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POTABILITY AND IRRIGATION POTENTIAL OF GROUNDWATER SOURCES AT THE FEDERAL UNIVERSITY OF AGRICULTURE, ABEOKUTA, NIGERIA

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ABSTRACT

Groundwater is an important source of freshwater and its quality determines it's potential for domestic and agricultural use. Water samples from ten boreholes located within the Federal University of Agriculture Abeokuta, Nigeria were collected and analysed for physico-chemical and bacteriological properties, cations and metals using standard procedures. Results were compared with the regulatory standards while water quality index (WQI) method was used to classify the water potability. Potential of groundwater for irrigation was investigated using appropriate indices. The range of values for the measured parameters include: pH: 6.9 – 7.82; electrical conductivity(EC): 127 – 650 µS/cm; total dissolved solids (TDS): 58 to 284 mg/L; magnesium (Mg^{2+}): 10 - 61 mg/L; nitrates (NO_3^-): 0.01 – 1.38 mg/L; iron (Fe): 0.02 – 0.05 mg/L; biological oxygen demand (BOD): 0.1 – 2.83 mg/L and *total coliform*: ND - 28×10cfu/mL. Majority of the water quality parameters fell within regulatory limits with the exception of magnesium and total coliforms. *Escherichia coli*, an indicator of faecal contamination was also absent in the water samples. On the average, groundwater within the study area has a WQI = 46.3 and can be classified to be of good quality for domestic use. Sodium absorption ratio (SAR) was less than 10% and Magnesium adsorption ratio (MAR) was less 50 %, and are therefore classified as of excellent quality for irrigation purpose. Soluble sodium percentage (SSP) values range between 11.1 and 51 %. All samples were found to be good or fair for irrigation purpose with no harmful effects to the soil.

Keywords: Groundwater, Potability, Irrigation, Water quality index, Sodium adsorption ratio

INTRODUCTION

Water is life and access to good quality water which is fit for purpose is a basic human need. This is a daily challenge in the developing countries such as Nigeria (USAID, 2018). The quality of water available for use influences hygiene and sanitation and should be of concern as this is directly linked with public health. Similarly, industrial and agricultural activities are heavily dependent on water supply. This is because adequate supply of good quality water plays a large role in crop/animal health and production (Ilori *et al.,* 2019). Out of the diverse water sources available, ground water remains the largest available source of fresh water, thus forming a very significant part of the water supply chain in both rural and urban areas of Nigeria. Groundwater is perceived to be less susceptible to pollution and

also comes in handy during the dry seasons when some surface waters such as streams dry up.
Despite its location below the ground surface, groundwater quality can depend on factors such as the quality of recharge water, atmospheric precipitation, municipal dumpsites and landfills and most importantly, the type of sewerage systems employed by the population (Kayode *et al.*, 2018) Unfortunately, once groundwater is contaminated, it is usually very difficult and costly to remediate (Olatunji *et al.*, 2015). Water contaminated with microbial and chemical contaminants can negatively affect cells of the nervous and reproductive systems as well as serve as vehicles for the spread of water borne diseases such as cholera and dysentery (Ameloko *et al.*, 2018).

The Federal University of Agriculture, Abeokuta is a University specifically setup to promote agricultural production and research. Like most University campuses, it has a huge water demand due to the presence of many laboratories, offices, lawns, livestock housing projects and irrigated farms (Sobowale and Adeyemo, 2020). The University is also partly residential for students, with an increasing population strength who rely solely on water supplied via boreholes for domestic activities. In addition, the University is located around farming communities who depend on groundwater for irrigation, especially during the dry season. This huge reliance on groundwater necessitates as assessment and constant monitoring of groundwater within the study area.
This study assessed the potability and irrigation potential of groundwater within the campus of the Federal University of Agriculture, Abeokuta, Ogun State, Nigeria.

