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Evaluation of Quality and Irrigation Characteristics of Surface Water from Okochiri Creek in Rivers State Nigeria

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Abstract:- Levels of Physicochemical and Irrigation Properties of surface water from Okochiri creek in Rivers State, Nigeria were assessed in this study. Physicochemical properties were determined by using standard methods recommended by the American Society for Testing and Materials (ASTM) and American Public Health Association (APHA), water quality index was determined using an adopted mathematical model, and classification of water for irrigation purposes was made by plotting the Wilcox diagrams and other irrigation parameters such as Sodium Absorption Ratio, Soluble Sodium Percentage, Residual Sodium Bicarbonate, Permeability Index, Magnesium Adsorption Ratio and Kelly Ratio. The results show maximum mean levels of pH (7.3±0.1), pH levels were generally within set limits. The levels of chloride, hardness, total dissolved solids, conductivity, calcium, magnesium, sodium, dissolved oxygen and chemical oxygen demand (46.80 – 485.06 mg/l) exceeded their permissible limits. Water Quality Indices showed that the water in the area is generally unsuitable for drinking. Plots of the Wilcox diagrams indicate that the surface water in the area is unsuitable for irrigation. The results showed that the water is very poor for consumption and therefore should not be used for both drinking and irrigation purposes without proper treatment.

Keywords**:-** *Surface Water, Okochiri Creek, Okrika, Irrigation Index, Water Quality Index*

I. INTRODUCTION

The water quality of rivers, creeks, wetlands, and other surface and groundwater bodies has significantly changed as a result of human activity (USGS, 2021). Water is one of the most in-demand commodities and accounts up more than seventy percent (70%) of the earth's surface, especially in developing nations (Karikari & Ansa-Asare, 2006). One of the most sought-after natural resources is water, which is necessary for human activity. Despite the fact that there is a lot of water on the planet, Oketola and colleagues (2010) pointed out that it is not always accessible to ecosystems or people at the right times or in the right places. They asserted that water is without a doubt the most priceless natural resource required for existence. According to Oketola et al. (2010), water is found in nature in both surface and subsurface forms and comes from a variety of sources, including oceans, seas, rivers, streams, lakes, ponds, wells, boreholes, and springs. Surface water (lakes, rivers, and streams) has traditionally been the most readily available supply of water for domestic and other uses in the majority of rural and urban areas in the developing world, particularly in sub-Saharan Africa. Rivers are among the planet's oldest bodies of water, according to Higler (2012).

Water is a resource that can be used for a wide range of purposes, including household, industrial, and commercial ones in addition to recreation, transportation, and the generation of hydroelectric power (Kumar, 2007). According to Kumar (2007), water is essential for all forms of life and affects our health, manner of life, and financial well-being. Despite making up over 71% of the planet's surface, just 2.8% of the water is fit for human use (Iskandar, 2010). A third of the world's population currently lives in countries with moderate to severe water stress. Additionally, between 1900 and 1995, the volume of fresh water consumed worldwide increased sixfold, which is more than twice as quickly as the rate at which the world is currently experiencing a water deficit due to a lack of water resources in light of the growing population (UNEP, 2002; Kumar & Putri, 2012).

Rivers have poorer water quality sources than reservoirs, claim Wang et al. (2009). The assimilation of pollutants, the removal of industrial and urban waste, and runoff from agricultural land all depend on rivers. While the second of these activities is a seasonal occurrence, the former becomes a constant non-point source of pollution (Muduli & Panda, 2010). It is significant to note that the rivers and waters on the outskirts of urban centers are frequently becoming contaminated with hazardous wastes, effective discharges, sludge, and wastewater due to the rapid rate of urbanization, industrialization, and population growth as well as the rapid development of agriculture, mining, urbanization, and industrialization activities (Ali, 2012).

“The survival of the human race as well as the wellbeing of the environment and ecosystem are both threatened by water pollution, according to Bu et al. (2009). Water contamination can come from domestic, natural, or industrial sources (Iyama et al., 2020). The high levels of pollution in the water bodies pose a more serious danger to the sustainability and proper functioning of the biodiversity of the ecosystem. Ogolo & Abam (2021) claim that cleaning up contaminated water is extremely difficult, expensive, and practically impossible. UN (2019) has also stated that fish and aquatic mammals from all across the world have been found to contain detectable levels of persistent organic contaminants. However, eighty percent (80%) of the world's wastes—which range from highly toxic industrial discharges to human waste—are still dumped into bodies of water. Additionally, heavy metals and other toxins are prevalent and have adversely affected human health due to the bioaccumulation of metals by fish and shellfish used as human food sources.

The current level of pollution in the rivers and creeks of the Nigerian Niger Delta is frightening and dismal. Accordingly, studies indicate that most creeks and the water bodies inside them are tainted. Ali et al. (2012), as mentioned in Ogolo & Abam (2021), claim that the scope and severity of the contamination of the aquatic ecosystem in the Nigerian Niger Delta region is quickly increasing. This is a result of rapid population increase, industrialization, and low enforcement of environmental laws.

Sludge and waste water discharges, along with industrial effluent discharges, have contaminated the rivers and creeks of Rivers State's Okrika Local Government Area. Due to the discharge of refinery effluent there, high quantities of pollutants were discovered in the water and sediments of the Okrika arm of the Bonny River estuary (Otokunefor & Obiukwe, 2005). Additionally, it has been established that the fertilizer company's discharge of low-quality effluent has an extremely detrimental effect on the physicochemical characteristics of water and sediment in Okrika creeks (Obire et al., 2008a). The littoral zone, shallow water, sediments in the streams that go down the shore, and the way of life of the residents have all been impacted by this (John & Chimka, 2017). As a result, the objective of this study is to assess the water quality of the Okochiri Creek in the Okrika Local Government Area of Rivers State, Nigeria."

II. METHODOLOGY

- *Study Area*

Okrika is a local Government area in Rivers State, South-South Nigeria of Niger Delta area. Its headquarters is in Okrika mainland, an island in Rivers State, South-South Nigeria. The town is situated on an island south of Port Harcourt, making it a suburb of the larger city (Ogolo & Abam, 2021). It lies on the north of the Bonny River and on Okrika Island, 35 miles (56km) upstream from the Bright of Bonny, and can be reached by vessel of a draft of 29 feet (9 metres) or less (Otokunefor & Obiukwe, 2005). Geographically and at the North by Obio/Akpor and Eleme Local Government Areas. It is located approximately on latitude 4º44′23″ N and longitude, 7º4′58″E on the Greenwich Meridian (Okoye *et al.*, 2013) (Fig. 1).

- *Surface Water Collection*

All sample containers for water sample collection were rinsed with the water being sampled before putting the sample into the containers. The water samples were collected with the aid of a stainless steel surface water sampler.

Fig 1 Map of Study Area Showing Sample Locations

III. LABORATORY ANALYSIS

- *In-Situ Analysis*

In-situ analysis was carried out for fast changing parameters using WTW Multi 340i/set Meter. The water sample was added into a 50ml beaker and the WTW Multi 340i/set Meter was then inserted to ensure the following parameters: pH, Temperature, Turbidity, Conductivity, Total Suspended Solids, Salinity and Dissolved Oxygen. Prior to the measurement, the multi-meter probes were conditioned using distilled water.

- *Total Suspended Solid*

The Procedure for the gravimetric method (2540D) describes a well-mixed measured volume of a water sample is to be filtered through a pre-weighted glass fibre filter. The filter is heated to a constant mass at 104 ± 1 ℃ and then weighed. The mass increase divided by the water volume filtered is equal to the TSS in mg/L.

$$TSS = \left(\frac{A - B}{V}\right) \qquad (1)$$

A = Mass of filter + dried residue (mg), B = Mass of filter (fare weight) (mg), and

V = Volume of sample filtered (L)

- *Phosphate*

Phosphate in water are measured as orthophosphate following the Method 4500-P(B) by which complex is formed with Ammonium molybdate and reduced by Stannous Chloride ($SnCl_2$) and develops a blue coloration which defines the concentration of orthophosphate colormetrically at 690 nm. To calculate the actual

$$PO_4\ concentratiom = \frac{Absorbance\ reading \times 1000}{Slope\ value \times Sample\ volume\ (ml)} \qquad (2)$$

- *Nitrate*

The test method used to determine the Nitrate-nitrogen content of the water sample is the Brucine Colorimetric method in accordance with EPA-NERL: 352.1.

