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ASSESSMENT OF GROUNDWATER QUALITY IN OKE-OYI IRRIGATION SCHEME, NIGERIA

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ABSTRACT

Irrigating with poor quality water affects the quality of soils and crops and often results to a reduction of crop yield and this study assessed the groundwater quality in Oke-Oyi irrigation scheme, Kwara State, Nigeria. Twelve (12) sampling points were randomly selected within the irrigation scheme using Global Positioning System (GPS), coordinates were 08°37'N/04°45'E and 08°37'N/04°46'E at an average elevation of 261meters. Groundwater samples were taken during the peak of dry and wet seasons in March and July, 2016 respectively. The physicochemical properties (temperature, pH, Electrical Conductivity (EC), Total Dissolved Solid (TDS), calcium, bicarbonate, magnesium, potassium, sodium, iron, chloride, boron, nitrate and sulphate) were determined on the groundwater samples collected. Spatial distribution maps for each of the tested parameters at the various sampling locations were plotted using ArcGIS 10.0 software. Physico-chemical properties were obtained using American Public Health Association (APHA) procedures and Food Agricultural Organization (FAO) standard to determine its suitability for irrigation. Results showed that temperature, pH, EC, and TDS varied from 27.00-32.70 °C; 7.91-10.57; 437-729 µS/cm and 251.67- 1948.30 mg/L.Values for calcium, bicarbonate, magnesium, potassium, sodium, iron, chloride, boron, nitrate and sulphate ranged from 163.30-406.70 mg/L; 0.33-0.86 mg/L; 180-195 mg/L; 31.67-75 mg/L; 1350-2102 mg/L; 0.50-1.30 mg/L; 8.17-36.73 mg/L; 0.33-3.33 mg/L; 2.37-6.63 mg/L and 31.67-95.00 mg/L. The mean water quality indices values during the dry season were RSBC (-13.14 meq/L), PI (0.77 meq/L), TH (1198.29 meq/L), MAR (42.66 meq/L), KR (3.14 meq/L).

While wet season values were RSBC (-15.69 meq/L), PI (0.73 meq/L), TH (1378.71 meq/L), MAR (42.98 meq/L), KR (2.67 meq/L) respectively. Aside values of K (44.03 mg/L), Na (1668.50 mg/L), SAR (30.30 meq/L), SSP (75.29%) for dry season and wet season values of K (62.05 mg/L), Na (1641.83 mg/L), SAR (27.47 meq/L), SSP (72.44%).Which were slightly high. All other parameters were within the acceptable standard. As the results obtained were compared with guideline values of FAO to determine the suitability for irrigation purposes aside few locations.

KEYWORDS: Assessment, Irrigation, Groundwater, Global Positioning System (GPS).

1. INTRODUCTION

Groundwater is an important part of the hydrologic cycle; which involves the continuous movement of water between the earth and the atmosphere through the process of evaporation, evapotranspiration and precipitation.[1] Plants require water and all irrigation water contains various amounts of dissolved salts, these dissolved salts usually originate from rocks when weathering occurs, or as water percolates through the various surfaces layers (soils, rocks, etc). Some of these salts can be beneficial and lead to an improvement of growth, only if they exist at tolerable level; otherwise it may results to various degrees of damage to the soil and crop thereby resulting in lower crop yield.[2] The following water quality parameters have been found to be of great important in the assessment of irrigation water quality and as such very important to crop production Sodium Absorption Ratio (SAR), Soluble Sodium Percentage (SSP), Residual Sodium Bicarbonate (RSBC),Permeability Index (PI),Total Hardness (TH), Magnesium Adsorption Ratio (MAR) and Kelly ratio (KR).[3,4,5] and were calculated from standard equations and employed to assess the suitability of groundwater for irrigation purposes in the study area.