MATERIALS AND METHODS

Study area

This study was carried out within the premises of the Federal University of Agriculture Abeokuta, situated within latitude 7°20'N to 7°25'N and longitude 3°40'E to 3° 45'E in Odeda Local Government Area, Abeokuta, southwest Nigeria (Figure 1). The study area is characterized by a tropical climate with two seasons: wet and dry seasons. The wet season typically starts around May and ends in October while the dry season runs through November to March/April. The area is underlain by the sedimentary rocks of the eastern Dahomey basin and the basement rock is unconformable, overlain by organically-rich friable reddish sand (Aladejana *et al.*, 1999). The major divisions include; biotite granite gneiss, porphyroblastic gneiss, porphyritic biotite granite, biotite schist and migmatite. Groundwater occurrence is contained within fractured and *in-situ* weathered portions of rocks which are exploited through boreholes.

Sample collection

Water samples were collected from ten boreholes which provide water to the central part of the University. Samples were carefully stored in lightproof insulated boxes containing ice-packs to ensure cooling before transporting to the laboratory for analysis. Quality control procedures were ensured to avoid contamination during sampling and laboratory analysis. These included the collection of water samples in acid washed Pet bottles and the inclusion of analytical blanks during analysis. All chemicals used were of analytical grade.

The pH, total dissolved solids (TDS) and electrical conductivity (EC) were determined in-situ using an HI98129 electrode which had been calibrated with buffers pH 4.0 and

9.0 prior to measurement. Ca^{2+}, Mg^{2+}, Na^{+} and K^{+} were determined using the PerkinElmer PinAAcle 500 FAA spectrometer, while SO_4^{2-}, PO_4^{3-}, Cl^{-1}, NO_3^{-} and Fe^{2+} were determined by Hach DR/2000 spectrophotometer. The total coliform counts (TCC) and *Escherichia coli* were determined by using the Millipore filtration method (Valenzuela *et al.,* 2009. The results of the various water quality parameters were compared with the Nigerian Standard for Drinking Water (NSDWQ, 2015) and World Health Organization's (WHO, 2017) drinking water quality guidelines. Results were also compared with the FAO water quality guidelines for irrigation.

Determination of water quality

The potability of groundwater samples was investigated using the water quality index (WQI), an index that has been used extensively to determine the potability of surface water and groundwater, using the measured values of selected water quality parameters. It is calculated using the Weighted Arithmetic Water Quality Index Method that generates a number that is used to characterize the overall water quality at a certain location and time, using the water quality (Table 1) rating (Akinbile and Omoniyi, 2018; Oni and Fashakin, 2016).

$$WQI = \frac{\sum Q_i W_i}{\sum W_i}$$

Where the quality rating scale

$$Q_i = 100 * \frac{V_i - V_0}{S_i - V_0}$$

V_i = Estimated Concentration of the *i*th parameter of interest in water sample.

V_o = The ideal value of the *i*th parameter in pure water. V_o = 0 (except pH = 7.0; and DO = 14.6 mg l−1)

S_i = Recommended Standard value of the *i*th parameter. The NSDWQ guideline was used in this regard.