Nitrate-nitrogen (NO_3^- N) content of the water sample was calculated as follows:

$$NO_3\text{-}\left(\frac{mg}{l}\right) = \left(\frac{mg}{l} NO_3\text{-}in\ sample\ from\ calibration\ graph\right) - (mg\ NO_3\text{-}in\ reagent\ blank) \qquad (3)$$

- *Chloride*

In following the Argentometric method (4500-Cl^- B), a neutral or slightly alkaline sample solution, potassium chromate can indicate the end point of the silver nitrate titration of chloride. Silver chloride was precipitated quantitatively before red silver chromate is formed. The concentration (mg Cl^-/L) was determined by calculating thus:

$$(A - B) \times N \times 35.450\ mL/\ sample \qquad (4)$$

Where:
A = mL titration of sample,
B = mL titration for blank, and
N = normality of $AgNO_3$

- *Sulphate*

In this Turbidimetricmethod (4500-SO_4-E), Sulphate ion was precipitated in an acetic acid medium with Barium Chloride so as to form Barium Sulphate ($BaSO_4$) crystals of uniform size: $K_2SO_4 + BaCl \rightarrow BaSO_4 + 2KCl$

Light absorbance of the $BaSO_4$ suspension was measured at 420 nm and the sulphate (SO_4^{2-}) concentration was determined photometrically.

- *Ammonia*

The method described as Phenate (4500-NH_3 F) is based on an intensely blue compound, indophenol. It was formed by the reaction of Ammonia, hypochlorite, and phenol catalyzed by nitroprusside. The ammonia concentration was determined at 640 nm by using a blank to get the absorbance readings against Ammonia standards and computing sample concentration by comparing sample absorbance with standard curve.

- *Chemical Oxygen Demand*

The titrimetric method of analysis was applied using APHA 5220D standard method. The Chemical Oxygen Demand (COD) was calculated thus:

$$\text{COD as } mg\ O_2/l = \frac{(A - B) \times M \times 8000}{Volume\ of\ sample,\ ml} \qquad (5)$$

Where:
A = ml titrant used for blank,
B = ml FAS used for sample,
M = molarity of titrant, and

8 = equivalent weight of oxygen, 1000 = conversion factor to liter

- *Biochemical Oxygen Demand and Dissolved Oxygen*

The respirometric method, as described in APHA 5210D was used in water analysis based on the manufacturer's instructions, reaction vessel type, and volume, and instrument operating characteristics. The Biochemical Oxygen Demand (BOD) values were be read from the equipment.

- *Water Quality Index (WQI)*

A Water Quality Index (WQI) according to Liou *et al.* (2004) in simplified concept is a way of combining complex water quality data into a single value or single statement.

To determine surface water quality index, some specific water quality parameters must be measured and quantified. These parameters are different from one another, because they depend on the intended use (Olatunji *et al.*, 2015). WQI is calculated from the perspective of the suitability of water for human consumption (Atulegwu and Njoku, 2004).

$$WQI = \sum (q_i W_i) / \sum W_i \qquad (6)$$

Where the unit weight of the *i*th parameter (W_i) can be calculated as follows:

$$W_i = {}^{K}\!/_{S_i} \qquad (7)$$

$$K = {}^{1}\!\Big/_{\sum \frac{1}{S_i}} \qquad (8)$$

K is the constant of proportionality and S_i is water standards for the parameters. Then, q_i which is the quality rating for all the parameters, can be calculated as follows:

$$q_i = 100 \left(\frac{V_i - V_o}{S_i - V_o} \right) \qquad (9)$$

V_i is the concentration of the *i*th parameter of interest in the investigated surface water, while V_o is the ideal value of the *i*th parameter in pure water. V_o= 0 (except pH = 7.0; and DO = 14.6 mg/l).

Furthermore, the grades of Water Quality Index (WQI) and status of water rating are shown in Table 1.

Table 1 Rating for WQI and Status of Water

Class	WQI	Category of Water and Quality
1.	<50	Excellent
2.	50 – 100	Good
3.	100 – 200	Poor
4.	200 – 300	Very poor
5.	> 300	Unsuitable

Source: APHA (2017)

- *"Irrigation Water Quality Index (IWQI)*

To determine Irrigation Water Quality Index (IWQI) of the surface water for agricultural purposes and other activities, water quality parameters such as electrical conductivity, salinity, chloride, magnesium, were used.

Irrigation parameters such as In order to determine the irrigation quality of sampling water from the study area, the Sodium Absorption Ratio, Soluble Sodium Percentage, Residual Sodium Bicarbonate, Permeability Index, Magnesium Adsorption Ratio, and Kelly Ratio were evaluated. The sodium absorption ratio is a helpful metric for determining if surface water is suitable for irrigation.

"The Sodium Adsorption Ratio (SAR) was calculated by the following equation given as:

$$\text{SAR} = \frac{Na^+}{\sqrt{\frac{Ca^{2+} + Mg^{2+}}{2}}} \qquad (10)$$

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

Soluble Sodium Percentage (SSP) was calculated by the following equation:

$$\text{SSP} = \frac{Na^+ + K^+}{Ca^{2+} + Mg^{2+} + Na^+ + K^+} \times 100 \qquad (11)$$

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

The Residual Sodium Bi-carbonate (RSBC) was calculated as:

$$\text{RSBC} = HCO_3{}^- - Ca^{2+} \qquad (12)$$

Where, RSBC and the concentration of the constituents are expressed in meq/L.

The Permeability Index (PI) was calculated by the following Equation:

$$\text{PI} = Na^+ + \left(\frac{\sqrt{\text{HCO3}^-}}{Ca^{2+} + Mg^{2+} + Na^+} \right) \times 100 \qquad (13)$$

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

Magnesium Adsorption Ratio (MAR) was calculated by the equation:

$$\text{MAR} = \frac{Mg^{2+}}{Ca^{2+} + Mg^{2+}} \times 100 \qquad (14)$$

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

The Kelly's Ratio was calculated using the equation:"

$$\text{KR} = \frac{Na^+}{Ca^{2+} + Mg^{2+}} \qquad (15)$$

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

This IWQI model was applied in this study as used by Hussian *et al.* (2014)."

IV. RESULTS AND DISCUSSION

- *Physicochemical Properties*

The physicochemical properties obtained from the surface water samples were compared with national and international standards – WHO (1996), USEPA (2004), NSDWQ (2015) and DPR (2002).

The acceptable limit for pH set by NSDWQ is 6.5 – 8.5. Only samples from Stations 2, 3. 4, 10 and Control with pH levels of 7.2, 7.2, 6.9, 7.0 and 6.8 respectively were within the acceptable limit. The pH values of the surface water were in agreement with those obtained by Onojake *et al.* (2017) in a study carried out on Bonny/New Calabar River.

Temperature levels were within acceptable limits (ambient temperature) in all stations. Temperature of water influences the amount of dissolved oxygen with only lesser oxygen dissolved in warm water than cold water (Tenagne, 2009).

All stations, except Station 2, had Turbidity levels below the acceptable limit of 5.0 NTU set by WHO. A turbidity level of 43.1 NTU was recorded at station 2, which was above the acceptable limit. Olorode *et al* (2016), in a study in the Niger Delta region of Nigeria, had reported turbidity levels of 0.76 NTU, 2.00 NTU and 3.60 NTU at Bonny, Onne and Okpoka Rivers, respectively, during the dry season; levels which are in agreement with the levels obtained in this study.

High conductivity levels were recorded which were all above the acceptable limit of 1000 µS/cm by NSDWQ; Station 2 (2375 µS/cm) had conductivity level below that of the control (24,750 µS/cm). Onojake *et al.* (2017) reported similar electrical conductivity levels for surface water, seasonally ranging from 27,169.33 - 39,851.33 µS/cm. Electrical conductivity measures the degree of ions in water, which greatly affects taste and thus has a significant impact on the user's acceptance of the water.

High TDS levels were also recorded in all samples, which were above the acceptable limit of 500 mg/L set by USEPA and NSDWQ. Station 2 (1665 mg/L) also had TDS level below that of the control (17,325 mg/L). The TDS values obtained in this study were generally higher than the levels of 3572 mg/L, 6800 mg/L and 7931 mg/L obtained in a similar study by Olorode *et al.* (2016) at Okpoka, Onne and Bonny Rivers respectively. TDS affect the taste of drinking water if present at levels above the standard limits.

Total Hardness levels in all surface water samples were above the set limit of 150 mg/L by NSDWQ. Only Station 2 had total hardness level of 179 mg/L, which was slightly above the standard limit.

The WHO set an acceptable limit of 120 mg/L for alkalinity. All surface water samples had alkalinity levels below the set limit; the control recorded the highest level of 41.0 mg/L. Olorode *et al.* (2016) had reported alkalinity levels of 8.0 mg/L, 26.0 mg/L, 30.0 mg/L and 36.0 mg/L for Bonny, Onne, Okpokpa and Imo Rivers respectively, in a study carried out in the Niger Delta region of Nigeria, which are within the range of those obtained in this study for surface water.

