Original Research Article

Assessment of Physico-Chemical Properities of Surface Water, of Oji Town And its Adjoining Areas, Anambra Basin, Se. Nigeria for Irrigation Purpose

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ABSTRACT

The study tends to assess the quality of surface water for irrigation purpose. The following parameters were test for: $_pH$, Turbidity, Electrical Conductivity, and temperature, Total Dissolved Solid (TDS), Mg^{2+}, SO_4^{2-}, Cl^-, K^+, Na^{2+}, HCO_3^{3-}, Ca^{2+} and NO^{3-}. $_pH$ ranges from (6.0 to 6.9), Turbidity ranges from (0.5 to 2.9 NTU), EC ranges from (34.7 to 60.8μS/cm), temperature ranges from (23 to 29^{0}C), TDS ranges from (22.4 to 31.6 mg L^{-1}), magnesium ranges from (1.2 to 3.5 mg L^{-1}/0.09 - 0.21meq/L), sulphate ranges from (2.1 to 12.2 mg L^{-1}/ 0.04 to 0.25 meq/L), chloride ranges from (1.4 to 17.6 mg L^{-1}/ 0.03 to 0.49 meq/L) potassium ranges from (0.9 to 2.6 mg L^{-1}/0.02 to 0.06 meq/L), sodium ranges from (0.3 to 4.3 mg L^{-1}/ 0.01 to 0.18 meq/L), bicarbonate ranges from (30.8 to 66.7 mg L^{-1}/ 0.5 to 1.09 meq/L), calcium ranges from (4.2 to 12.6 mg L^{-1}/ 0.34 to 0.62 meq/L) and nitrate ranges from (0.0 to 26.0 mg L^{-1} / 0 to 0.41 meq/L). Calculated indices such a SAR, MAR, PI, TH, RSBC, Kelly ratio SSP and CAI indicate that majority of the water are suitable for irrigation. All the sampled values of Na% are excellent for irrigation purpose except for OJI/02 and OJI/06. The water qualities satisfy the condition for use in irrigation. From the Piper an Schoeller diagrams it reveals that OJI/01 is of Ca-HCO$_3$-NO$_3$ water type, OJI/02 - 07 are of Ca- HCO$_3$-Cl water type, OJI/08 is of Mg- HCO$_3$-Cl-SO$_4$ water type, while OJI/09 and OJI/10 are of Ca-Mg- HCO$_3$-Cl with HCO$_3$ as the dominat ionic specie found in all the water samples.

INTRODUCTION

Oil production in Nigeria has been a major engine driving the economy of the country, but since the pass one and a half year the price of crude oil has drastically drop in global market and this has lead to economic recession in Nigeria. Both the executive and legislative arm of government has been drumming support for diversification of the nation economy to agriculture. And for this to happen all hand must be on desk to rebuild the economy. Government herself must be serious to introduce mechanized farming and irrigation close to farm settlements so as to provide water all year round for the crop as water is the most important input required for plant growth. Water of good quality has the potential to allow high yield of crops under good soil and water management conditions. Globally chemical contaminants are present in water which could possibly threaten the use of water for domestic and other uses (Eyankware, *et al*., 2015). Waste from anthropogenic activities (Leachate) also has varying degrees of pollution on water resources (Eyankware, *et al*., 2015; Moses, *et al*., 2016). Hence, the need to access the hydrogeochemical quality of water resources from available surface water for irrigation purpose. It is also necessary to increase awareness of the fact that clean

environment is necessary for smooth living and also keep water resources free from pollution (Eyankware, *et al*., 2016). Irrigated agriculture dependent on an adequate water supply of usable quality. In irrigation water evaluation, emphases are placed on the chemical and physical characteristics of the water and only rarely are any other factors considered important (Dhirendra, *et al*., 2009). The irrigation water is paramount in assessment of irrigation schemes and especially in the saline or alkaline conditions in irrigated areas. Water quality could have a profound impact on crop production; low quality water for irrigation can impose a major environmental constraint to crop productivity. All irrigation water contains dissolved mineral salts, but the concentration and composition of the dissolved salts vary depending on the water source (Stephen, 2002).

Although study and research over the last few years have led to understanding the degrading of water quality and thus has brought to forefront the consequences within Oji and its environs (Egboka, 1985; Eyankware, *et al*., 2014; Eyankware, *et al*., 2015). But assessment of water quality for irrigation purpose has not carried out within the study area. This paper is gear towards providing a meaningful guide to quality of water that can be used for irrigation purpose.

Location, Accessibility and Climate

The study area is located in Oji River Local Government Area of Enugu state, Nigeria a semi urban area. The area has a landmass of approximately 403 km² and a population of 126,587 at the 2006 census. The area is made up of village namely: Ojinator, Ugwuoba, Achi, Egbagu, Upkata and Agbalengi. Geographically it is located in latitude 6^014^lN-6^020^lN and longitude 7^017^lE-7^021^lE. The total annual rainfall ranges from 1600m to more than 2000m, the inversion in the tropical air mass causes convectional rainfall. The area falls within the tropical rainforest belt of Nigeria with temperature ranges from 28^0C to 32^0C.

The scarp slope is gullied more intensely than the dip slope. Two main seasons exist in Nigeria: the dry season (October to March) and the rainy season (March to October). The Saharan air mass causes the dry season as it advances southwards while the Atlantic Ocean air mass causes the rainy season as it moves northwards. The average annual rainfall for Enugu is about 2000 mm. It occurs as conventional rain that alternates in quick succession between short sunny and rainy conditions. The area is ravaged by soil and gully erosion on both sides of the escarpment (Egboka, *et al*., 1984; Egboka, *et al*., 1985; Floyd, 1965; Ofomata, 1965; Ogbukagu, 1976). The rainfall occurs often as violent downpours. This may be accompanied by thunderstorms, heavy flooding, soil leaching, erosion, gullying, and groundwater recharge. The urbanized nature of Enugu area encourages intense runoff and environmental pollution. Around coal mines, waste dumps provide leachates that are pollutants.

Geology and Hydrogeology of the Study Area

The failed arm of the triple radial rift system involving the separation of the South African and African Continents gave birth to the southern section of NE/SW aulacogen (Oladele, 1975). Stages of sedimentations in the trough were in three cycles; the Pre-Cenomanian deposit of Asu River Group followed by the Cenomanian-Santonian sedimentation. According to Hogue (1977) the inversion tectonics of the Abakaliki anticlinoria which lead to the evolution of both Afikpo Syncline and Anambra basin, represented the third cycle of sedimentation which produced the incipient Nkporo shale, Enugu shale and Owelli sandstone. The Nkporo group is overlain conformably by the Coal Group consisting of the Mamu, Ajali and Nsukka Formations that forms the terminal units of the Cretaceous series (Fig. 1 & Table 1). By sequence, Ajali Formation which is about 330m thick is underlain by Mamu and Nkporo Formations that are 400 and 200 m thick, respectively. The Ajali Formation is typically characterized by

white coloured sandstone (Reyment, 1965) while the Mamu Formation is essentially composed of sandy shale and some coal seams whereas; the Nkporo Formation consists mainly of grey - blue mudstone and shale with lenses of sandstone (Obaje, 2009). According to Reyment (1965), the prevailing unit of Ajali Formation consists of thick, friable, poorly sorted sandstone.