The unit weight

$$W_i = \frac{K}{S_i}$$

Where the proportionality constant

$$K = \frac{1}{\sum \frac{1}{S_n}}$$

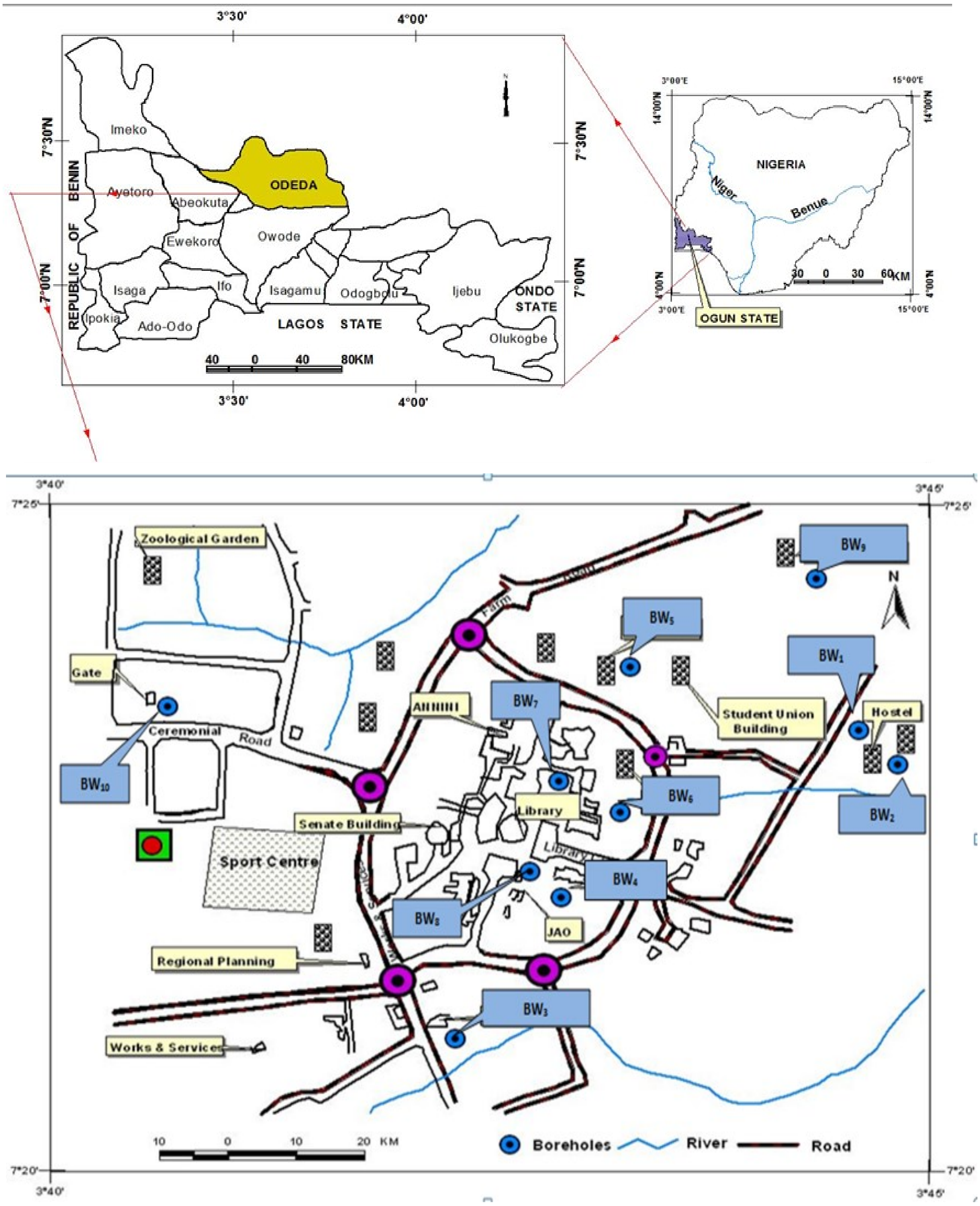

Figure 1: Map of study area showing sampling points (Boreholes).

Table 1: Water Quality Ratings (Tyagi *et al.,* 2013)

WQI value	Water quality rating	Grading
0 – 25	Excellent	A
25 – 50	Good	B
50 – 75	Poor	C
75 – 100	Very poor	D
> 100	Unsuitable for drinking	E

Determination of irrigation potential

The salinity index (or crop productivity salinity hazard) is the major criterion for assessing the suitability of any water source for irrigation potential. It measures the direct relationship between Electrical Conductivity (EC) and moisture. Other indices used to measure the suitability of water for irrigation include the sodium absorption ratio (SAR), the magnesium absorption ratio (MAR) and the soluble sodium percentage (SSP). These indices are indicators for the suitability of water for use in agricultural irrigation, as determined from the concentrations of the main alkaline and earth alkaline cations present in the water (Rehman and Cheema, 2016).