2 MATERIALS AND METHOD

Description of the Study Area

Oke-Oyi scheme (Figure 2.1) is located between latitudes 8˚30`N and 8˚45`N and longitudes 4˚40`E and 5˚00`E, of Ilorin East Local Government of Kwara State. It's one of the small scale irrigation schemes of the federal government initiated in 1994, the land area has a slope of less than 10 degrees.[6] Two climatic seasons exist annually: the dry and wet seasons. The wet season falls within April-October, while dry season runs from November - March of each year. Mean annual rainfall of 1231 mm, and average temperature ranges between 30 °C and 35 °C. Natural vegetation consists broadly of rain forest and wood savannah and crops grown include; yam, cassava, maize, cowpea, rice, sugar cane, onions, guinea corn, castor, pepper, tomatoes, eggplant, fruits and vegetables.

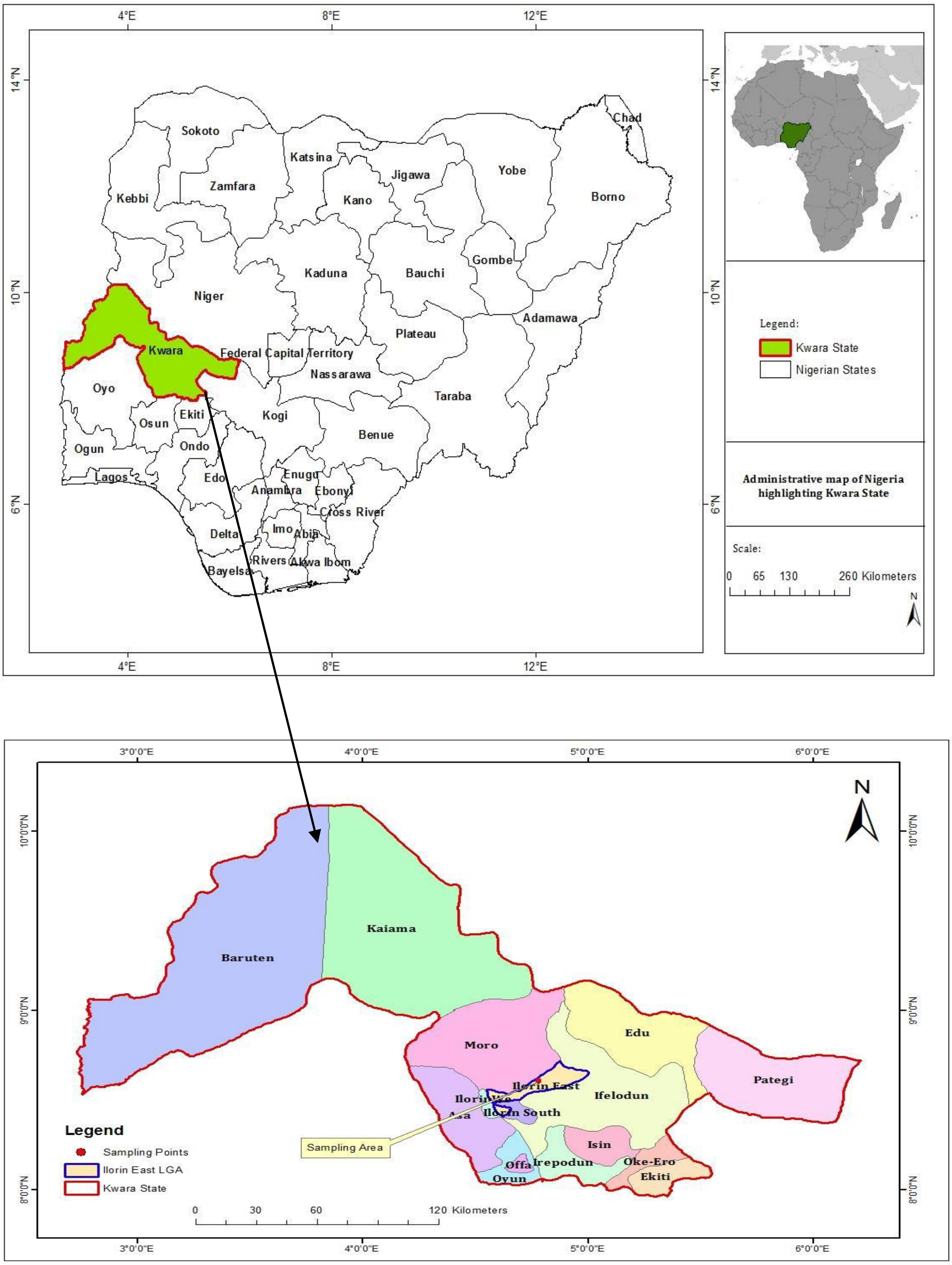


Figure 2.1: Ilorin East Map showing Oke-Oyi irrigation scheme.

The area is well drained by river Oyi and its tributaries flowing north-east and surrounded in the west by the National Electrical Power grids line. River Oshin and River Oyi are both major seasonal rivers which flow in the same direction, while irrigation of the farm land is usually done during the dry period of the year [7, 8, and 9].

3. Methodology

Twelve (12) points were randomly selected for the groundwater quality assessment within the irrigation field. Co-ordinates of the selected locations were obtained using a Global Positioning System (GPS) device. Groundwater samples and levels were taken and recorded for both dry and wet seasons for 2017. The water samples were collected in a clean 1.0 liter plastic bottle, sealed, label and iced packed before being transported to the laboratory for analysis. Four physical parameter (temperature, pH, electrical conductivity and total dissolved solids) were immediately determined on the field using a potable multipurpose probe meter. Chemical analysis was carried out on nine major parameters which