The major water body in the area is the perennial, well-aerated and fast-flowing Oji River, a tributary of the Anambra River, which itself is a major tributary of the lower Niger River. Many rivers and streams traversing the Udi Hill escarpments flow into Oji River with tributaries Nwangele Stream, Agu Spring.
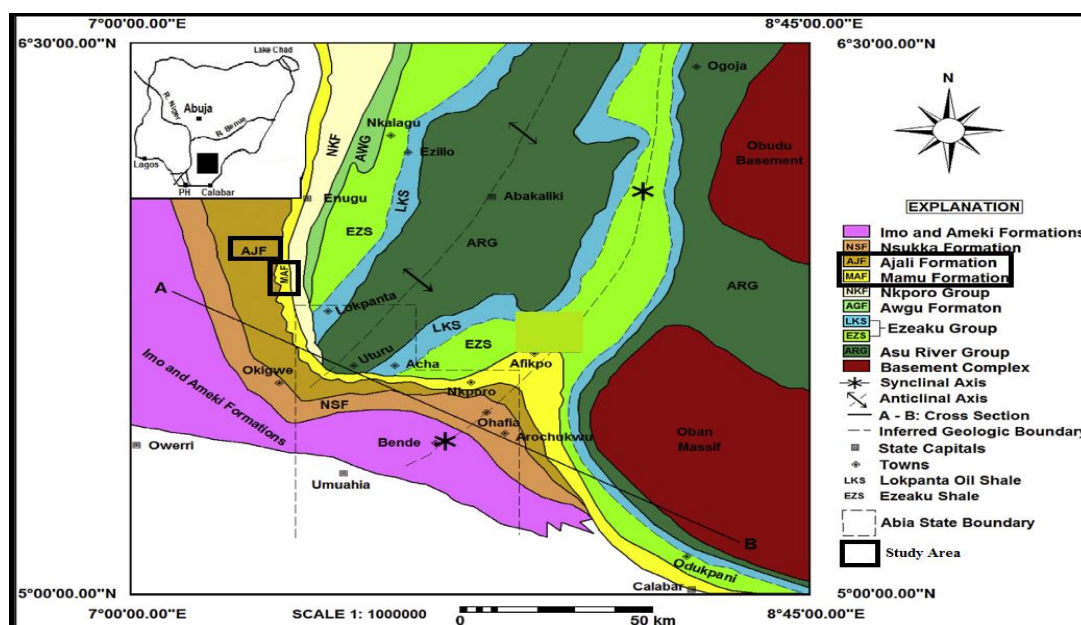

Figure 1: Regional Geological Map of the Southern Benue Trough. Source: (Modified after Okoro, *et al*., 2016).

Table 1: Correlation Chart for Early Cretaceous Tertiary Strata in the Southeastern Nigeria (After Nwajide, 1990)

Age		Abakaliki – Anambra Basin	Afikpo Basin
M.Y 30	Oligocene	Ogwashi- Asaba Formation	Ogwashi- Asaba Formation
54.9	Eocene	Ameki/Nanka Formation, Nsgube Sandstone (Ameki Group)	Ameki Formation
5.5	Paleocene	Imo Formation Nsukka Formation	Imo Formation Nsukka Formation
75	Maastrichian	Ajali Formation Mamu Formation	Ajali Formation Mamu Formation
83 – 87.5	Campanian	Nkporo, Owelli/ Enugu Shale	Nkporo Shale/ Afikpo Sandstone
	Santonian	Agbani Sandstone /Agwu Shae	Non Deposition erosion
88.5	Coriacian		Eze- Aku Group
	Turonian	Eze- Aku Group	(Incl. Amasiri Sandstone)
93 –100	Cenomanian-Albian	Asu River Group	Asu River Group

METHODOLOGY

Table 2: Method of Analysis for Physical and Chemical Parameters.

Parameters	Standard Test Method	Description of Method
Turbidity (NTU)	APHA 214A	Turbidity Meter
$_p$H	ASTM D1293	$_p$H Meter
Temp(^{0}C)		Thermometers
EC (μS/cm)	APHA 145	Conductivity Meter
(TDS) (mg L^{-1})	APHA 2080	TDS Meter
Sodium(mg L^{-1})	ASTM D93 – 77	ASS
Potassium(mg L^{-1})	ASTM D93 – 77	ASS
Magnesium(mg L^{-1})	ASTM DS 11	ASS
Chloride(mg L^{-1})	Titration	Titration
Bicarbonate(mg L^{-1})	Titration	Titration
Calcium(mg L^{-1})	ASTM 93 -77	ASS
Nitrate(mg L^{-1})	APHA 419C	Diazotization
Sulphate(mg L^{-1})	APHA 427C	Colorimetric

A total of ten water samples were collected from different rivers traversing different communities (Table 10).

Statistical analyses

The results from laboratory were subjected to relevant descriptive statistical analyses to establish relationship and variation using (SPSS software).

RESULTS AND DISCUSSION

Physical Parameters

Turbidity

The value of turbidity ranges from 0.5 to 2.9 NTU with mean value of 1.33 NTU (Table. 4 & 5).

$_pH$

The value of $_pH$ ranges from 6.0 to 6.9 with mean value of 6.28 (Table. 4 & 5). The pH values for ten sampling points of the irrigation scheme is in normal to neutral range (pH = 6.5 - 8.5) and below (FAO, 1985) limit. Water suitable for irrigation must have pH range of 6.5-8.4 (Bauder, *et al*., 2010).

Temperature (^0C)

The value ranges from 34.7 to 60.2^{0}C with mean value 25.2^{0}C (Table. 4 & 5).

Electrical Conductivity (μS/cm)

Electrical conductivity ranges from 34.7 to 60.2 μS/cm with mean value of 48.2 μS/cm (Table. 4 & 5) The most significant water quality guideline on crop productivity is the water salinity hazard as measured by electrical conductivity (Johnson, *et al*., 1990).

Total Dissolved Solid (TDS)

Total dissolved solid has a mean value of 1.58 with value ranging from 0.3 to 4.3 mg L^{-1}. Total Dissolved solid ranges from 22.4 to 31.6 mg L^{-1}(Table. 4 & 5). According to WHO, (1996) any TDS value less than 300 signify that the TDS concentration is classified as excellent as shown in Table 3. Total Dissolved solids (TDS) are index of the amount of dissolved substances in the water (McNeely *et al*; 1979). In natural water dissolved solids are composed of carbonates, bicarbonates, chlorides, sodium, sulphate magnesium and phosphate. Concentrations of dissolved solids are important parameter in drinking water.

Table 3: Showing Total Dissolved Solid (TDS) rating according to WHO, (1996)

Level of TDS (mg L^{-1})	Rating	Number of Sample	Remarks
Less than 300	Excellent	10	All samples >300
300 – 600	Good	10	NVWR
600 – 900	Fair	10	NVWR
900 – 1000	Poor	10	NVWR
Above 1000	Unacceptable	10	NVWR

Source: Taste of Water with Different TDS Concentrations;
www.who.int/water_sanitation_health/dwq/chemicals/tds.pd
NVWR: No Value within the Range.