Very high chloride levels were recorded in the surface water samples; all of which were above the standard limit of 250 mg/L set by USEPA and NSDWQ. The lowest chloride level of 988.0 mg/L was recorded at Station 2; which was also above that of the control (3458.0 mg/L). Similar range of chloride levels of 2421 mg/L and 5160 mg/L were obtained in a study carried out in Onne and Bonny Rivers respectively by Olorode *et al*. (2016). High chloride concentration damages metallic pipes and structure, as well as harms growing plants (Meride and Ayenew, 2016).

High sulphate levels were also recorded in the study area. The acceptable limit for sulphate is 100 mg/L as set by NSDWQ. Station 2 had sulphate level of 144 mg/L which was slightly above the standard limit. Lower sulphate levels of 111.72 mg/L, 294 mg/L, 390.432 mg/L were obtained in a study carried out in Otobiri, Onne and Okpoka Rivers respectively by Olorode *et al*. (2016). One of the problems associated with polluted water containing sulphate in excess quantity is to attack the fabric of concrete sewer pipes (EPA, 2011).

Nitrate levels in the surface water samples were below the standard limits of 50 mg/L set by WHO and NSDWQ, 10 mg/L set by USEPA. These levels pose no toxicity threats to humans. Problems such as diuresis, increased starch deposits and hemorrhaging of the spleen could be caused by high nitrate levels (Reimann *et al*., 2003).

Very low phosphate levels were also recorded in the study area. There are no set limits for phosphate. These low phosphate levels could be due to minimal seepage from run-offs or sewage discharges; it is also indicative of absence of Phosphorus - containing mineral apatite in the area (Ideriah and Ikoro, 2015).

The acceptable limit for calcium as set by WHO is 50 mg/L. All surface water samples had calcium levels above the set limit; except for Station 2 which had a calcium level of 8.1 mg/L, below the set limit. Kaizer and Osakwe (2010), in a study carried out in Delta State, Nigeria, reported mean calcium levels of 1.60 mg/L, 2.57 mg/L and 4.02 mg/L in Agbarho, Ase and Afiesere Rivers respectively; and these are not in agreement with the levels obtained in this study.

All surface water samples had magnesium levels above the acceptable limit of 50 mg/L and 20 mg/L set by WHO and NSDWQ respectively; except Station 2 which had magnesium level of 38.6 mg/L, below the WHO limit. Kaizer and Osakwe (2010), also reported mean magnesium levels of 1.08 mg/L, 1.60 mg/L and 2.73 mg/L in Ekakpamre, Agbarho and Afiesere Rivers respectively; and these are not in agreement with the levels obtained in this study.

The USEPA and NSDWQ set acceptable limits for sodium at 250 mg/L and 200 mg/L respectively. All surface water samples had sodium levels exceeding the set limits; except for Station 2 and the Control which recorded levels of 240.5 mg/L and 241.1 respectively, below the USEPA limit. Kaizer and Osakwe (2010), in a study carried out in Delta State, Nigeria, reported mean sodium levels of 3.88 mg/L, 4.69 mg/L and 5.13 mg/L in Ekakpamre, Agbarho and Ethiope Rivers respectively; and these are not in agreement with the levels obtained in this study.

There are no set limits for bicarbonate and carbonate levels. Bicarbonate helps to buffer lactic acid generated during exercise and also reduces the acidity of dietary components (Mason, 2001).

The WHO acceptable limit for Dissolved Oxygen is ≥ 5.0 mg/L. All surface water samples recorded DO levels above the acceptable limit except for Stations 6, 9 and 10 with levels of 4.7 mg/L, 4.8 mg/L and 4.8 mg/L respectively, which were slightly below the set limit. Enetimi *et al* (2016), in a study carried out on River Orashi in Eastern Niger Delta of Nigeria, reported mean dissolved oxygen levels of 5.80 - 7.60 mg/L and 11.10 - 15.73 mg/L for dry and wet seasons respectively; the levels obtained during the dry season were in agreement with those obtained in this study. Dissolved oxygen, which indicates the healthy nature of a water body with respect to organic wastes, is a very important water quality parameter and a minimal recommended value of 5 mg/L is necessary for domestic use and to maintain aquatic life (Hemant *et al*., 2012). It is a fundamental factor for metabolism of the aerobic aquatic organisms and determines natural depuration capacity or freshness of a river (Naubi *et al*., 2018).

The Chemical Oxygen Demand acceptable limit, as set by WHO, is 10 mg/L. All surface water samples recorded COD levels higher than that of the set limit. Station 2 recorded the lowest level of 46.80 mg/L while the highest level of 485.06 mg/L was recorded at Station 3. Edori *et al.* (2019), in a study carried out on Silver River, Bayelsa State, recorded COD levels of 46.5 – 54.3 mg/L; and these levels are generally not in agreement with those obtained in this study. COD gives information on the level of oxidizable organic matter that might be responsible for river or water pollution (Edori *et al.*, 2019). COD levels in this study suggest a high organic content in the surface and groundwater in the study area, thus making it unsafe for human consumption.

The Biochemical Oxygen demand levels in the surface water samples recorded in this study were all below the acceptable limit of 4 mg/L set by WHO; except for Stations 3 an 5 which recorded levels of 4.7 mg/L and 4.1 mg/L respectively, slightly above the set limit. Enetimi *et al* (2016), in a study carried out on River Orashi in Eastern Niger Delta of Nigeria, reported mean BOD levels of 4.00 - 6.05 mg/L and 6.45 - 6.97 mg/L for dry and wet seasons respectively; the levels were above those obtained in this study. Biochemical Oxygen Demand (BOD) of a water channel indicates the level of oxygen required by microorganisms to decompose organic waste under aerobic conditions.

- *Water Quality Index*

The water quality index values obtained from the surface water samples indicate that only Station 2 (WQI = 180) had its water rated as ‘poor’ for drinking while other stations had their water rated as ‘unsuitable for drinking’. The high level of heavy metals in the surface water samples contributed largely to the high WQI levels.

- *Irrigation Indices*

The quality of surface water samples for irrigation was determined by using various indices such as Sodium Absorption Ratio (SAR), Soluble Sodium Percentage (SSP). Kelly ratio (KR), Permeability Index (PI), Magnesium Absorption Ratio (MAR), Residual Sodium Carbonate (RSC) as shown in Figs. 5 – 4.10 respectively.

Sodium Absorption Ratio (SAR) values fell between 0.8 and 14.1; Soluble Sodium Percentage (SSP) values fell between 3.1 and 26.0; Kelly ratio (KR) values fell between 0.03 and 0.35; Permeability Index (PI) values fell between 3.40 and 26.0; Magnesium Absorption Ratio (MAR) values fell between 97.8 % and 98.7 % while Residual Sodium Carbonate (RSC) values fell between -637.2 and -287.5.

Sodium Adsorption Ratio and Soluble Sodium Percentage are widely used for assessing the suitability of water for irrigation purposes and the Wilcox diagram (Wilcox, 1995) relates a plot of Sodium Absorption Ratio (SAR) vs Electrical Conductivity (EC) to designate irrigation water quality.

Plots of the Wilcox (Fig.11) and Unites States Salinity Laboratory (USSL) diagrams (Fig. 12) were used to classify the surface water quality for irrigation purposes. Sodium Adsorption Ratio and Soluble Sodium Percentage are widely used for assessing the suitability of water for irrigation purposes. The Wilcox diagram (Wilcox, 1995) relates a plot of Soluble Sodium Percentage (SSP) vs Electrical Conductivity (EC) to designate irrigation water quality while the USSL diagram relates a plot of Sodium Absorption Ratio (SAR) vs Electrical Conductivity (EC) to designate irrigation water quality

The different classes of the Wilcox SAR vs EC diagram include low, C1 (EC < 250 µS/cm); medium, C2 (EC 250–750 µS/cm); high, C3 (EC 750 -2250 µS/cm); and very high, C4 (EC > 2250 µS/cm), and the sodium hazard classes include: low, S1 (SAR < 10); medium, S2 (SAR 10 - 18); high, S3 (SAR 18–26); and very high, S4 (SAR > 26)”.

The different classes of salinity hazard include low, C1 (EC < 250 µS/cm); medium, C2 (EC 250–750 µS/cm); high, C3 (EC 750 -2250 µS/cm); and very high, C4 (EC > 2250 µS/cm), as shown in figure 4.13. Also, the sodium hazard classes include: low, S1 (SAR < 10); medium, S2 (SAR 10 - 18); high, S3 (SAR 18–26); and very high, S4 (SAR > 26).The Salinity Laboratory of the United States Department of Agriculture (USSL) recommends SAR because of its direct relation to adsorption of Na^+ by soil (Richards, 1954).

The Sodium Absorption Ratio (SAR) plot showed that 27.7 % of the surface water samples (Stations 2, 6 & Control) were rated as ‘excellent’ for irrigation while 72.7 % (Stations 1, 3, 4, 5, 7, 8, 9 and 10) were rated as ‘good/safe’ for irrigation. Udom *et al* (2017), opined that the suitability of water for agricultural purposes will be based on the result obtained from the calculated sodium adsorption ratio (SAR) as it is the most important parameter.