These indices are calculated by using the equations:

$$SAR = \frac{Na}{\sqrt{(Ca + Mg)/_2}}$$

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

$$SSP = \frac{(Na + K) * 100}{(ca + Mg + Na + K)}$$

Statistical analysis

Data obtained from laboratory investigations were analysed with descriptive statistics, using SPSS 23.0 (SPSS Inc., USA) software.

RESULTS AND DISCUSSION

The pH values of groundwater samples revealed that the water was neutral to slightly alkaline with a range of 6.9 – 7.82 and a mean pH of 7.50 (Table 2). Total Dissolved Solids (TDS) of the samples ranged from 58 to 284 mg/L while the mean value was 155 mg/L. All the water samples were colourless and fell within the recommended standards for pH, and TDS stipulated by the WHO and NSDWQ. Electrical conductivity (EC) values ranged from 127 - 650 µS/cm, with a mean value of 346.4 µS/cm. Two samples (BW_3 and BW_{10}) had EC above 500 µS/cm recommended by the WHO for drinking water. However, all samples were within 1000 µS/cm stipulated by the NSDWQ. The variation in EC can be linked to soil composition and different degrees of enrichment in the deposition environment during groundwater recharge. A high water EC is not known to have a direct negative impact on human health. It can however cause an unwelcome mineral taste in water and as well increase production costs in the industrial sectors due to corrosion on boiler systems. In the soil, EC can influence the salinity status. Waters with EC greater than 700µS/cm are considered inappropriate for irrigation purposes due to the development of alkaline soils (Narany *et al.,* 2014).

Chloride concentrations ranged from 17 to 146 mg/L, with an average of 50.7 mg/L (Table 2). Nitrates in water samples ranged between 0.01 and 1.38 mg/L, with a mean value of 0.4 mg/L. All the samples fell within acceptable limits of 250 mg/L and 5 mg/l for Cl^- and NO_3^-, respectively. The concentration of SO_4^{2-} in groundwater samples had an average of 15.1 mg/L and ranged from 12.4 mg/L to 23.7 mg/L. All the samples were within the maximum allowable limit of 100 mg/L stipulated by the WHO and NSDWQ. Phosphates in groundwater can be attributed to infiltration from onsite septic tank sewerage systems and/or leaching from agricultural waste disposal sites. Phosphates in groundwater samples in this study had an average of 0.07mg L^{-1} and ranged from 0.03 mg/L to 0.11 mg/L.

The abundance of cations is in the order $Ca^{2+}>Mg^{2+}>Na^{+}>Mn^{2+}> K^{+}$. The calcium concentrations in groundwater samples ranged from 23 - 264 mg/L, with a mean value of 89.7 mg/L. Magnesium ion ranged from 10 - 61 mg/L, with a mean value of 33 mg/L. More than half (60%) of groundwater samples within this study had Mg^{2+} concentrations greater than 20 mg/L recommended by the WHO and NSDWQ for drinking water. Magnesium in groundwater is derived from the dissolution of basal rocks such as limestone and shale and is partly responsible for water hardness (Saha *et al.*, 2019). Hard water is not a health risk except for those who are marginal for calcium and magnesium intake (Sengupta, 2013). It however constitutes nuisance due to build-up of mineral on water pipes and the need for increased use of soap during washing (Olatunde *et al.*, 2021). Sodium concentration varied from 20 mg/L to 43 mg/L while K^+ in the groundwater varied from 0.83 mg/L to 4.72mg/L. All the samples had sodium concentrations within the permissible limit of 200 mg L^{-1} for potable water quality (WHO, 2017; NSDWQ, 2015).