were, Calcium (Ca), Magnesium (Mg), Sodium (Na), Potassium (K), Boron (B), Iron (Fe), Nitrate (NO_3), Sulphate (SO_4), and Bicarbonates (HCO_3) using standard procedures (APHA, 1998). Atomic Absorption Spectrophotometry was used for cations and conventional titration for anions. Ions conversions were done from milligram per litre to milliequivalent per litre. Geographical Information System (GIS) and coordinate obtained from the GPS devices were plotted using ArcGIS 10.0 software to generate spatial distributions maps of the groundwater quality parameters and sampling locations.

The Sodium Absorption Ratio (SAR) use in classifying the suitability of groundwater for irrigation purpose was calculated using (Richard, 1954) equation.[10]

$$SAR = \frac{Na^+}{\sqrt{\frac{Ca^{2+} + Mg^{2+}}{2}}} \qquad 1$$

Where, all the ions are expressed in meq/L.

Soluble Sodium Percentage (SSP) was calculated by following (Todd, 1995) equation.[11]

$$SSP = \frac{(Na^+ + K^+) \times 100}{Ca^{2+} + Mg^{2+} + Na^+ + K^+} \qquad 2$$

Where, all the ions are expressed in meq/L

Residual Sodium Bi-Carbonate (RSBC) was proposed by and calculated using the equation Gupta and Gupta (1987),[12]

$$\text{RSCB} = HCO_3 - Ca^{2+} \qquad 3$$

Where, all the ions are expressed in meq/L

Permeability Index (PI) was calculated according to Doneen (1962) [13] as:

$$PI = \frac{\left(Na^+ + \sqrt{HCO_3}\right)100}{Ca^{2+} + Mg^{2+} + Na^+} \qquad 4$$

Where, all the ions are expressed in meq/L.

Total Hardness (TH) was calculated according to Raghunath (1987) [14] as:

$$TH = (Ca^{2+} + Mg^{2+}) \times 50 \qquad 5$$

Where, all the ions are expressed in meq/L.

Magnesium Adsorption Ratio (MAR) It was calculated by Raghunath (1987) [14] as:

$$MAR = \frac{Mg^{2+} \times 100}{Ca^{2+} + Mg^{2+}} \qquad 6$$

Where, all the ions are expressed in meq/L.

Kelly's Ratio was calculated using the Kelly (1963) [15] equation as:

$$KR = \frac{Na^+}{Ca^{2+} + Mg^{2+}} \qquad 7$$

Where, all the ions are expressed in meq/L.