The Soluble Sodium Percentage (SSP) plot showed that 18.2 % of the surface water samples (Stations 8, & Control) were rated as ‘excellent’ for irrigation while 81.8 % (Stations 1, 2, 3, 4, 5, 7, 9 and 10) were rated as ‘good/safe’ for irrigation. High contents of sodium ions in surface water, relative to calcium and magnesium ions, react with the soil and decrease its permeability, which contributes to a deterioration of the soil structure, arising in stunted growth of plants (Doneen, 1964; Todd, 1980).

The Kelly Ratio (KR) plot showed that 100 % of the surface water samples were rated as ‘suitable’ for irrigation. The Kelly Ratio reveals the excess quantity of sodium in irrigation water (Sudhakar and Narsimha, 2013).

The Permeability Index (PI) plot showed that 54.5 % of the surface water samples (Stations 1, 2, 3, 4, 9 and 10) were rated as ‘good (class 1)’ for irrigation while 45.5 % (Stations 5, 6, 7, 8, and Control) were rated as ‘unsuitable’ for irrigation. According to (Ravikumar *et al*, 2011), the Permeability Index is often utilized to assess the suitability of the irrigation water, which is influenced by the long-term exposure of irrigation water with a high content of Na^+, Ca^{2+}, Mg^{2+} and alkalinity ions.

The Magnesium Ratio (MAR) plot showed that 100 % of the surface water samples were rated as ‘suitable’ for irrigation. Magnesium Adsorption Ratio (MAR) causes harmful effect to soil when it exceeds 50 %.

The Residual Sodium Carbonate (RSC) plot showed that 100 % of the surface water samples were rated as ‘suitable’ for irrigation. High concentration alkaline earth metals (Ca^{2+} and Mg^{2+}) generates the term Residual Sodium Carbonate (RSC), which indicates the hazardous effect of alkalinity on water quality for irrigation (Sundaray *et al*, 2009; Ravikumar *et al*, 2011).

The Wilcox diagram revealed that only Station 2 was classified as ‘doubtful-unsuitable’ for irrigation while others station were classified as ‘unsuitable’ for irrigation.

The Unites States Salinity Laboratory (USSL) Diagram revealed that Station 2 was plotted in the C4-S1 class, the Control in the C4-S2 class while other stations were plotted in the C4-S4 class. C1-S1 classes are perfect for irrigation. C2-S1 classes can be used for irrigation on almost all soils with little danger of sodium problem. C4-S4 classes are generally not suitable for irrigation. C2-S4, C3-S2 and C3-S4 classes are marginal /doubtful for irrigation.