The mean Dissolved Oxygen (DO) was generally low, with values varying between 2.7 mg/L and 5.6 mg/L. The Biochemical Oxygen Demand (BOD) ranged between 0.1 mg/l and 2.83 mg/l with a mean of 0.53 mg/L. BOD is a measure of the microbial facilitated decomposition of all organic materials in water over a five day period. Waters with BOD < 3mg/L indicate clean water relatively free of organic matter (EPA, 2011).

The presence of microorganisms especially faecal coliforms in groundwater is an indication of organic contamination possibly from waste disposal. The result of bacteriological analysis of groundwater samples showed the presence of total coliforms in all but one of the samples, ranging from 0 to 28×10 cfu mL^{-1} which is above the WHO and NSDWQ standards for drinking water. *E. Coli*, a faecal coliform indicative of sewage contamination was however absent in all water samples. Water contaminated with faecal coliforms can serve as a vehicle for the spread of water borne diseases such as lymphatic filariosis, parasitic and viral infections (Batterman *et al*., 2009).Boiling and chlorination can be employed as treatments for groundwater from the study area prior to consumption.

Water quality index (WQI)

The computed WQI for each sampling point within the study area ranged from 22.27 to 54.29 (Table 3). All but one of the samples (BW_7) can be classified to be of excellent or good quality for drinking purpose. The WQI of sample BW_7 that was calculated to be 54.29 is claassified as of poor quality for drinking purposes (Table 3). On the average, groundwater within the study area can be classified to be of good quality (Table 4), based on the water quality index classification (Tyagi *et al*. 2013).

Suitability of water for irrigation purpose

Generally, water with electrical conductivity values less than 700 μS/cm are considered as good for agricultural purposes (Narany *et al.,* 2014). For the salinity index, all the water samples had electrical conductivity values less than 700 μS/cm (Figure 2).