4. RESULTS AND DISCUSSION

The analyzed parameters and descriptive statistic of the groundwater assessment obtained from the various locations are presented (table 4.1). The result reveals that temperature for the scheme was between 27.00 °C and 32.70 °C with st.dev of 1.37°C. Temperature an important parameter; a high temperature would increase the rate of metabolic reactions within plants ecosystem, while low temperature slow down reactions.[6] The pH values ranges between 7.91 -10.57 with st.dev of 0.90 which indicate a slightly alkaline nature which suggest a low tendency on the availability of trace and heavy metal within the scheme, thus reducing risk of heavy metal uptake by crops.[6]

Electrical conductivity (EC) and Total dissolve solid (TDS) had values of between 437-729 µS/cm and 251.57–1948.30mg/L with st.dev of 143.84µS/cm and 472.99mg/L respectively. Dissolution of mineral salts, temperature, sewage and salt concentration, runoff, sewage, environmental changes, rainfall and other human activities within the scheme might be responsible for such changes,[16,17] and when compared with USSL,1954,[18] and FAO standard, both values correspond to class of water with good quality.

The area had high potassium (K^+) concentration which was above the FAO recommended standard for irrigation, as this might be connected to high human and animal waste disposal within the field, including the rate of run-off and the use of fertilizer rich (K^+) salts. Values were between 31.67-75.00 mg/L, with st.dev of 7.90 mg/L. A high concentration would adversely affect water, soil and is not suitable for most crops as similar findings were also observed by Adejumobi.[19]

The Na^+ varies between 1282-2102.00 mg/L with a st.dev of 250.46 mg/L. This is high, which could degrade certain soil structure and restrict soil water movement thereby affecting crop growth. High values of Na^+ in groundwater may be due to chemical weathering of feldspars or over exploitation of groundwater resources. As this values were above the FAO standard for irrigation and such water may be not very suitable for irrigation and should be monitored.

Ca^{2+}, Mg^{2+} and Fe^{2+} were 163.30-406.70 mg/L, 180-190 mg/L and 0.50-1.30mg/L, with st.dev of 53.04 mg/L, 347.9 mg/L and 0.12 mg/L respectively. Ca^{2+} and Fe^{2+} contents were within FAO standard. Magnesium ion for groundwater quality was found to be slightly higher as this might be due to its presence in natural existing water.[20]

Boron, HCO_3 and NO_3^- had values of between 0.33-3.33mg/L, 0.33-0.86 mg/L and 2.37-6.67mg/L, with st.dev of 0.12mg/L,0.15mg/L and 0.96 mg/L which were within acceptable limits. Cl^- and SO_4^{2-} values ranges between 8.17-36.78mg/L and 31.67- 95.00mg/L respectively, with st.dev of 6.38 mg/L and 16.59 mg/L. both values were within acceptable limit prescribe by FAO for irrigation, making it suitable for crop productions. High values of sulphate have been known to affect crops and emitters pipes of irrigation facilities.

Table 4 1: Physico-chemical characteristics of groundwater in the study area.

S/N	Parameter	Range	Mean	St.dev
1.	Temperature (^{0}C)	27.00-32.70	29.85	1.37
2.	PH	7.91-10.57	9.24	0.90
3.	Electrical conductivity (Ec) (µS/cm)	437 -729	583.00	143.84
4.	Total dissolved solids (mg/L)	251.67- 1948.30	1099.90	472.99
5.	Potassium (K)	31.67-75.00	53.35	7.90
6.	Calcium (Ca),	163.30-406.70	285.0	53.04
7.	Magnesium (Mg)	180-190	185.0	347.90
8.	Sodium (Na)	1282-2102	1692.0	250.46
9.	Boron (B)	0.33-3.33	1.83	0.12
10.	Iron (Fe)	0.50-1.30	0.90	0.12
11.	Nitrate (NO_3)	2.37-6.67	4.52	0.96
12.	Sulphate (SO_4)	31.67- 95.00	63.34	16.59
13.	Bicarbonates (HCO_3)	0.33-0.86	0.60	0.15
14	Chloride	8.17-36.78	22.48	6.38

