425meq/l, Cl of 62.258mg/l, Fe of 0.48mg/l and Mn of 0.105mg/l. These result falls within the recommended industrial limit thereby making the water fit for industrial use.

Conclusion

The suitability of shallow groundwater in Abeokuta was investigated for irrigation and other usability status. Calculated indices such as MAR, SAR, RSBC, PI, TH and KR was employed to determine its suitability status for irrigation and other agricultural purposes. Results indicated that sodium is the dominant metals in the analysed samples. However, the groundwater revealed low sodium hazard and alkalinity hazard. Majority of the groundwater samples satisfy the required quality needed for irrigation and other agricultural uses. In general, most of the water from shallow wells in Abeokuta and environs are suitable for domestic, industrial and irrigation purposes provided they are free from harmful pathogens.

References

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

APHA, (1995), Standard methods for the examination of water and wastewater, 19th edn. American Public Health Association, Washington, DC

American Water Works Association. (1971), Water quality and treatment. McGraw-Hill. New York, 654pp

Ayers R.S and Westcot D.W, (1985), Water quality for Agriculture, FAO irrigation and drainage paper no. 29 (1): 1-109.

Babiker I.S, Mohamed M.A. and Hiyama A.T, (2007), Assessing groundwater quality using GIS, Water Resources Management, 21: 699–715.

Bauder T.A, Waskom R.M. and Davies J.G, (2010), Irrigation water quality, Colorado State University Extension

David, S.N. and Deweist, R.J.M. (1966), Hydrogeology, John Wiley and Sons, 463pp

Doneen I.D. (1962), The influence of crop and soil on percolating waters. Proceedings of the 1961 biennial conference on groundwater recharge.

Elango L, Kannan R and Senthil Kumar M, (2003) Major ion chemistry and identification of hydrogeochemical processes of groundwater in part of Kancheepuram district, Tamil Nadu, Indian Journal of Enviromental Geoscience, 10(4) 157–166.

Gupta S.K, and Gupta I.C. (1987). Management of Saline Soils and Water, Oxford and IBH Publication. Co. New Delhi, India, 399pp

Jain C.K, Bhatia K.K.S. and Vijay Kumar O. (2000), Groundwater quality in Sagar district, Madhya Pradesh. Indian Journal of Environmental Health, 42 (4): 151-158.

Johnson G. and Zhang H. (1990), Classification of Irrigation water quality, Oklahoma Cooperative Extension Fact Sheets, (available at www.osuextra.com).

Kelley, W.P. (1940), Permissible composition and concentration of irrigation waters", Proc. ASCE, 66, 607.

Kuipers J, MacHardy K. and Merschat W, (2004), Coal bed methane-produced water: management options for sustainable development. 11th International Petroleum Environmental Conference, Albuquerque, NM, USA.

Naseem S, Hamza S. and Bashir E. (2010), Groundwater geochemistry of Winder agricultural farms, Balochistan, Pakistan and assessment of irrigation water quality, European Water Publications, Vol. 31, pp 21-32.

Offodile, M.E. (1992), An approach to groundwater study and development in Nigeria. MECON Services Ltd. P. O. Box 6022, Jos, Nigeria, pp.178-191.

Oke S.A, and Tijani M.N, (2012), Impact of chemical weathering on groundwater chemistry of Abeokuta area SW-Nigeria, Elixir Pollution Vol. 46, pp 8498-8503

Olabisi O.E, Awonusi A.J. and Adebayo O.J. (2008), Assessment of bacteria pollution of shallow well water in Abeokuta, southwestern Nigeria, Life Science Journal, Vol 5, No 1

Raihan F, and Alam J.B, (2008), Assessment of groundwater quality in Sunamganj of Bangladesh. Iran Journal of Environmental Heath Sciences and Engineering, Vol. 5, No. 3, pp. 155-166.

Raghunath, I. I. M, (1987). Groundwater. Second edition; Wiley Eastern Ltd., New Delhi, India, 344-369.