Sodium (Na$^+$)

The value of Na$^+$ ranges 0.3 to 4.3 mg L^{-1} with mean value of 1.58 mg L^{-1}(Table. 4 & 5). Sodium ions are generally highly soluble in water and are leached from the terrestrial environment to groundwater and surface water. They are nonvolatile and will thus be found in the atmosphere only in association with particulate matter (WHO, 1996).

Potassium (K$^+$)

Potassium is an essential element for both plants and animals. The value of K$^+$ ranges 0.9 to 2.6 mg L^{-1} with mean value of 1.73 mg L^{-1}(Table. 4 & 5).

Chloride (Cl$^-$)

The value of Cl$^-$ ranges 1.4 to 17.6 mg L^{-1} with mean value of 11.86 mg L^{-1} (Table. 4 & 5).Chloride ions are generally present in natural waters and its presence can be attributed to dissolution of salts.

Calcium (Ca^{2+})

Calcium is a major constituent of most Igneous rock, metamorphic and sedimentary rocks. The principal sources of calcium in groundwater are some members

of the silicate minerals such as pyroxenes, amphiboles among igneous and metamorphic rocks, and limestone, dolomite and gypsum among sedimentary rocks (Ideriah, 2015). The value of calcium ranges from 4.4 to 12.6 mg L^{-1} with mean value of with mean value of 10.34 mg L^{-1} (Table. 4 & 5).

Magnesium (Mg^{2+})

Magnesium is the fourth most abundant cation in the body and the second most abundant cation in intracellular fluid. The value of magnesium ranges from 1.2 to 3.5 mg L^{-1} with mean value of 2.0 mg L^{-1} (Table. 4 & 5).

Bicarbonate (HCO_3^-)

HCO_3^- has mean value of 52.3 mg L^{-1} with value ranging from 30.8 to 57.7 mg L^{-1} (Table. 4 & 5). Bicarbonate combines with calcium carbonate and sulphate to form heat retarding, pipe clogging scale in boilers and in other heat exchange equipment. The source of bicarbonate irons in ground water is from the dissolution of carbonate rocks and from carbonate species present and the pH of the water is usually between 5 and 7 (Taylor, 1958).

Nitrate (NO_3-)

Nitrate is naturally occurring ions that are part of the nitrogen cycle. The nitrate ion (NO_3^-) is the stable form of combined nitrogen for oxygenated systems. Although chemically unreactive, it can be reduced by microbial action (WHO, 1996). Ranges from 0.0 to 26.0 mg L^{-1} with mean value of 2.97 mg L^{-1} (Table. 4 & 5). In soil, fertilizers containing inorganic nitrogen and wastes containing organic nitrogen are first decomposed to give ammonia, which is then oxidized to nitrite and nitrate. The nitrate is taken up by plants during their growth and used in the synthesis of organic nitrogenous compounds. Surplus nitrate readily moves with the groundwater (USEPA, 1987; Van, *et al*., 1989).

Sulphate (SO_4^{2-})

Sulphate is a naturally occurring substance that contains sulphur and oxygen. Sulphate value ranges from 2.1 to 12.2 mg L^{-1} with mean value of 3.30 mg L^{-1} (Table.4 & 5). Sulphate occurs in water as the inorganic sulphate salts as well as dissolved gas. Sulphate is not a noxious substance although high sulphate in water may have a laxative effect

IRRIGATION QUALITY PARAMETERS

Irrigated agriculture is dependent on an adequate water supply of usable quality. Just as every water is not suitable for human beings, in the same way, every water is not suitable for plant life. Water containing impurities, which are injurious to plant growth, is not satisfactory for irrigation, and called unsatisfactory water (Nata, *et al*., 2011).The quality characteristics studied in the present investigations were as follows: Electrical conductivity (EC) Soluble sodium percentage (SSP) Magnesium adsorption ratio (MAR), sodium percentage (Na%), Sodium adsorption ratio (SAR), Kelly ratio (KR), Pollution Index (PI) and Chloro alkaline Indices (CAI)

Sodium Percentage (SP)

Sodium percentage is an important criterion for defining the type of irrigation. It is another important factor to study sodium hazard. The value of Na% ranges from 1.65 to 27.27% with mean value of 11.39% (Fig.2 &Table. 8). All the sampled values of Na% are classified excellent for irrigation purpose except for OJI/02 and OJI/06 which classified good (Table 11). Na % was calculated by using (Doneen, 1964) formula:

$$\text{Na \%} = \frac{Na^+ \times 100}{Ca^{2+} + Mg^{2+}} \text{ .... (eqn 1)}$$