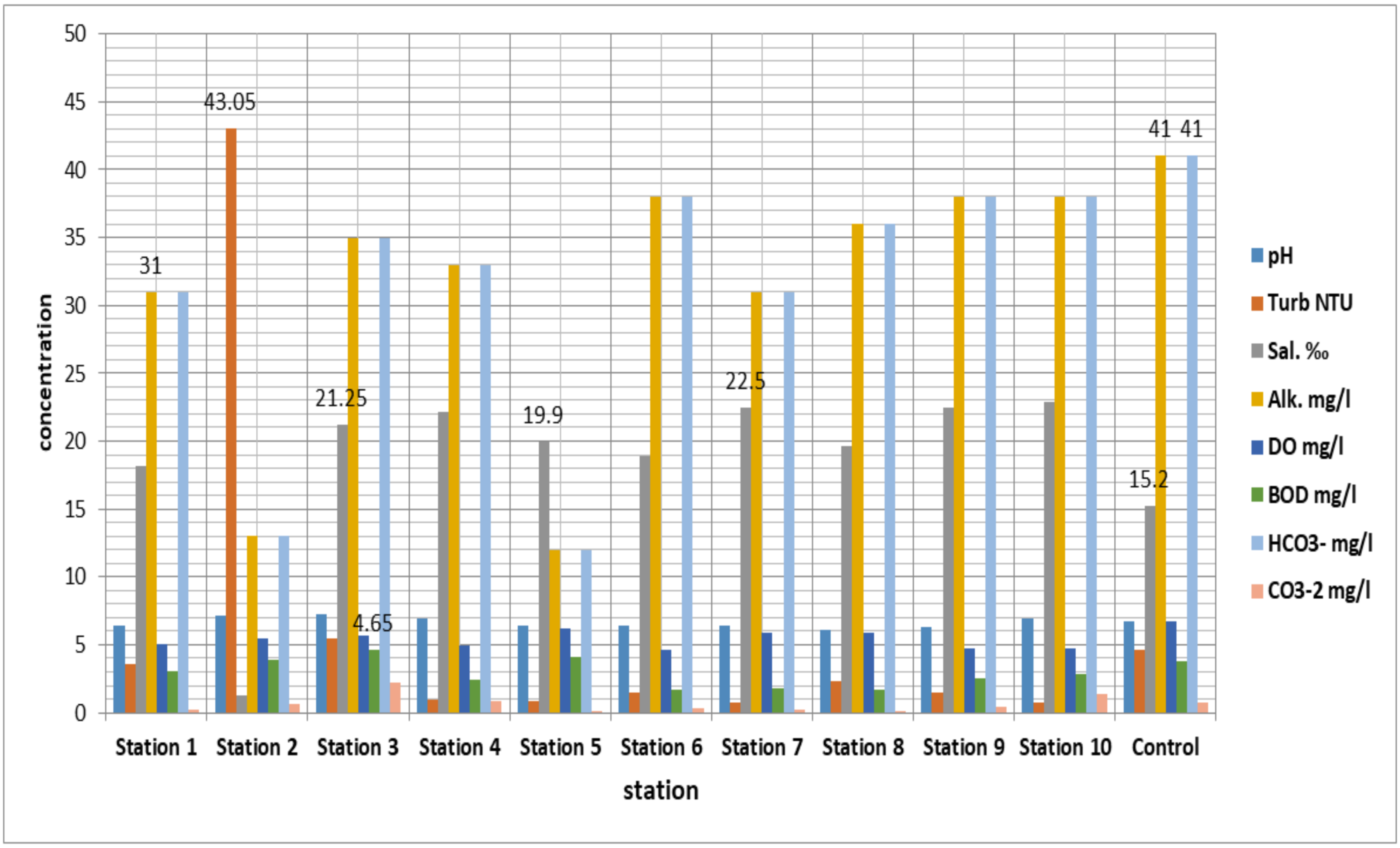

Fig 2 Comparisons of Levels of some Physicochemical Properties

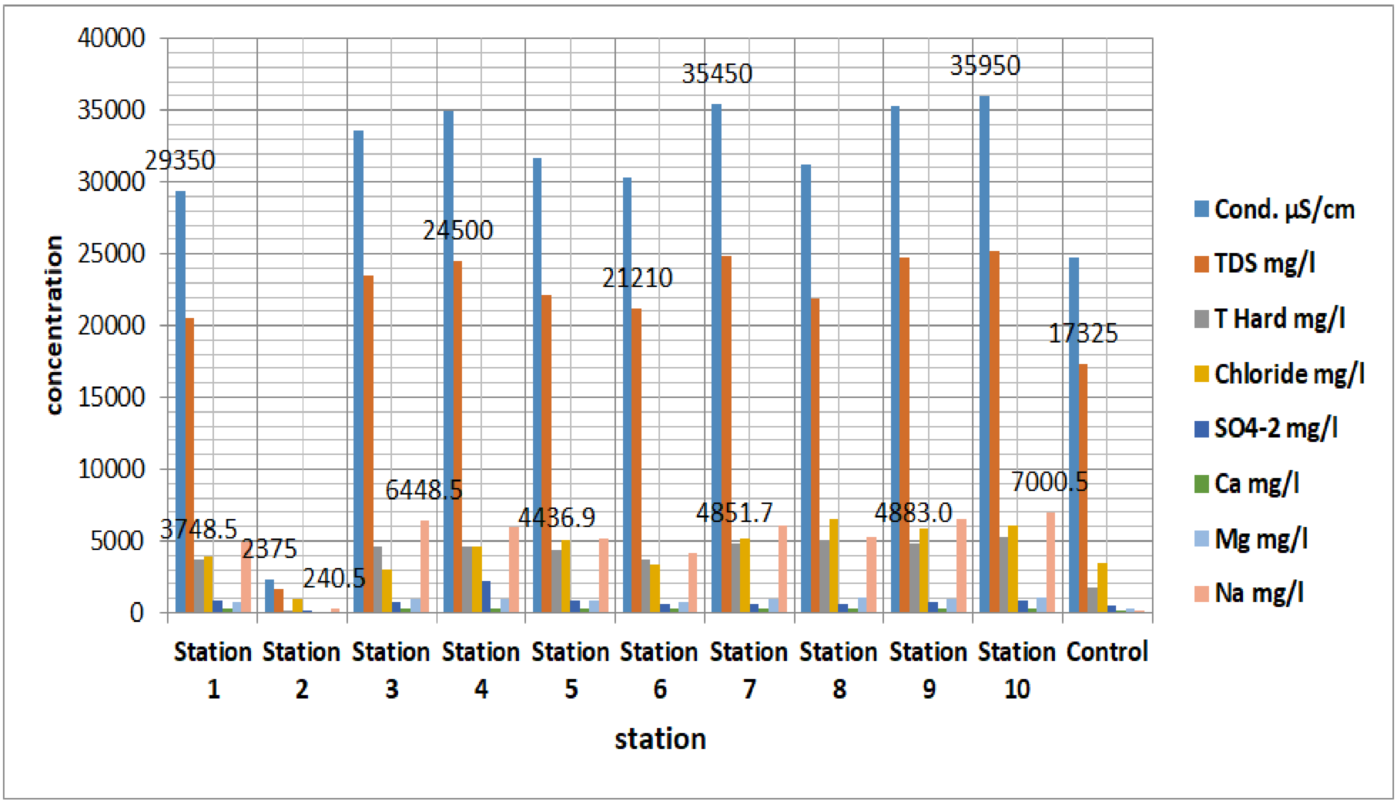

Fig 3 Comparisons of Levels of some Physicochemical Properties

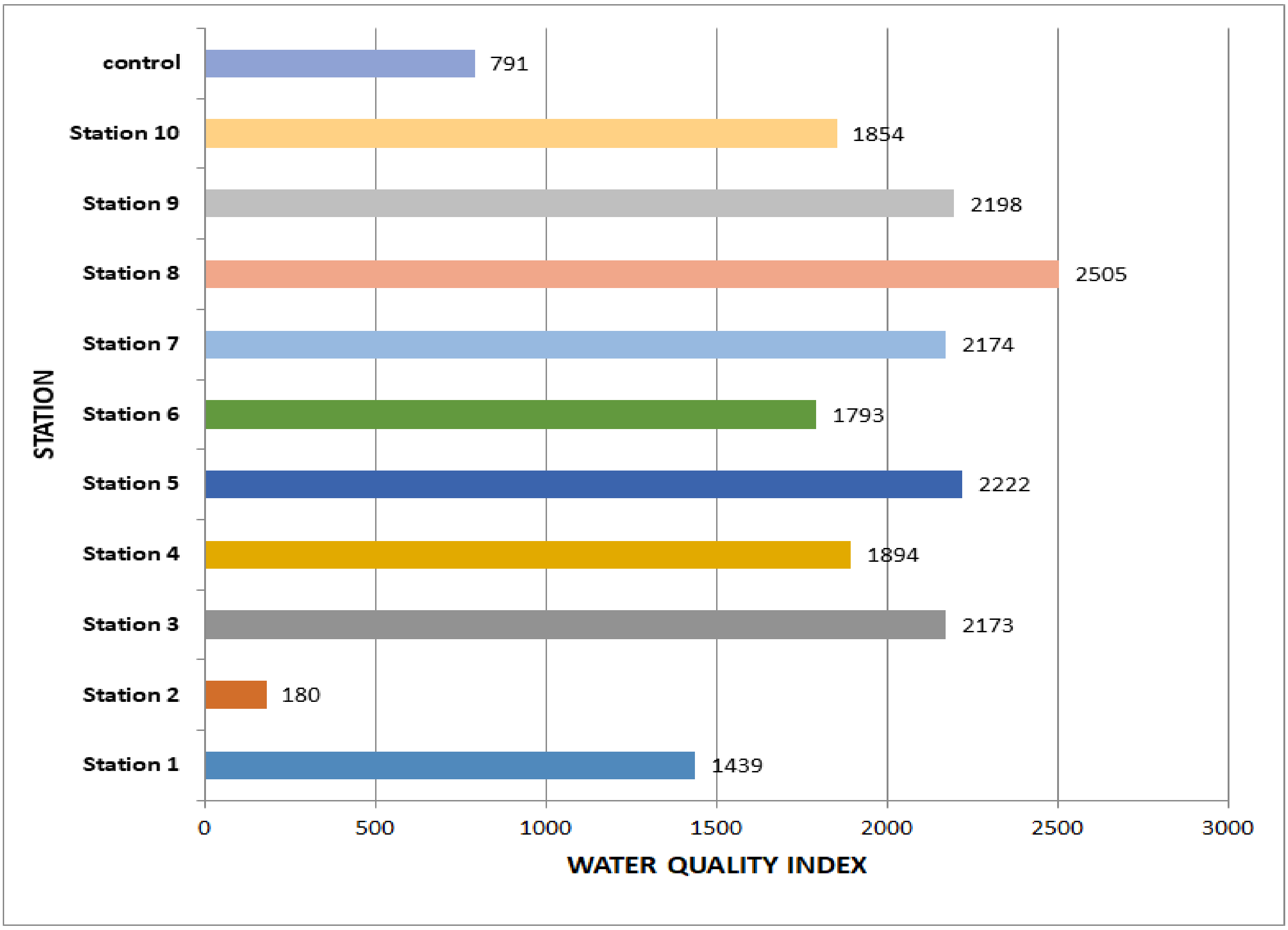

Fig 4 Water Quality Index

- *WQI Rating:*

✓ *0 – 50 = Excellent, 50 – 100 = Good, 100 – 200 = Poor, 200 – 300 = Very Poor*
✓ *>300 = Unsuitable for Drinking*

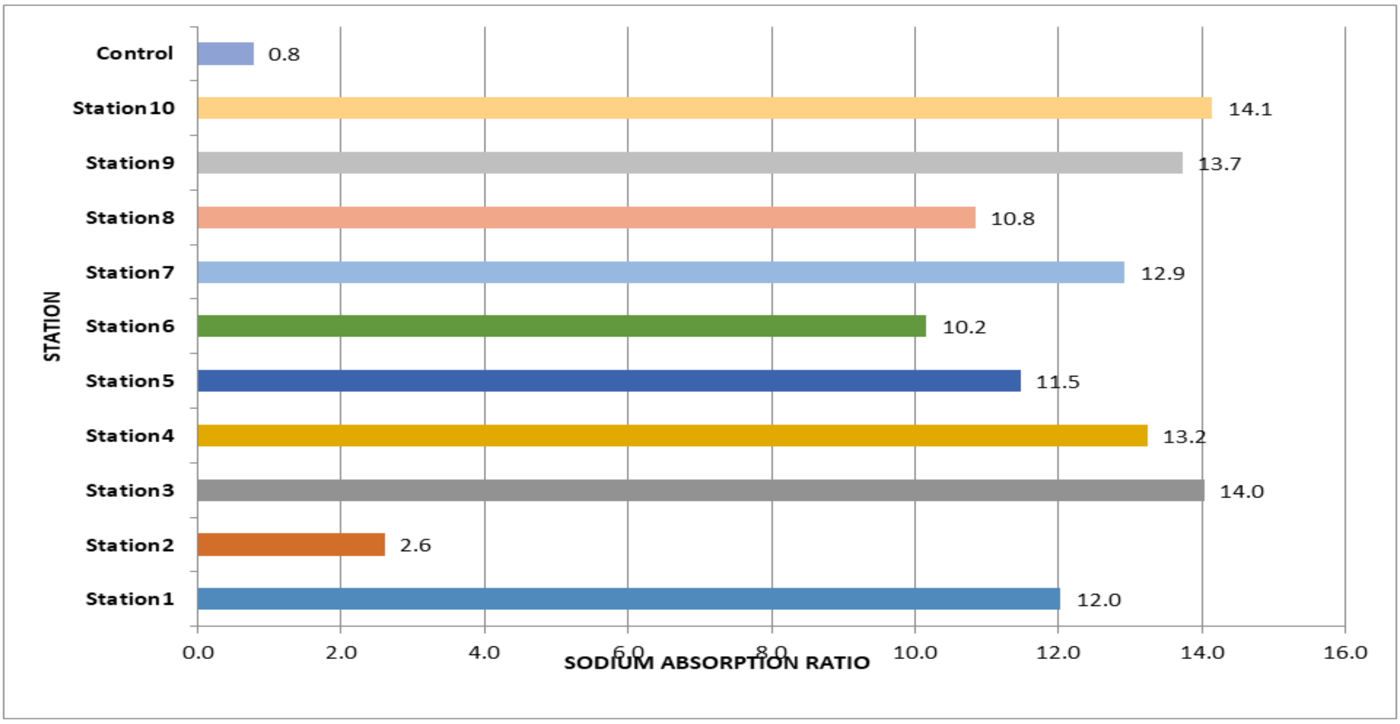

Fig 5 Sodium Absorption Ratio Values

- *Sar Rating:*

✓ *SAR<10 = Excellent, SAR= 10-18 = Good/Safe, SAR= 18-26 = Doubtful/moderate*
✓ *SAR> 26 = Unsuitable*