SAI, (Spectrum Analytical Inc) (2010), Guide to interpreting irrigation water analysis, 1087 Janison Road, Washington CH, Ohio 43160 (Available: spectrumanalytic.com)

Sawyer, C.N. and McCarthy, P.L. 1967: Chemistry for sanitary engineers. 2nd edition. McGraw-Hill, New York, 518pp

Sayyed M.R.G, and Sayadi M.H, (2011), Variations in the heavy metal accumulations within the surface soils from the Chitgar industrial area of Tehran. Proceedings of the International Academy of Ecology and Environmental Sciences, 1(1): 36-46

Tijani M.N, (1994), Hydrochemical assessment of groundwater in Moro area, Kwara State, Nigeria, Environmental Geology, Vol. 24:194–202

Tijani M.N, and Abimbola A.F. (2003), Groundwater chemistry and isotope studies of weathered basement aquifer; a case study of Oke-Ogun Area, SW. Nigeria. African Geoscience Review. 2003 Vol. 10(4): 373-387.

U.S. Salinity Laboratory Staff (1954), Diagnosis and improvement of saline and alkali soils. Agricultural handbook,No. 60, USDA, US Government Printing Office, Washington, DC

Table 1: Summarized values of groundwater in Abeokuta Nigeria

Element	Min	Max	Ave	S.D
Elev (M)	50.00	152.00	104.62	28.22
DTW(M)	0.80	18.20	5.62	3.09
DTB(M)	1.70	20.20	6.77	3.12
Temp©	27.60	30.50	29.04	0.61
Ca (mg/l)	5.97	62.24	25.97	14.29
Mg (mg/)l	0.98	21.48	8.58	5.38
Na (mg/l)	11.82	125.88	42.58	29.66
K (mg/l)	0.72	55.06	8.60	9.79
Fe (mg/l)	0.05	1.97	0.48	0.32
Mn (mg/l)	0.004	1.21	0.10	0.09
P (mg/l)	0.03	2.25	0.31	0.41
S (mg/l)	0.001	5.00	0.49	1.09
CL- (mg/l)	18.10	209.90	62.26	41.81
HCO3 (mg/l)	3.00	34.00	11.03	6.68
NO3 (mg/l)	0.40	16.00	3.52	3.70
PO4 (mg/l)	0.00	3.20	0.53	0.73
F- (mg/l)	0.25	1.50	0.79	0.37
SO4 (mg/l)	34.00	109.00	53.65	15.65
PH	5.10	7.30	6.39	0.62
T.D.S (mg/l)	126.00	850.00	329.03	154.88
E.C	102.00	1133.00	427.38	209.72
SAR	0.61	5.70	1.96	1.30
PI	56.89	105.34	79.65	14.66
TH	26.03	229.30	100.43	53.28
MAR	7.88	60.37	35.03	10.84
K.R	0.35	3.71	1.14	0.88
SSP	27.38	79.25	49.42	14.40
RSBC	-0.57	1.45	0.17	0.50

Table 2: A range of water hardness in shallow groundwater of Abeokuta, Nigeria

Index Range	Description	Percentage
120-180	Very Hard	34%
60-120	Moderately Hard	38%
<60	Soft	28%

Table 3: Concentration of major ions present in shallow groundwater of Abeokuta, Nigeria