Irrigations Water Quality Assessment

These parameters, Sodium Adsorption Ratio (SAR), Soluble Sodium Percentage (SSP), Residual Sodium Bicarbonate (RSBC), Permeability Index (PI), Total Hardness (TH), Magnesium Adsorption Ratio (MAR) and Kelly Ratio (KR) (table 4:2a and 4:2b) were used to measure the suitability of water in Oke- Oyi stream for irrigation purpose.

The SAR was between 23.84 - 40.8 meq/L with mean value of 30.03 meq/L, for dry season and between 23.08 - 34.18 meq/L with mean 27.49 meq/L for wet season. Higher values were obtained during the dry season, than wet season, such high values may be due to.

Table 4.2: Computed SAR, SSP%, RSBC, PI, TH, MAR and KR values (dry) 2017

Locations	SAR	SSP %	RSBC	PI	TH	MAR	KR
W1	40.80	84.63	-8.16	0.85	702.00	41.81	5.44
W2	24.57	72.43	-12.92	0.73	1138.00	7.74	2.58
W3	36.08	78.31	-13.91	0.79	1283.50	54.26	3.54
W4	34.71	78.23	-13.37	0.79	1202.00	44.34	3.54
W5	27.48	73.24	-16.16	0.74	1314.00	38.47	2.68
W6	26.35	72.42	-13.66	0.82	1305.00	47.62	2.58
W7	23.84	72.23	-16.66	0.73	1093.00	23.74	2.55
W8	30.41	75.23	-14.49	0.76	1285.00	43.58	2.99
W9	26.09	72.13	-12.99	0.73	1312.50	50.48	2.55
W10	37.31	80.89	-8.32	0.81	990.50	57.95	4.19
W11	27.67	71.96	-15.07	0.73	1498.50	49.68	2.53

W12	25.08	71.75	-11.99	0.72	1255.50	52.21	2.50
Mean	30.03	75.29	-13.14	0.77	1198.29	42.66	3.14

Table 4.2b: Computed SAR, SSP%, RSBC, PI, TH, MAR and KR values (wet) 2017.

Locations	SAR	SSP %	RSBC	PI	TH	MAR	KR
W1	34.18	80.80	-9.74	0.82	856.50	43.03	4.13
W2	23.08	70.02	-16.58	0.73	1294.00	35.90	2.27
W3	30.93	73.92	-17.08	0.74	1544.50	44.67	2.78
W4	30.46	76.51	-16.18	0.75	1417.50	42.89	2.86
W5	23.27	64.43	-20.32	0.69	1522.00	33.21	2.11
W6	24.66	69.52	-17.91	0.70	1545.00	42.00	2.22
W7	26.84	75.06	-14.08	0.76	1046.00	32.69	2.93
W8	26.98	71.06	-18.08	0.72	1567.00	42.28	2.41
W9	26.93	72.46	-14.16	0.73	1371.00	48.32	2.57
W10	33.63	77.95	-10.41	0.79	1163.00	55.20	3.49
W11	25.46	68.96	-19.08	0.69	1719.50	44.49	2.17
W12	23.48	68.62	-14.66	0.69	1498.50	51.05	2.14
Mean	27.49	72.44	-15.69	0.73	1378.71	42.98	2.67

Evapotranspiration occurring more in irrigated field.[21] Computed SAR hazard value was greater than 26.00 meq/L recommended, indicating poor water class (USSL, 1954). All samples locations falls within very high sodium hazard range, and may not be suitable for irrigation. This may be due to high values of Na^+ ions found in feldspars and other salts which easily disintegrate during weathering thereby affecting groundwater resources, high value of sodium may lead to difficulty in meeting the crop water demand.[22,23] SSP computed values obtain were between 84.64 –71.75% with a mean value of 75.29% dry season and between 64.43 – 80.80% with mean value of 72.44% the wet season. Higher values were obtained during the dry season than the wet season. Sodium percentage plays an important role in water quality use for irrigation and other purposes, the use of high sodium water content can cause stunt in plant growth and react with the soil to affect permeability thereby leading to reduction in agricultural yield.[24] The soluble sodium percentage values were greater than 60%, and such water could result in sodium accumulation, thereby resulting in structural degradation of the soil and further reducing crop yield.[25] Such groundwater may pose a challenged, and should be monitored.