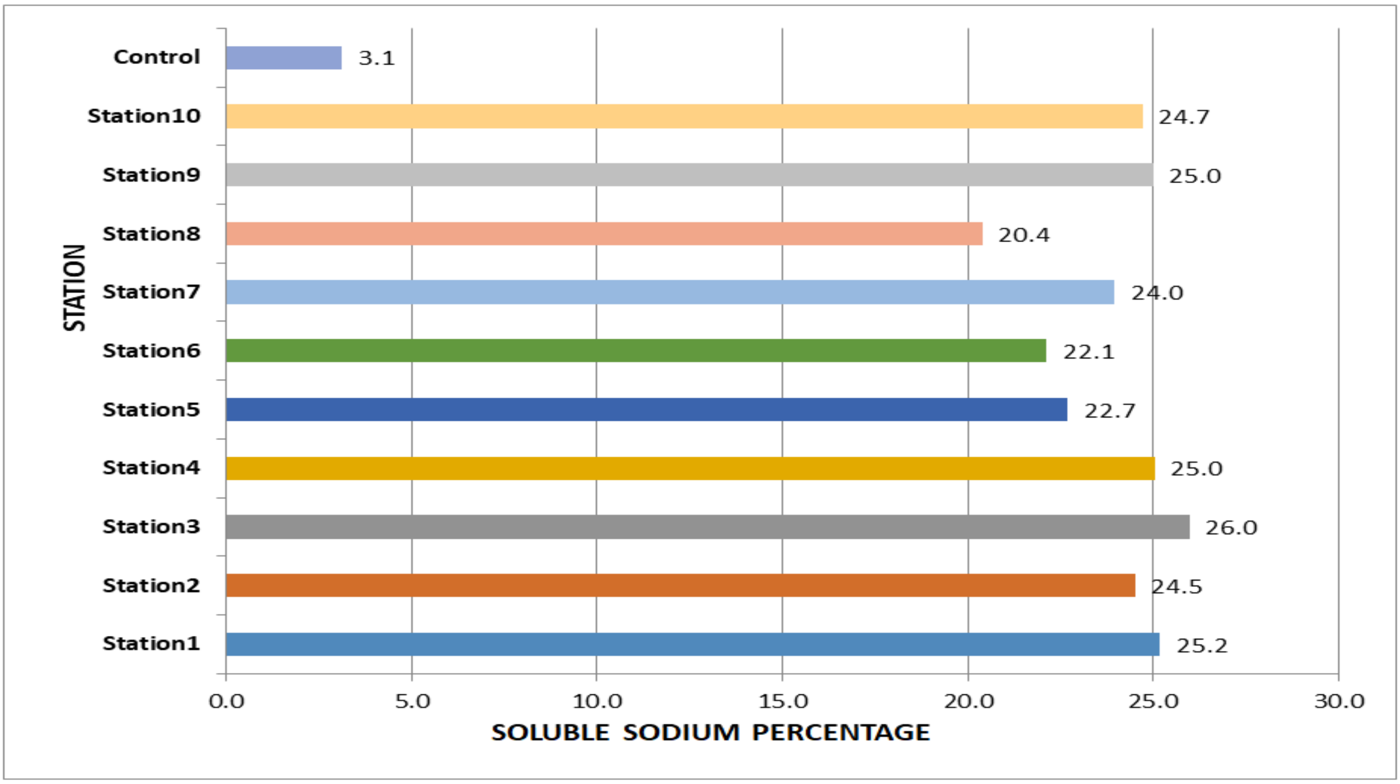

Fig 6 Soluble Sodium Percentage Values

- *SSP Rating:*

✓ *SSP < 20 = Excellent, SSP (20 – 40) = Good, SSP (40 – 60) = Permissible*
✓ *SSP (60 – 80) = Doubtful, SSP > 80 = Unsuitable*