Sample ID	Ca meq/l	Mg meq/l	Na meq/l	K meq/l	HCO_3 meq/l	CL- meq/l	SO_4 meq/l	NO_3 meq/l	T.D.S uS/cm	E.C mg/l
1	1.14	0.73	0.71	1.41	0.57	1.92	1.08	0.35	367.00	489.00
2	0.43	0.19	2.06	0.12	0.49	1.86	0.31	0.08	242.00	323.00
3	0.75	0.38	2.12	0.10	0.75	1.51	0.48	0.40	275.00	366.00
4	0.67	0.16	0.81	0.10	0.44	0.65	0.29	0.24	139.00	185.00
5	1.10	0.27	0.55	0.17	0.79	0.80	0.52	0.09	167.00	222.00
6	2.28	0.44	1.40	0.19	1.72	1.23	0.81	0.14	321.00	428.00
7	0.30	0.22	1.01	0.25	0.25	0.92	0.39	0.52	168.00	224.00
8	0.37	0.19	0.51	0.05	0.26	0.52	0.26	0.16	102.00	136.00
9	0.44	0.22	0.81	0.10	0.30	0.79	0.47	0.09	145.00	193.00
10	1.59	0.79	0.87	0.57	1.33	1.04	1.04	0.01	303.00	404.00
11	1.76	0.92	1.18	0.15	1.50	1.23	0.73	0.47	305.00	407.00
12	0.41	0.35	0.73	0.02	0.43	0.73	0.34	0.11	126.00	168.00
13	0.77	0.77	0.54	0.04	0.61	0.79	0.60	0.08	173.00	230.00
14	1.66	1.11	1.30	0.14	1.75	1.19	0.75	0.25	306.00	408.00
15	3.05	1.21	2.15	0.05	2.75	1.76	1.01	0.52	444.00	592.00
16	2.16	0.73	1.35	0.41	1.77	1.54	0.80	0.50	443.00	591.00
17	1.37	0.45	1.25	0.25	1.44	1.00	0.63	0.36	261.00	348.00
18	1.04	0.61	1.07	0.04	0.84	0.51	0.67	0.72	205.00	273.00
19	2.14	1.79	3.47	0.10	3.33	2.10	1.15	0.30	525.00	700.00
20	1.61	1.35	1.92	0.05	1.95	1.58	0.96	0.34	362.00	482.00
21	1.12	1.70	1.50	0.05	1.98	1.39	0.85	0.08	331.00	441.00
22	0.95	0.62	5.06	0.02	2.40	2.59	1.52	0.03	512.00	682.00
23	1.25	0.50	3.71	0.16	2.10	2.75	0.75	0.01	466.00	621.00
24	0.74	0.62	1.83	0.12	1.18	1.48	0.64	0.34	266.00	355.00
25	1.75	1.31	1.15	0.08	2.10	1.44	0.63	0.10	323.00	430.00
26	1.37	0.54	1.35	0.20	1.77	1.22	0.59	0.09	279.00	373.00
27	0.95	0.08	0.75	0.06	1.07	0.60	0.35	0.14	129.00	173.00
28	0.52	0.53	3.91	0.11	1.74	2.46	0.58	0.21	438.00	584.00
29	3.11	1.47	5.47	0.24	3.31	5.27	1.29	0.09	850.00	1133.00
30	1.71	0.87	3.51	0.38	2.10	2.79	1.17	0.10	551.00	734.00
31	0.82	0.61	0.94	0.25	0.93	0.74	0.50	0.43	229.00	306.00
32	1.42	0.68	1.98	0.08	1.72	1.62	0.75	0.05	323.00	430.00

Table 4: Physical parameters and calculated irrigation indices for shallow wells in Abeokuta, Nigeria