Where all ionic concentration is expressed in meq/L

The Wilcox, (1955) diagram relating sodium percentage and electrical conductivity shows that 100% of the groundwater samples fall within excellent to good OJI/01 to 10 (Fig.3). This implies that the water is fit for irrigation purpose.
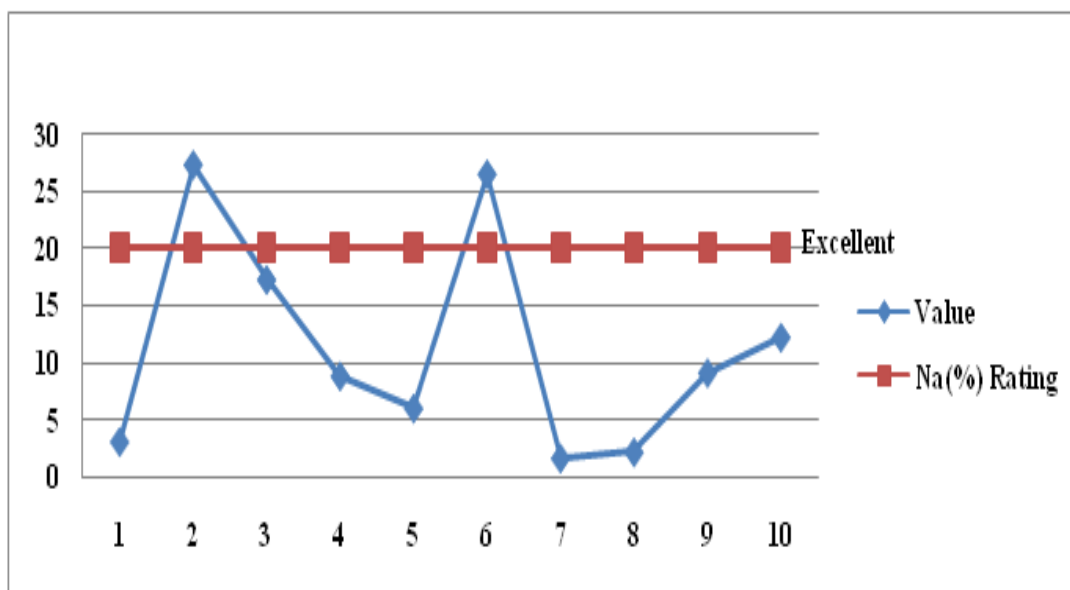
Figure 2: Value of SSP from OJI/01 to OJI/10 Compared to Na% Rating.
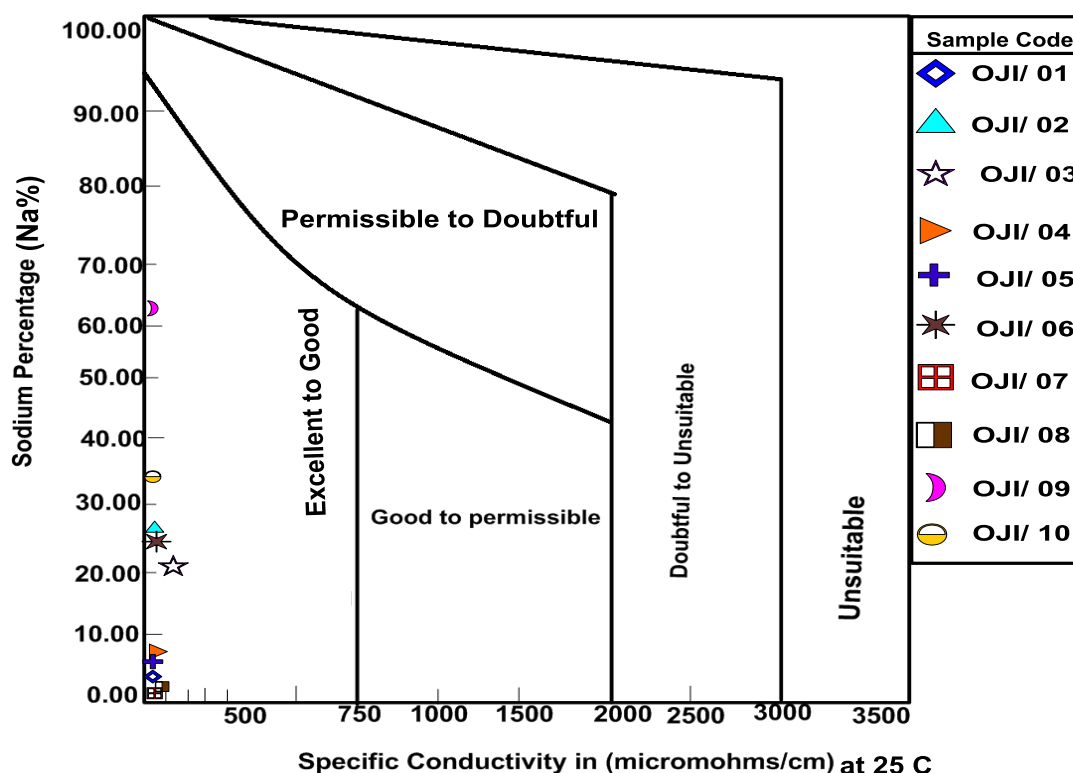

Figure 3: Rating of water samples on the basis of electrical conductivity and percent sodium (after Wilcox, 1955).

Soluble sodium percentage (SSP)

The values of SSP less than 50 indicates good quality of water and higher values shows that the unacceptable quality of water for irrigation (USDA, 1954). SSP value ranges from 1.66 to 17.24% with mean value of 7.39% (Fig. 4 &Table 8). The water samples are suitable for irrigation purpose because SSP value is less than 50 (Table 10). SSP calculated by using Todd, (1980).

$$SSP = \frac{Na^+ \times 100}{Ca^{2+} + Mg^{2+} Na^+} \text{............... (eqn 2)}$$

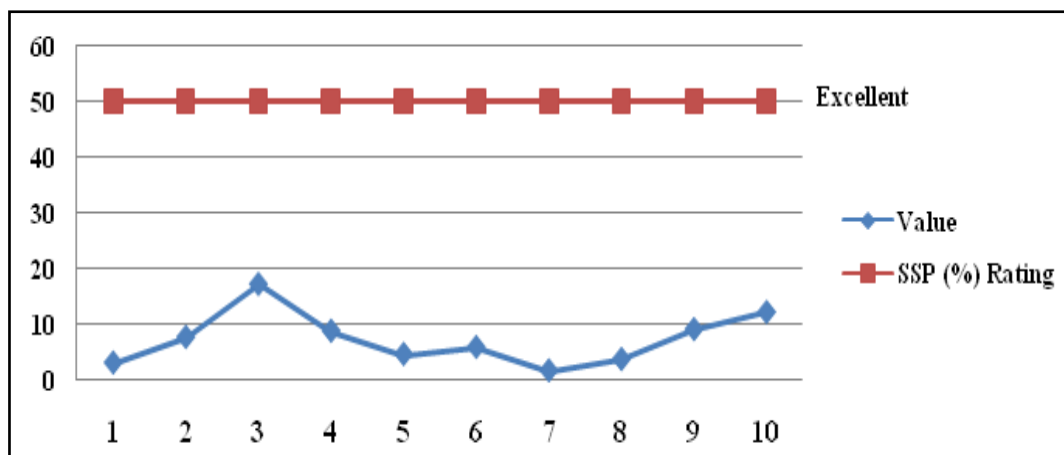Where all ionic concentration is expressed in meq/L

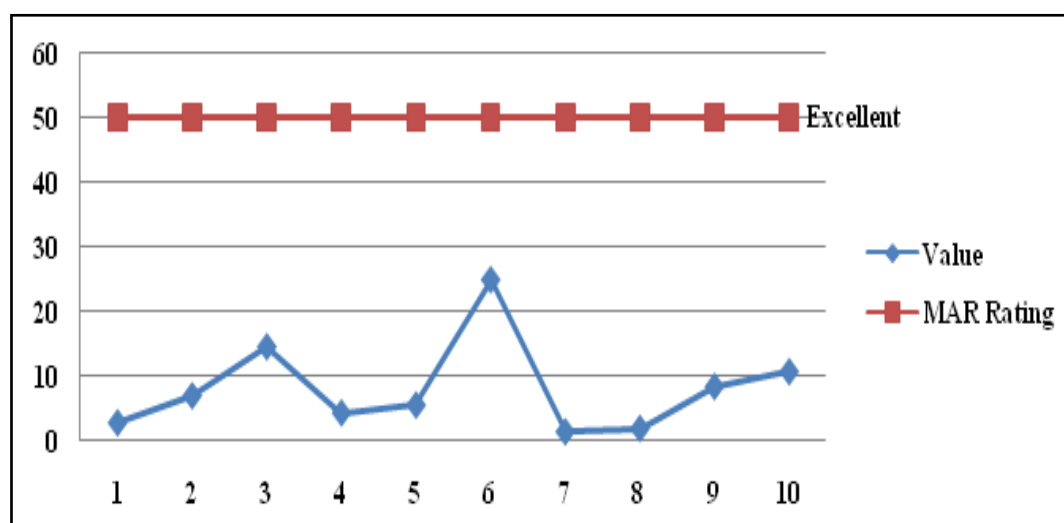**Figure 4: Value of SSP from OJI/01 to OJI/10 Compared to SSP Rating**

Figure 5: Value of MAR from OJI/01 to OJI/10 Compared to MAR Rating.