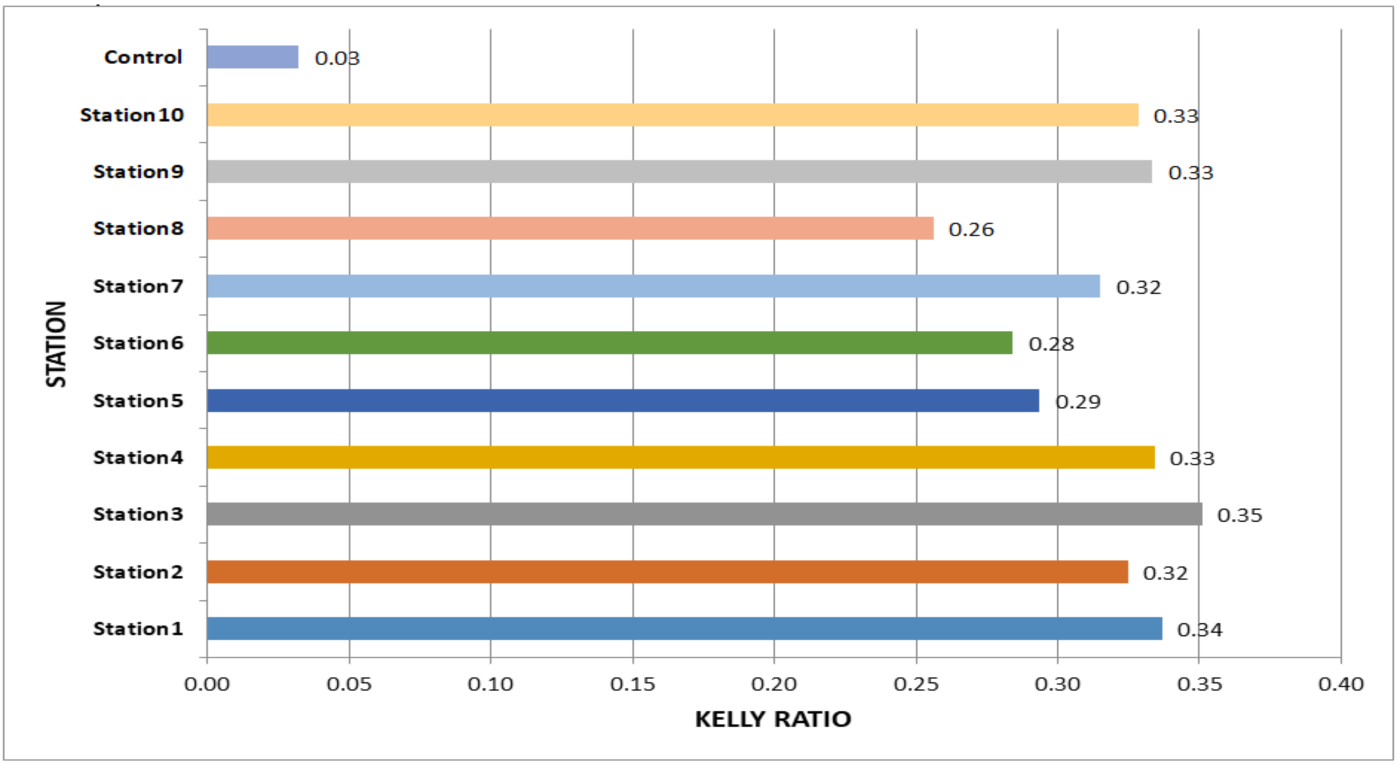

Fig 7 Kelly Ratio Values

- *KR Rating:*
  KR < 1 = Suitable, KR > 1 = Unsuitable

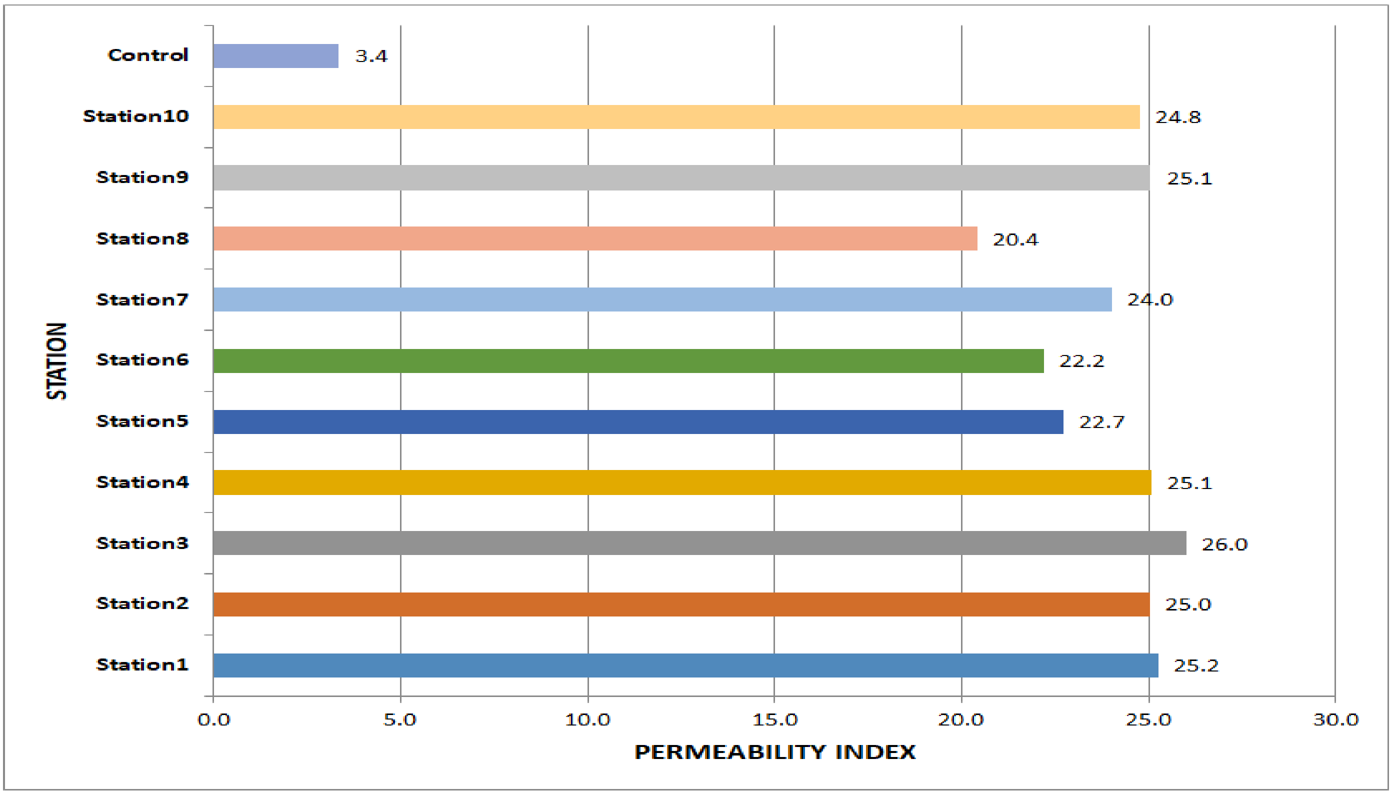

Fig 8 Permeability Index Values

- *PI Rating:*
  PI >75% = Good (Class 1), PI (25% - 75%) = Good (Class 2), PI < 25%= Unsuitable