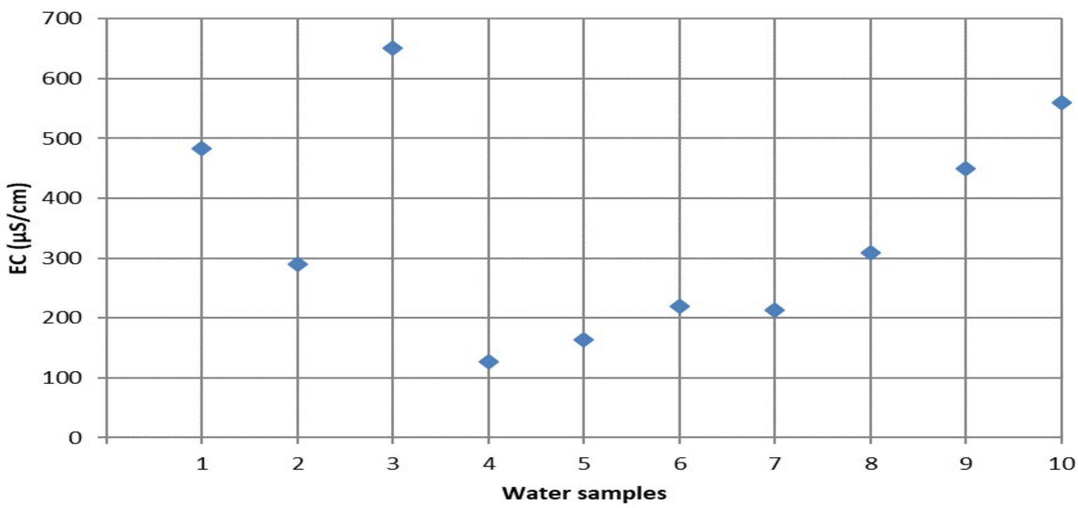

Figure 2: Salinity index for groundwater samples for study area

Table 2: Physicochemical and microbiological parameters of groundwater samples

	Mean	**Std. Deviation**	**Range**	**Number of samples exceeding**	**Acceptable limits**		
					FAO[a]	NSDWQ	WHO
pH	7.50	0.25	6.90 - 7.82	-	6.5 – 8.4	6.5 – 8.5	6.5 – 9.2
EC (µS/cm)	346.40	178.54	127.00 - 650.00	2	700	1000	500
TS (mg/L)	219.30	126.48	63.00 - 470.00				
TDS (mg/L)	155.00	83.52	58.00 - 284.00	-	<450	500	500
Hardness	109.10	80.10	39 0 - 273.00	-		150	
Alkalinity	31.80	11.25	16.0 - 56.00				
DO (mg/L)	3.72	0.87	2.7 - 5.60	-		7.5	6.2
BOD (mg/L)	0.53	0.82	0.10 - 2.83	-		< 3	
Cl^- (mg/L)	50.70	41.23	17.0 - 146.00	-	<144	250	250
NO_3^{2-} (mg/L)	.40	0.47	0.01 - 1.38	-		5	10
SO_4^{2-} (mg/L)	15.1	3.81	12.4 – 23.7	-		100	
PO_4^{2-} (mg/L)	0.07	0.02	0.03 – 0.11				
Ca^{2+} (mg/L)	89.70	71.91	23.0 - 264.00	-		75	
Mg^{2+} (mg/L)	33.00	18.63	10.0 -61.00	6		20	
Na^+ (mg/L)	29.30	9.59	20.0 - 46.00	-	<46	200	
P (mg/L)	1.80	1.21	0.05 - 3.62			5	
K^+ (mg/L)	2.54	1.40	0.83 - 4.72				
Mn^{2+} (mg/L)	7.72	2.89	4.61 - 12.41		0.2		
Fe (mg/L)	0.03	0.01	0.02 - 0.05	-	5	0.10	
Zn (mg/L)	0.05	0.04	0.02 - 0.15		2		
Total coli-form (10 cfu/	4.62	8.42	ND - 28.00	9		0	
E coli (10 cfu/ml)	-	-	ND	-		0	0

[a] (Ayers and Westcot, 1994)

A high Sodium adsorption ratio (SAR) in the soil leads to the development of hard alkaline soils which are resistant to water Penetration (Zaman *et al.*, 2018). This affects soil permeability making it inappropriate for plant growth. All groundwater samples from the study area had SAR values less than 10, indicating that they pose little or no sodium danger to crops. Such waters are classified as being of good quality (SAR <10) for agricultural purposes. SAR values ranged between 2.5 and 8.8 within the present study (Figure 3). The values obtained for the Magnesium Adsorption Ratio (MAR) varied between 18.8% and 43.9%. High concentrations of magnesium in water (MAR> 50%) will increases the salinity of the water and therefore a cause of potential reduction in crop yield (Raihan and Alam, 2008).

The soluble sodium percentage is used to determine the concentration of sodium in irrigation water and used to categorize the chemical composition of groundwater. All samples are considered suitable with no harmful effects to the soil. In this study, soluble sodium percentage (SSP) values ranged between 11.1% and 51%. About 30% of water samples had SSP < 20% and could be classified as being of excellent quality for irrigation purposes (Hwang *et al.*, 2017). Also, 60% of the samples were of good quality while and only one sample (BW_9: SSP=51) could be classified to be of fair quality for irrigation purposes. (Figure 3)

Table 3: Water quality index (WQI) per sampling point

Sampling point	Location	WQI	Rating
BW_1	Female hostel	34.81	Good
BW_2	Male hostel	40.13	Good
BW_3	COLVET	41.64	Good
BW_4	COLERM	25.27	Good
BW_5	BIOTECH	36.54	Good
BW_6	COLENG	47.11	Good
BW_7	ICT	54.29	Poor
BW_8	COLANIM	22.27	Excellent
BW_9	COLANIM FARM	29.76	Good
BW_{10}	Gate	36.89	Good