Magnesium Adsorption Ratio (MAR)

Generally, calcium and magnesium maintain a state of equilibrium in most waters. High magnesium in water will adversely affect crop yields as the soil becomes more saline (Joshi *et al*, 2009). The value of MAR ranges from 1.61 to 25.00 with mean value of 8.32. Based on the value of MAR the water is fit for irrigation purpose (Fig.5; Table 8 & 10). More magnesium in water will adversely affect crop yields as the soils become more alkaline. Value below 50 is considered the acceptable limit of MAR (Ayers & Westcot, 1994). The Magnesium Adsorption Ratio was calculated using the following equation (Raghunath, 1987):

$$MAR = \frac{Mg^{2+} \times 100}{Mg^{2+} + Ca^{2+}} \text{ .... (eqn 3)}$$

Where all ionic concentration is expressed in meq/L

Permeability Index (P.I.)

Doneen, (1964) evolved a criterion for assessing the suitability of water for irrigation based on the permeability index. The value of PI ranges from 0.3 to 0.54 with mean value of 0.54 (Fig.6 & Table 8). Based on value range of PI the water is fit for irrigation purpose (Table 7&10). PI was calculated based on Domenico, *et al*., (1990).

$$PI = \frac{Na^+ + \sqrt{HCO_3^-}}{Ca^{2+} + Mg^{2+} + Na^+} \text{ .... (eqn 4).}$$

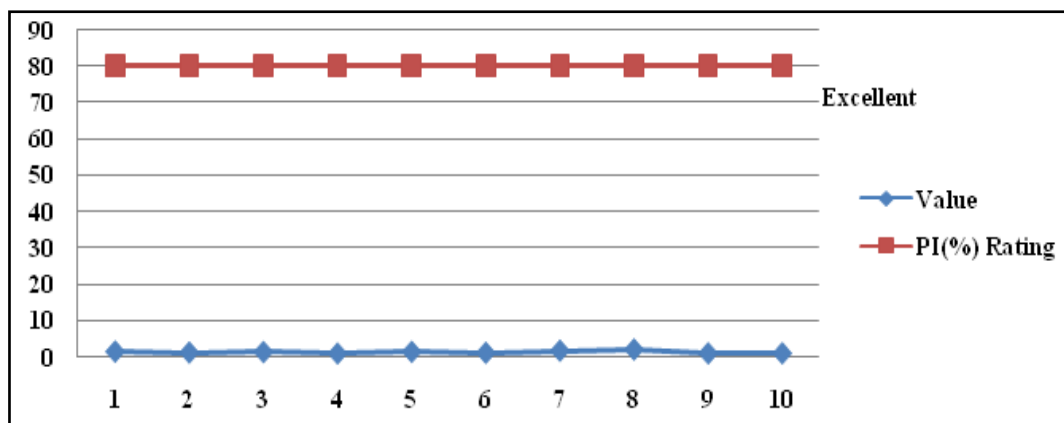Where all ionic concentration is expressed in meq/L

Figure 6: Value of MAR from OJI/01 to OJI/10 Compared to PI% Rating.
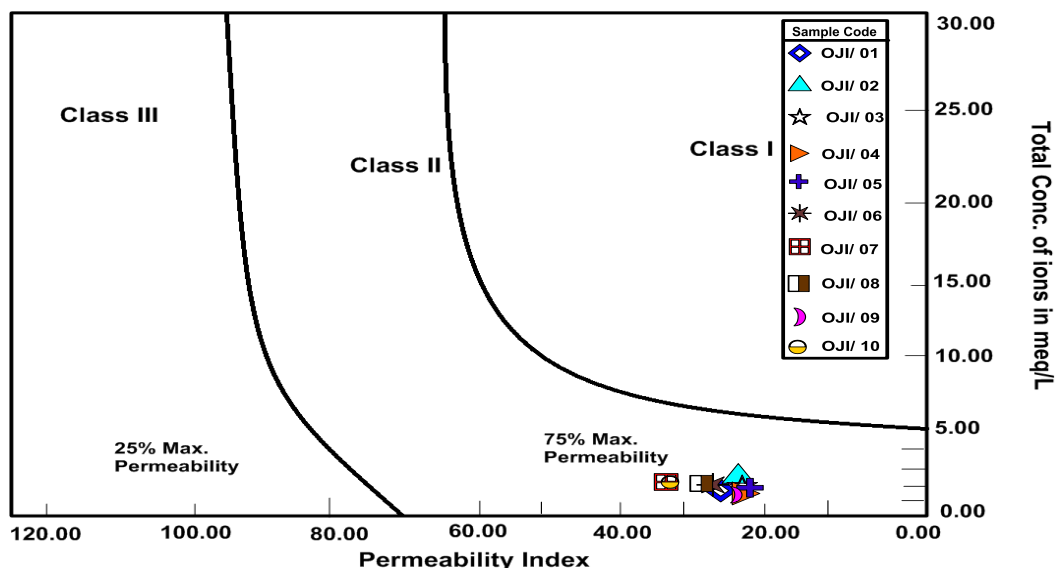

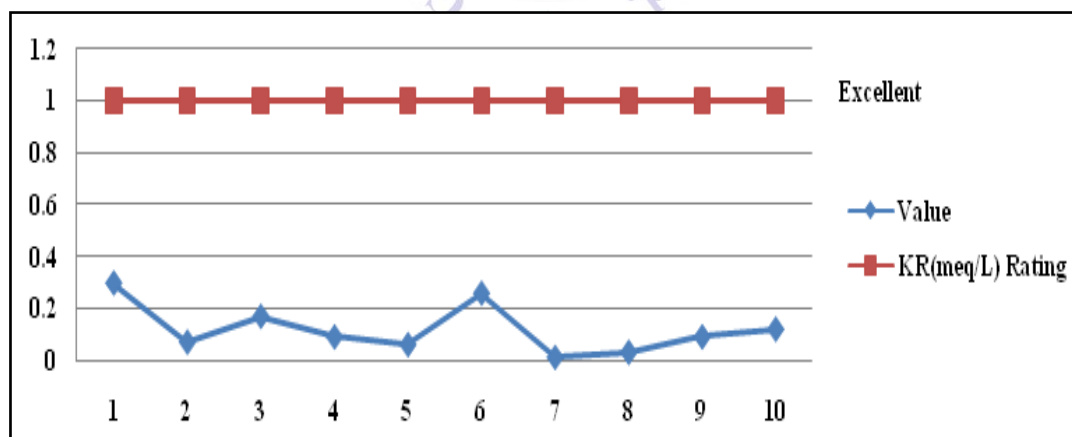**Figure 6b: Doneen's, (1964) Chart for P.I. values of Water Sources.**

Figure 7: Value of MAR from OJI/01 to OJI/10 Compared to PI% Rating.