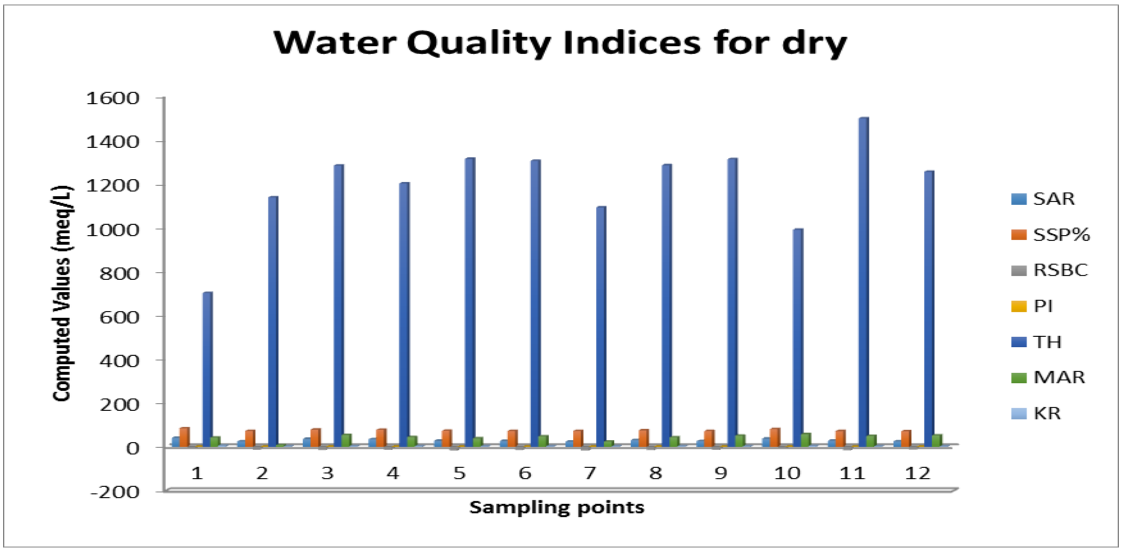
RSBC values for dry season were between -8.18 to -16.16 meq/L with mean of -13.14 meq/L, and between –20.32 to -9.74 meq/L with mean of -15.69 meq/L for wet season. RSBC index is used in the determination of the effect of bicarbonate ion on crops. When a value is less than 1.25 meq/L, it is term suitable.[26] High RSBC value may leads to an increase in the adsorption of Na^+ in the soil, which may further reduces soil permeability and not support plant growth.[27] The RSBC values from the study area were negative (carbonates are less than the alkaline earths ions) and less than the 1.25 meq/L recommended, we may conclude that the water is suitable for irrigation purpose according to Eaton, 1950.[26]

PI ranged between 0.72 – 0.85 meq/L with mean of 0.77 meq/L, for dry season and between 0.69 – 0.82 meq/L with mean of 0.73 meq/L wet season. Slightly higher values were obtained in all other locations for the dry season than the wet season. These might be due to the effect of the dry season on the environment, as soils are dryer absorb more water than required, making large amounts of salts present in water bodies to accumulate and affect the growth of organisms, plants, soil structure, permeability and aeration.[5] The groundwater is considered good and suitable for irrigation according Doonen, 1962.[13]

TH ranges between 702.00 – 1498.50 meq/L with mean of 1198.29 meq/L, for dry season and between 856.50-1719.50 meq/L with a mean of 1378.71 meq/L, for wet season. Natural sources of hardness in groundwater are cause by sedimentary rocks, seepage and runoff.[28] Classified water with total hardness as soft, moderately hard, hard, and very hard depending on their values, the groundwater values obtained at the scheme falls within the category of the class of water hard.