Samplle ID	Elev(M)	DTW(M)	DTB(M)	pH	TEMP©	T.D.S	E.C	SAR	PI	TH	MAR	K.R	SSP	RSBC
1	111.00	3.90	4.30	5.70	27.60	367.00	489.00	0.74	56.89	93.57	39.01	0.38	53.17	-0.57
2	130.00	2.84	6.62	5.60	29.10	242.00	323.00	3.68	102.89	31.18	30.95	3.30	77.71	0.06
3	135.00	7.90	8.30	6.30	28.70	275.00	366.00	2.82	92.00	56.40	33.41	1.88	66.36	0.00
4	132.00	2.60	6.16	6.30	29.80	139.00	185.00	1.25	89.86	41.56	19.38	0.97	52.23	-0.23
5	108.00	0.80	1.70	6.70	29.50	167.00	222.00	0.67	75.08	68.40	19.82	0.41	34.73	-0.31
6	143.00	10.70	11.50	6.70	28.60	321.00	428.00	1.20	65.82	135.76	16.11	0.51	36.88	-0.56
7	135.00	3.80	4.70	5.10	27.90	168.00	224.00	1.99	98.38	26.03	42.67	1.95	70.76	-0.05
8	132.00	3.68	4.30	5.10	29.30	145.00	193.00	1.41	92.30	32.79	33.45	1.23	50.25	-0.11
9	119.00	7.50	8.10	5.30	28.30	136.00	102.00	0.98	96.12	27.68	33.57	0.93	58.12	-0.14
10	122.00	5.14	6.20	5.80	29.10	404.00	303.00	0.80	62.26	118.86	33.05	0.37	37.77	-0.26
11	83.00	5.80	6.10	6.70	28.90	305.00	407.00	1.02	62.32	133.90	34.42	0.44	33.21	-0.26
12	80.00	3.80	5.60	5.90	28.40	126.00	168.00	1.18	92.44	38.31	46.00	0.96	49.48	0.01
13	84.00	4.70	5.50	7.00	28.60	173.00	230.00	0.61	63.30	77.10	50.25	0.34	27.38	-0.16
14	65.00	7.00	7.20	7.0	29.60	306.00	408.00	1.10	64.29	138.83	40.08	0.47	34.07	0.08
15	69.00	7.10	7.50	6.80	29.60	444.00	592.00	1.47	59.40	213.01	28.46	0.50	34.04	-0.29
16	50.00	7.20	7.60	6.80	28.90	443.00	591.00	1.12	63.23	144.43	25.34	0.47	37.82	-0.39
17	53.00	4.00	5.30	7.20	29.90	261.00	348.00	1.32	80.08	90.58	24.60	0.69	45.38	0.08
18	56.00	3.70	4.20	7.30	29.20	205.00	273.00	1.18	72.84	82.74	36.94	0.65	40.19	-0.21
19	68.00	4.40	5.80	7.30	29.30	525.00	700.00	2.80	71.58	196.44	45.55	0.88	47.56	1.20
20	62.00	3.30	5.10	7.30	30.50	362.00	482.00	1.57	67.86	148.38	45.64	0.65	39.81	0.34
21	124.00	4.95	5.10	6.30	29.10	331.00	441.00	1.26	67.28	141.11	60.37	0.53	35.42	0.87
22	116.00	4.50	4.80	6.40	28.40	512.00	682.00	5.70	99.65	78.55	39.76	3.22	76.36	1.45
23	121.00	5.40	7.30	6.40	28.70	466.00	621.00	3.97	94.51	87.45	28.31	2.12	68.90	0.85
24	103.00	4.40	5.50	5.90	28.80	266.00	355.00	2.22	91.58	67.71	45.65	1.32	58.92	0.44
25	121.00	3.80	6.50	6.40	29.20	323.00	430.00	0.93	61.64	153.11	42.72	0.37	28.66	0.34
26	113.00	3.98	8.30	6.30	28.90	279.00	373.00	1.38	82.05	95.83	28.38	0.70	44.64	0.40
27	152.00	18.20	20.20	5.60	29.50	129.00	173.00	1.04	99.81	51.78	7.88	0.72	43.61	0.11
28	112.00	8.80	9.10	6.40	29.90	438.00	584.00	5.39	105.33	52.67	50.31	3.71	79.25	1.21
29	124.00	7.90	8.20	6.80	29.90	850.00	1133.00	3.61	72.50	229.30	32.14	1.19	55.47	0.20
30	105.00	4.30	5.20	6.50	28.50	551.00	734.00	3.09	81.38	129.21	33.66	1.36	60.11	0.38
31	113.00	3.30	3.40	7.00	28.90	229.00	306.00	1.12	80.50	71.37	42.69	0.66	45.62	0.11
32	114.00	2.60	3.00	6.80	28.60	323.00	430.00	1.93	80.63	105.11	32.34	0.94	49.51	0.30