Kelly Ratio (KR)

Kelley's Ratio of more than one (1meq/l) indicates an excess level of sodium in waters. Hence, waters with a Kelley's Ratio less than one are suitable for irrigation (Aher and Deshpande, 2011). The value of KR ranges from to 0.01 with 0.30 mean value of 0.12. Based on the value the water is suitable for irrigation purpose (Fig.7; Table 8 & 10). This was calculated employing the equation (Kelly, 1963) as:

$$KR = \frac{Na^+}{Ca^{2+} + Mg^{2+}} .... (eqn 5).$$

Where all ionic concentration is expressed in meq/L

Sodium Adsorption Ratio (SAR)

SAR is an easily measured property that gives information on the comparative concentrations of Na^+, Ca^{2+}, and Mg^{2+} in the water samples (Talabi, *et al.*, 2014). SAR takes into consideration the fact that the adverse effect of sodium is moderated by the presence of calcium and magnesium ions. When the SAR rises above 12 to 15, serious physical soil problems arise and plants have difficulty absorbing water (Munshower, 1994, Brady, 2002). The value of SAR ranges from 0.05 to 0.23 with mean value of 0.65 (Fig. 8 & Table 8) Based on this the value of SAR. The water

is fit for irrigation purpose. This was calculated employing the equation (Raghunath, 1987) as:

$$SAR = \frac{Na+}{\sqrt{\frac{(Ca2+ + Mg2+)}{2}}} \ldots\ldots\ldots (eqn\ 6).$$

Where all ionic concentration are expressed in meq/L.

From the US Salinity diagram OJI/01 to OJI/10 are classified as S1 for SAR and C1 for electrical conductivity. This implies that the water is excellently suitable for irrigation based on CGWB and CPCB (2000) Guidelines for evaluation of irrigation water quality.(Fig.9 and Table 10)
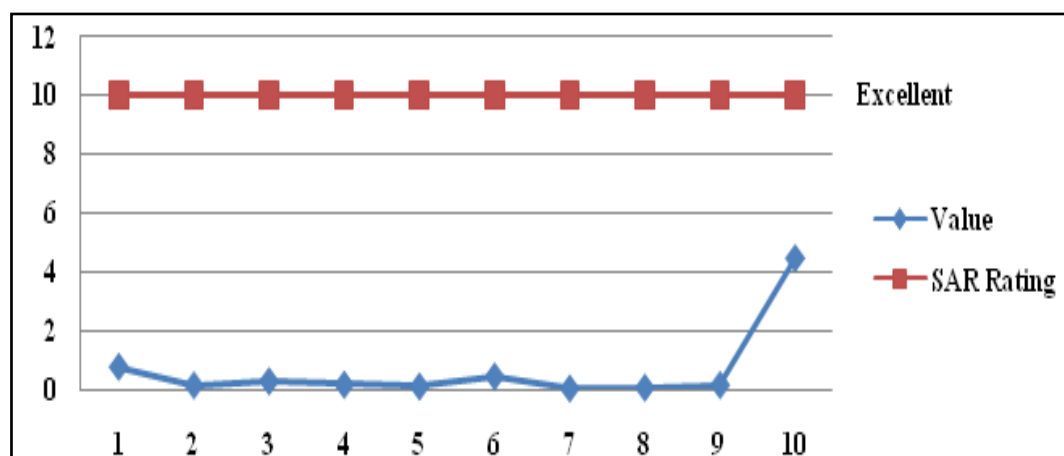
Figure 8: Value of MAR from OJI/01 to OJI/10 Compared to SAR(%) Rating.
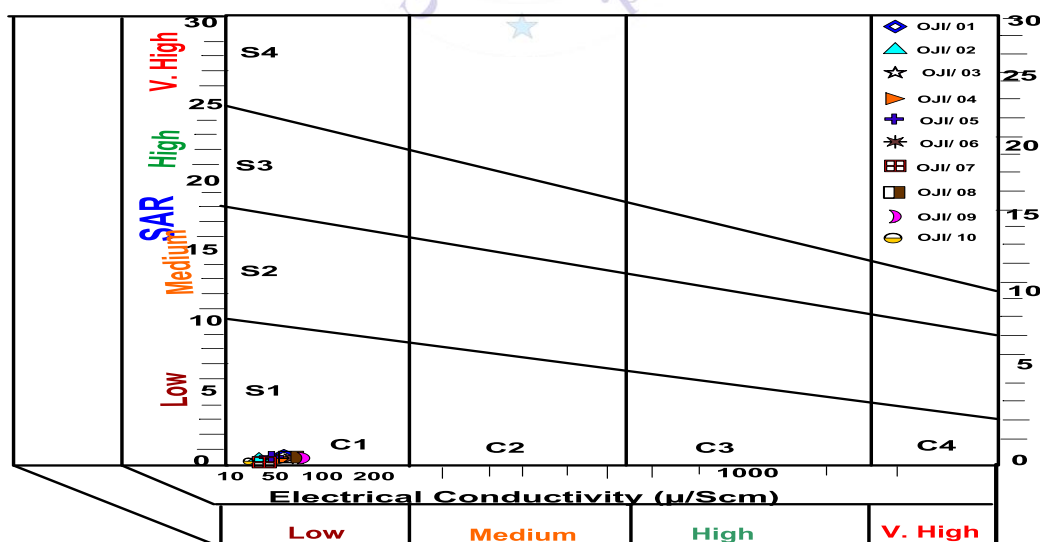
Figure.9: Classification of water based on US salinity diagram.

Where C1 = Excellent, C2 = Good, C3 =Doubtful, C4 = Unsuitable, S1 = Excellent, S2 = Good, S3 =Doubtful, S4 = Unsuitable.

Total Hardness (TH)

TH value ranges from 5.00 to 41.00 with mean value of 30.82 (Table. 8). Hence the water can be classified as soft water

based on Sawyer, *et al.*, (1967) see Table. 9. TH was calculated by the following equation (Raghunath, 1987):

$$TH = (Ca^{2+} + Mg^{2+}) \times 50 \ldots\ldots\ldots (eqn\ 7).$$

Where all ionic concentration is expressed in meq/L

Residual Sodium Bi-carbonate (RSBC)

Residual sodium bicarbonate (RSBC) exists in irrigation water when the bicarbonate (HCO_3^-) content exceeds the calcium (Ca^{2+}) 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 (i) Direct toxicity to crops, (ii) Excess soil salinity (EC) and associated poor plant performance, and (iii) Where appreciable clay or silt is present in the soil, loss of soil structure occur through clogging of pore spaces thereby hindering air andwater movement (SAI, 2010; Naseem, *et al*., 2010). The value of RSBC ranges 0.05 to 0.87 with mean 0.38 (Table. 8) indicating good quality for irrigation purpose. RSBC was calculated according to proposed formula by Gupta and Gupta (1987):

$$RSBC = HCO_3^- - Ca^{2+} \qquad \text{(eqn 8).}$$

Where all ionic concentration is expressed in meq/L

Chloro alkaline Indices (CAI)

The CAI is essential to know the changes in chemical composition of groundwater during its travel in the sub-surface. The Chloro-alkaline indices CAI suggested by Schoeller, (1977) which indicate the ion exchange between the groundwater and its host environment. CAI value ranges from -0.66 to 0.91 with mean value of 0.48 (Table 8). If CAI is negative, there will be an exchange between Na + K with calcium and magnesium (Ca + Mg) in rocks. If the ratio is positive (OJI/02, 03, 04, 06, 07, 08, 09 and 10) there is no base change in CAI see Table 8. The positive value indicates the absence of Base Exchange. The negative value of the ratio (OJI/01 and 05) indicates Base Exchange between sodium and potassium in water with calcium and magnesium in the samples (Jafar, *et al*., 2013).