Table 4: Water quality index (WQI) for groundwater within study area

Parameter	Mean values (V_i)	NSDWQ limits (S_i)	K	Weightage (W_i)	Quality rating (Q_i)	W_iQ_i
pH	7.50	8.5	1.149	0.1352	33.33	4.506
EC	346.40	500	1.149	0.0023	69.28	0.159
TSD	155.00	500	1.149	0.0023	31.00	0.071
DO	3.72	6.2	1.149	0.1853	129.48	23.996
BOD	0.53	3	1.149	0.3830	17.53	6.716
Cl^-	50.70	250	1.149	0.0046	20.28	0.093
NO_3^-	0.28	5	1.149	0.2298	5.64	1.296
Mg^{2+}	33.00	20	1.149	0.0575	165.00	9.480
				$\sum W_i = 1$	$\sum W_i Q_i =$	**46.3**
					WQI **=**	**46.3**

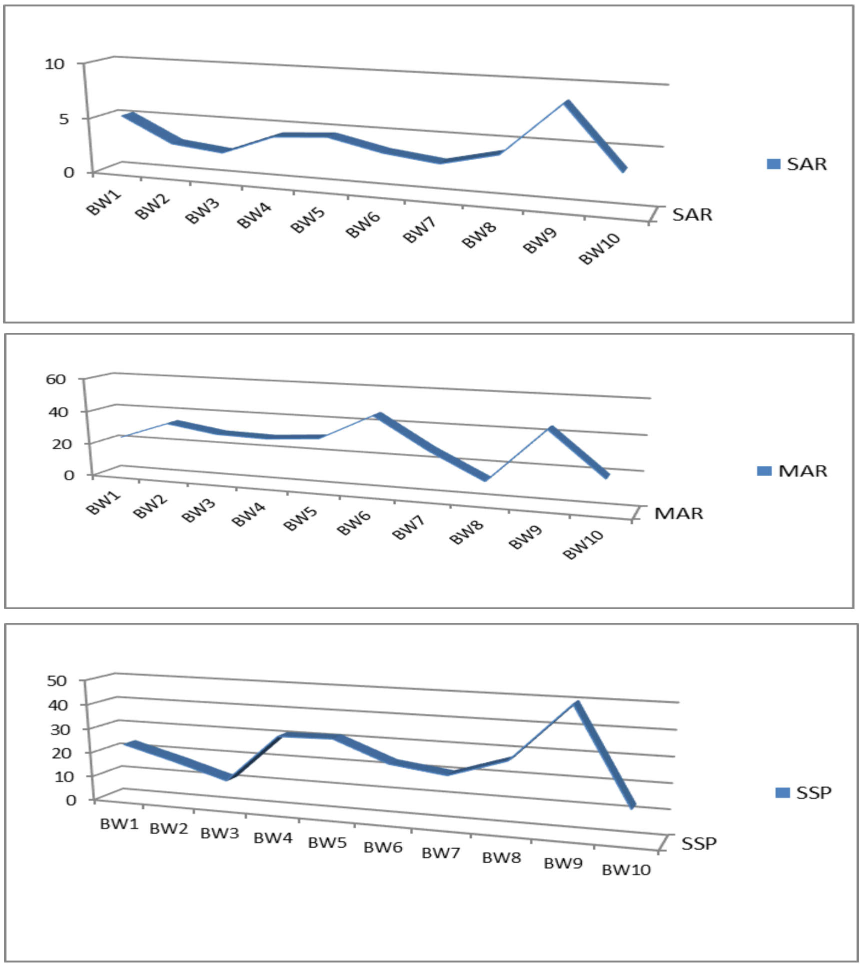

Figure 3: Plots of some parameter indices for rating irrigation potential of groundwater

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CONCLUSION

Majority of the quality parameters of groundwater samples from the Federal University of Agriculture Abeokuta (FUNAAB) fell within regulatory limits with the exception of magnesium and total coliforms. *Escherichia Coli*, an indicator of faecal contamination was absent in the water samples. On the average, groundwater within the Federal University of Agriculture Abeokuta can be classified to be of good quality based on the water quality index. Most of the water samples were excellent or good for agricultural purpose.

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