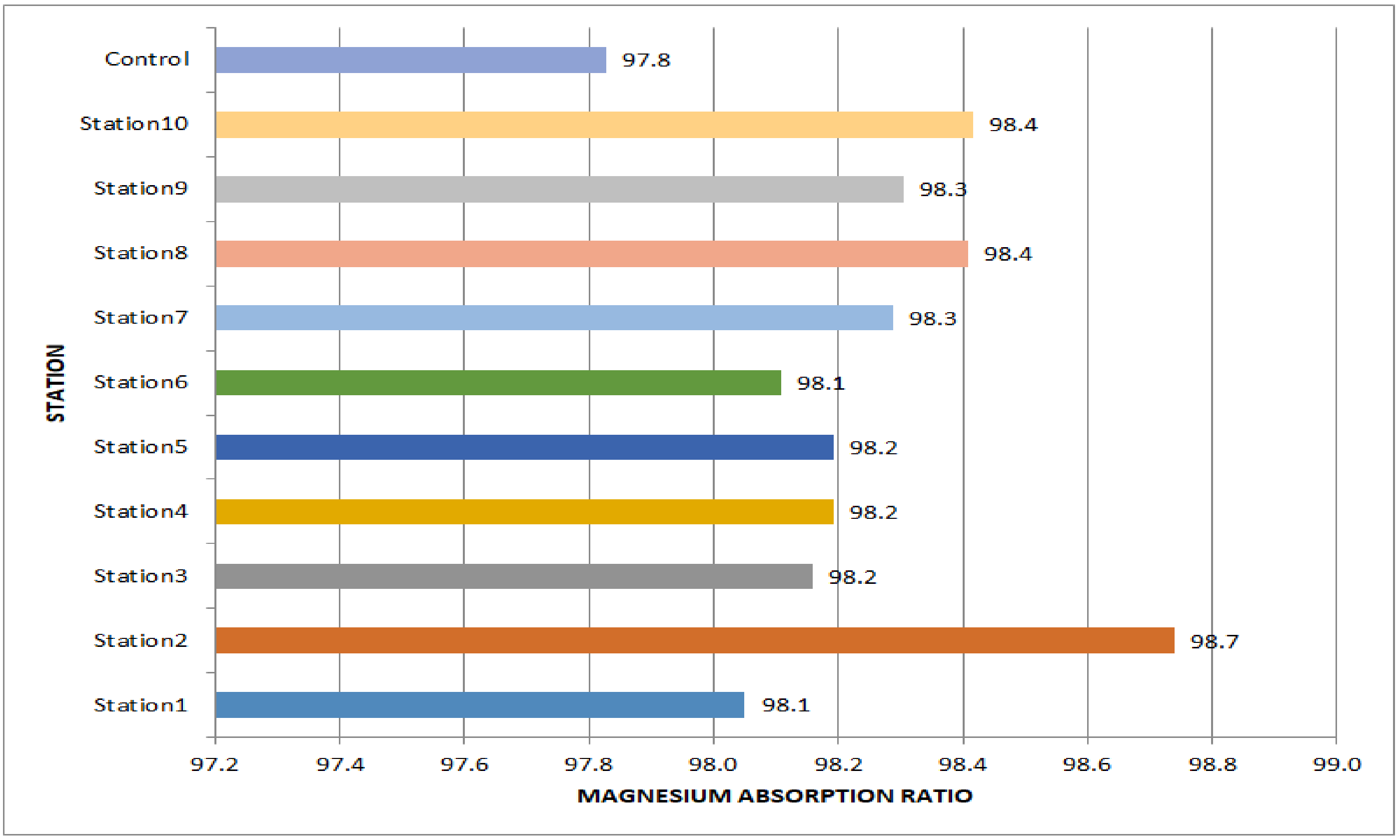

Fig 9 Magnesium Absorption Ratio Values

- *MAR Rating:*
  < 50 = Suitable, > 50 = Unsuitable

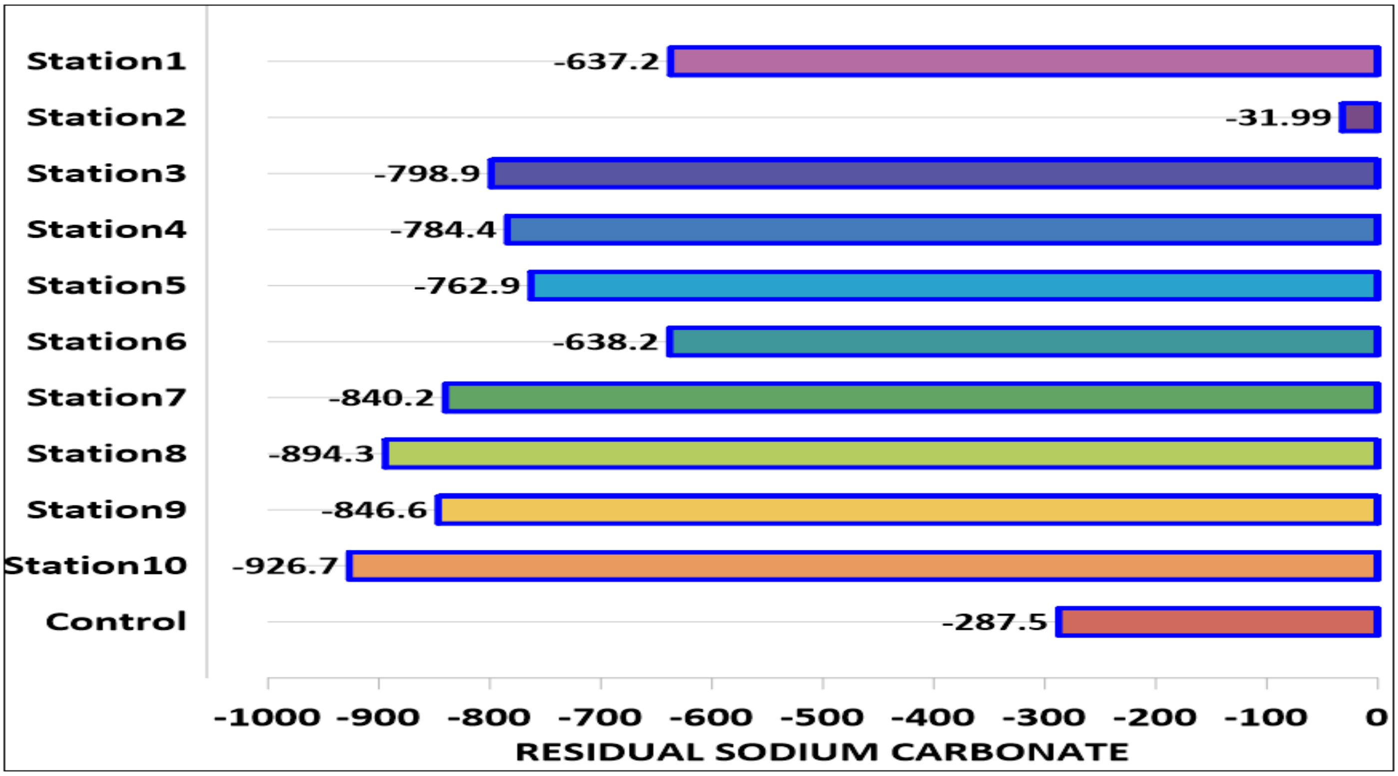

Fig 10 Residual Sodium Carbonate Values

- *RSC Rating:*
  RSC < 1.25 = Suitable, RSC (1.25 - 2.5) = Doubtful, RSC > 2.5 = Unsuitable

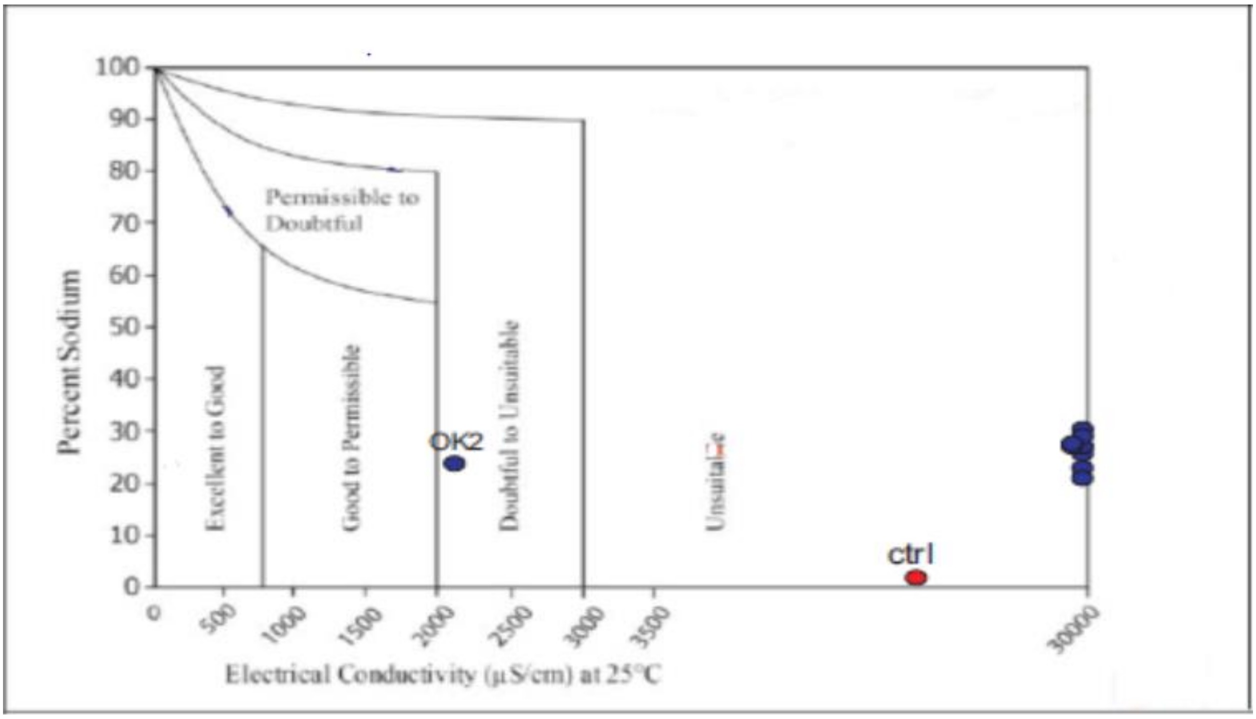

Fig 11 Wilcox Diagram
OK2 = Station 2, Ctrl = Control

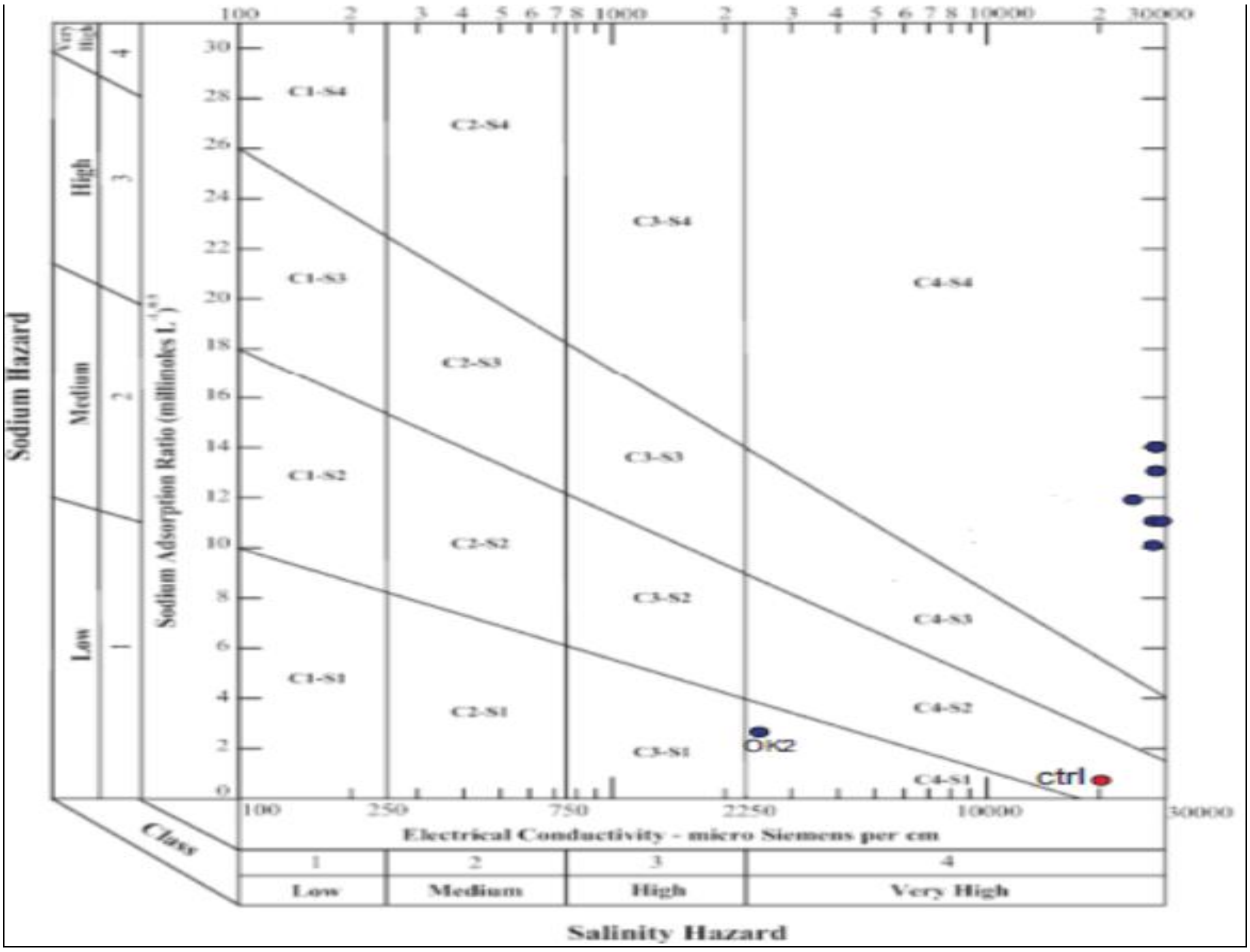

Fig 12 United States Salinity Laboratory (USSL) Diagram
OK2 = Station 2, Ctrl = Control

V. CONCLUSION

The results from the assessment of the surface water samples from the study area found pH levels of groundwater to be within acceptable limits; and slightly below the set limits in some stations. Very high sodium and electrical conductivity and TDS levels were recorded and above acceptable limits in most stations. Chemical Oxygen Demand levels recorded in this study indicate that the water bodies have high organic matter contamination. The Water Quality Index classified the water in the area as unsuitable for drinking purposes. Irrigation indices showed that the surface water samples in the area were generally unsuitable for irrigation and therefore should not be used for both drinking and irrigation without proper treatment. .

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