The Chloroalkaline indices used in the evaluation of Base Exchange are calculated using the below equations.

$$CAI = \frac{[Cl(Nn^+ + K^+)]}{Cl^-} \qquad \text{............ (eqn 9)}$$

Where all ionic concentration is expressed in meq/L

Table 4: Result of analyzed Physical and Chemical Parameters

Parameters	OJI/01	OJI/02	OJI/03	OJI/04	OJI/05	OJI/06	OJI/07	OJI/08	OJI/09	OJI/10
Turbidity (NTU)	2.0	0.9	0.8	0.7	0.8	0.9	0.5	1.5	2.3	2.9
$_pH$	6	6	6.4	6.5	6.5	6.3	6.9	6.0	6.2	6.0
EC (µS/cm)	56.0	43.8	50.2	43.8	46.5	52.5	49.1	52.4	60.2	34.7
(TDS) (mg L^{-1})	28.0	26.9	25.1	24.2	23.3	28.3	31.6	28.2	22.4	31.5
Na^{2+}(mg L^{-1})	0.5	1.6	2.4	1.5	0.9	4.3	0.3	0.4	1.5	2.4
K^+(mg L^{-1})	1.3	1.6	1.9	2.6	1.9	1.7	2.1	1.4	1.9	0.9
Mg^{2+} (mg L^{-1})	1.2	2.0	2.0	1.6	1.5	1.3	1.3	3.2	2.4	3.5
Cl^- (mg L^{-1})	1.4	8.6	8.5	12.5	10.8	14.3	13.7	14.6	17.6	16.6
HCO_3^- (mg L^{-1})	62.0	62.5	44.0	30.8	60.0	60.0	56.4	66.7	32.4	48.3
Ca^{2+} (mg L^{-1})	11.3	12.6	9.6	11.2	10.8	11.7	10.1	4.2	9.6	12.3
NO_3- (mg L^{-1})	26.0	0.0	0.0	0.0	0.4	1.8	0.9	0.6	0.0	0.0
SO_4^{2-} (mg L^{-1})	2.4	2.5	2.4	2.1	2.2	2.7	2.4	12.2	2.1	2.5

All concentrations are in mg L^{-1}.

Table 5: Summary of Statistics of Analyzed Physical and Chemical Parameters.

Parameters	Minimum	Maximum	Mean	Range	Standard Deviation
Turbidity (NTU)	0.5	2.9	1.33	2.4	0.25
$_pH$	6.0	6.9	6.28	0.9	0.30
EC (µS/cm)	34.7	60.2	48.2	25.5	7.1
(TDS) (mg L^{-1})	22.4	31.6	26.9	9.2	3.1
Na^{2+}(mg L^{-1})	0.3	4.3	1.58	4.0	1.2
K^+(mg L^{-1})	0.9	2.6	1.73	1.7	0.4
Mg^{2+} (mg L^{-1})	1.2	3.5	2.0	2.3	0.8
Cl^- (mg L^{-1})	1.4	17.6	11.86	16.2	4.7
HCO_3^- (mg L^{-1})	30.8	66.7	52.3	35.9	12.8
Ca^{2+} (mg L^{-1})	4.2	12.6	10.34	8.4	2.3
NO_3- (mg L^{-1})	0.0	26.0	2.97	26	8.1
SO_4^{2-} (mg L^{-1})	2.1	12.2	3.3	10.1	3.1

All concentrations are in mg L^{-1}.

Table 6: Result of Chemical Parameters

Parameters	OJI/01	OJI/02	OJI/03	OJI/04	OJI/05	OJI/06	OJI/07	OJI/08	OJI/09	OJI/10
Na^{2+} (meq/L)	0.02	0.06	0.10	0.06	0.03	0.18	0.01	0.01	0.06	0.10
K^+ (meq/L)	0.03	0.04	0.04	0.06	0.04	0.04	0.05	0.03	0.04	0.02
Mg^{2+} (meq/L)	0.09	0.16	0.16	0.13	0.12	0.16	0.10	0.15	0.19	0.21
Cl^- (meq/L)	0.03	0.24	0.23	0.35	0.30	0.40	0.38	0.41	0.49	0.46
HCO_3^- (meq/L)	1.01	1.02	0.74	0.50	0.98	0.98	0.92	1.09	0.53	0.79
Ca^{2+} (meq/L)	0.56	0.62	0.42	0.55	0.53	0.58	0.50	0.34	0.47	0.61
NO_3^- (meq/L)	0.41	0.0	0.0	0.0	0.00	0.02	0.01	0.00	0.0	0.0
SO_4^{2-} (meq/L)	0.04	0.05	0.04	0.04	0.04	0.05	0.04	0.25	0.04	0.05

All concentrations are in meq/L.

Table 7: Summary of Statistics of Analyzed Chemical Parameters

Parameters	Minimum	Maximum	Mean	Standard Deviation
Na^{2+} (meq/L)	0.01	0.18	0.06	0.05
K^+ (meq/L)	0.02	0.06	0.03	0.01
Mg^{2+} (meq/L)	0.09	0.21	0.14	0.03
Cl^- (meq/L)	0.03	0.49	0.32	0.13
HCO_3^- (meq/L)	0.5	1.09	0.85	0.20
Ca^{2+} (meq/L)	0.34	0.62	0.51	0.08
NO_3^- (meq/L)	0	0.41	0.04	0.12
SO_4^{2-} (meq/L)	0.04	0.25	0.06	0.06

All concentrations are in meq/L.

Table 8: Analytical results of irrigation water quality parameter

SAMPLE NO	SPP	MAR	KR	SAR	PI	Na%	TH	RSBC	CAI
OJI/01	3.07	2.98	0.30	0.76	1.52	3.07	32.50	0.45	-0.66
OJI/02	7.69	7.14	0.07	0.13	1.26	27.27	39.00	0.40	0.91
OJI/03	17.24	14.70	0.17	0.27	1.41	17.24	29.00	0.32	0.39
OJI/04	8.82	4.51	0.09	0.15	1.02	8.82	34.00	0.05	0.65
OJI/05	4.61	5.73	0.06	0.09	1.48	6.0	32.50	0.45	-0.13
OJI/06	5.88	25.00	0.26	0.43	1.22	26.47	37.70	0.40	0.45
OJI/07	1.66	1.61	0.01	0.025	1.77	1.63	5.00	0.87	0.84
OJI/08	3.69	2.12	0.03	0.05	2.10	2.17	24.50	0.75	0.90
OJI/09	9.09	8.57	0.09	0.14	1.08	9.09	33.00	0.06	0.79
OJI/10	12.19	10.86	0.12	4.44	1.06	12.19	41.00	0.18	0.73
Minimum	1.66	1.61	0.01	0.02	1.02	1.65	5.00	0.05	-0.66
Maximum	17.24	25.00	0.3	4.44	2.10	27.27	41.00	0.87	0.91
Mean	7.39	8.32	0.12	0.64	1.39	11.39	30.82	0.39	0.48
STDEV	4.71	7.14	0.09	1.35	0.34	9.45	10.26	0.26	0.51

Where: SSP = Soluble sodium percentage, MAR= Magnesium content, KR= Kelly Ratio, Na% = Percentage of sodium, SAR = Sodium absorption ratio, PI = Permeability Index, TH = Total hardness, RSBC = Residual Sodium Bi-carbonate, CAI = Chloro alkaline Indices and STDEV = Standard Deviation. (All concentrations are in meq/L).