MAR ranged between 7.74 – 57.95 meq/L with a mean of 42.66 meq/L for dry and wet season values were 32.69 – 55.20 meq/L with a mean of 42.98 meq/L respectively.[29] Suggested that MAR should not exceed 50.00 meq/L, and such water is considered to be harmful and unsuitable for irrigation as it would adversely affects crop production. High magnesium content would damages soil structure, which will consequently affect crop yields.[30,28] All computed MAR values at the locations had values less than 50meq/L. The groundwater MAR in the irrigation scheme is suitable for irrigation purpose and within limits.

The KR ranged from 2.58 – 5.44 meq/L with mean of 3.14 meq/L, dry season and wet season values range from 2.11 – 4.13 meq/L with a mean of 2.67 meq/L.[15] suggested the ratio for irrigation water should not exceed 1.00 meq/L, although the computed values for the two seasons were slightly higher than 1.00 meq/L as recommended. This might be as a result of the excess amount of sodium content in the water; nevertheless the groundwater still exhibited good qualities.



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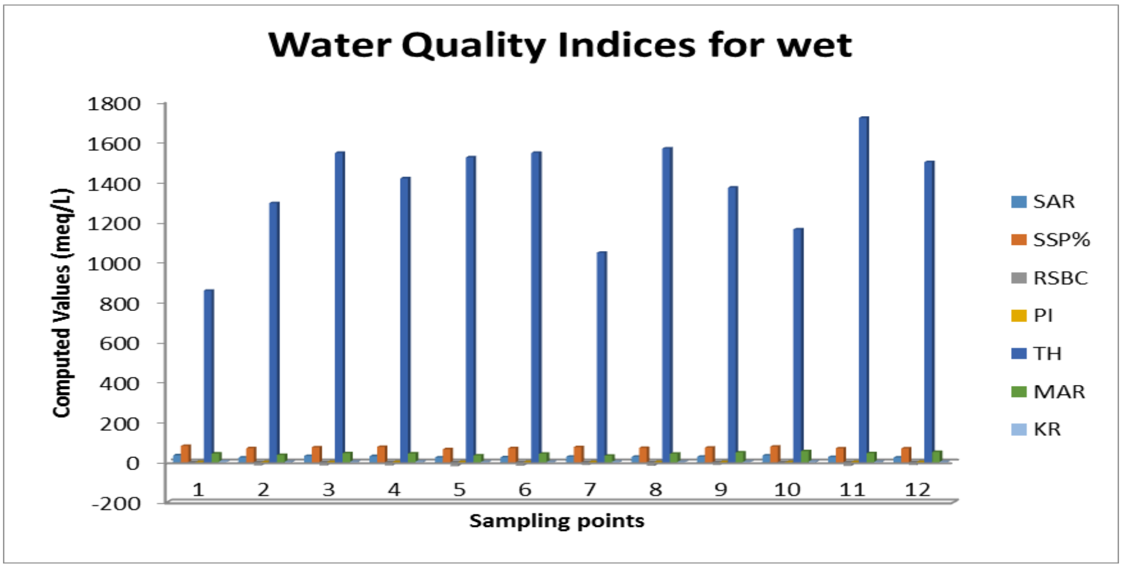

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Figure 2.2: Summary of groundwater indices for (a) dry season (b) wet season.

5. CONCLUSION

The study has shown that most of the irrigation groundwater parameter was within FAO, 1990 standard for irrigation aside high values from sodium and potassium respectively, which would require that the scheme be constantly monitored. Also values of SAR, and SSP which were found to be slightly above the recommended standard.

Recommendations

There is the need for constant monitoring of all human and agricultural activities going on within the scheme. The Periodic monitoring of the groundwater quality and level should be carried out.

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