Table 9: A range of water Total hardness (Sawyer, C.N. and McCarthy, P.L. 1967)

Index Range	Description	Percentage
<60	Soft	100%
60 - 120	Moderately Hard	
120 – 180	Very Hard	

Table 10: Water Sample Collection Site

Name of Location	Sample Code
Oji River Section I	OJI/01
Nwangele Stream	OJI/02
Ogba Spring	OJI/03
Ago Spring	OJI/04
Izele Stream	OJI/05
Ozom Stream	OJI/06
Oji River Section II	OJI/07
Ugwuoba	OJI/08
Oji River Section II	OJI/09
Oji River Section III	0JI/10

Hydrogeochemistry
Piper Trilinear Diagram

One of the most useful graphs for representing and comparing water quality analyses is the trilinear diagram by Piper shown in Fig.10

From the Piper an Schoeller diagrams (Fig. 10 & 11) it reveals that OJI/O1 is of Ca-HCO$_3$-NO$_3$ water type, OJI/02 - 07 are of Ca- HCO$_3$-Cl water type, OJI/08 is of Mg- HCO$_3$-Cl-SO$_4$ water type, while OJI/09 and OJI/10 are of Ca-Mg-HCO$_3$-Cl with HCO$_3$ as the dominat ionic specie found in all the water samples.
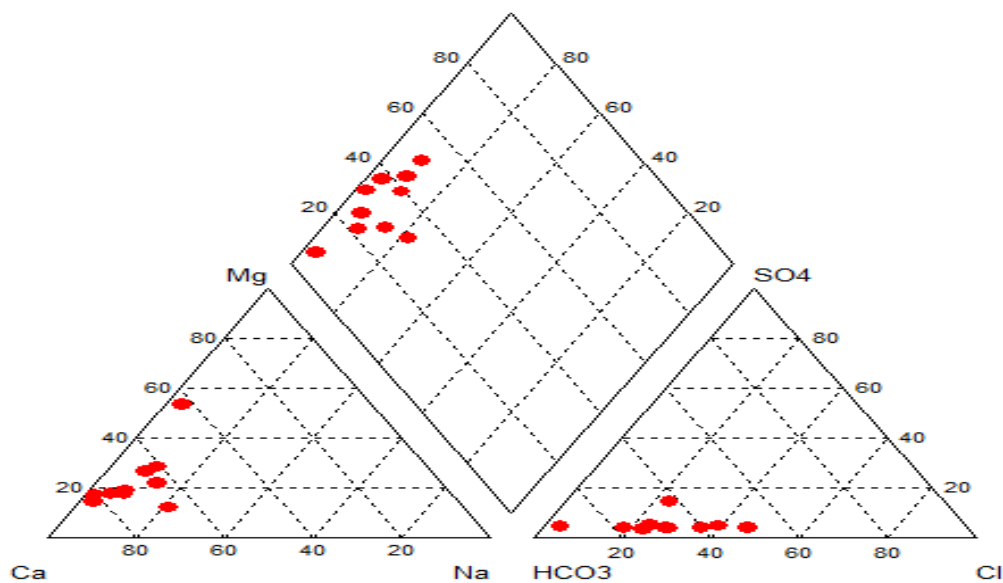
Figure 10: Piper Trilinear diagram for water characterization of the study Area.
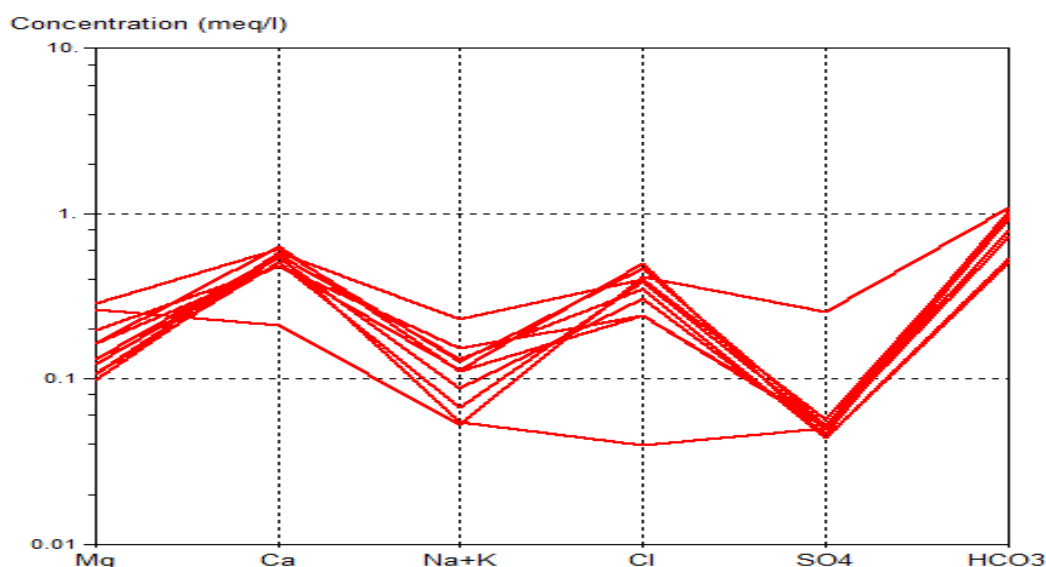

Figure 11: Schoeller semi logarithmic diagram showing the hydrogeochemical attribute.

Table 11: Guidelines for evaluation of irrigation water quality. Source: Modified after CGWB and CPCB (2000).

Water Class	Na%	SAR	MAR	PI	SSP	KR	EC (µS/cm)
Excellent	<20	<10	<50	<80	50	<1.0	<250
Good	20-40	10-18	<50				250-750
Medium	40-60	18-26		80-100			750-2250
Bad	60-80	>26	>50	100-120			2250-4000
Very Bad	>80	>26	>50			>1.0	>4000

CONCLUSION

The suitability of water in study area was investigated for irrigation and other usability status. Calculated indices such as SAR, Kelly ratio, PI, SSP, RSBC, TH, CAI and MAR was employed to determine its suitability status for irrigation and other agricultural purposes. All the sampled values of Na% are excellent for irrigation purpose except for OJI/02 and OJI/06. From the analysis the water samples satisfy the required quality needed for irrigation and other agricultural uses. From the Piper an Schoeller diagrams (Fig. 10 & 11) it reveals that OJI/O1 is of Ca-HCO$_3$-NO$_3$ water type, OJI/02 - 07 are of Ca- HCO$_3$-Cl

water type, OJI/08 is of Mg- HCO_3-Cl-SO_4 water type, while OJI/09 and OJI/10 are of Ca-Mg- HCO_3-Cl with HCO_3 as the dominat ionic specie found in all the water samples.

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