Hydrochemical Appraisal of Groundwater for Irrigation Purpose: A Case Study of Ekaeru Inyimagu and its Adjoining Area, Ebonyi State, Nigeria

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Abstract: The research is gear towards accessing the suitability of groundwater for irrigation purpose. A total of six groundwater sample were collected source for within Abakaliki to determine their physical and chemical parameters. These parameters were analyzed using APHA 1995. Parameters tested for include: pH, Electrical conductivity, Total Dissolved Solid, Magnesium, Calcium, Potassium, Sodium, chloride and Bicarbonate. The dominat ionic species in the study area is Cl from the Piper plot. The important constituents that influence the water quality for irrigation such as Electrical Conductivity (EC), Total Dissolved Solids (TDS), Total Hardness (TH) Sodium Adsorption Ratio (SAR), Magnesium Adsorption Ratio (MAR), Permeability Index (PI), Kellys Ratio (KR), Residual Sodium Bicarbonate (RSBC), Sodium Percentage (Na%) and Soluble Sodium Percentage (SSP) were assessed and compared with standard limits. The value of Electrical conductivity ranges from (126.24 to 752.43 µ/Scm), Total Dissolved Solid (90.32 to 855.27 mg L\(^{-1}\)), Total Hardness (41.00 to 95.00mg/L\(^{-1}\)) Sodium Adsorption Ratio (0.28 to 0.78), Magnesium Adsorption Ratio (11.7 to 536.8%), permeability Index (0.40 to 1.00%), Kelly Ratio (0.14 to 0.39meq/L), Residual Sodium Bicarbonate (-1.43 to 0.6 meq/L), Sodium percentage (14.00 to 39.02%), Soluble Sodium Percentage (0.28 to 0.78%). Based on the value of MAR sample EBY/01, EBY/02, EBY/03 is not fit for irrigation. While for sample EBY/04 and EBY/05 is considered suitable for irrigation. EBY/06 is considered fairly suitable for irrigation.

Keywords: Groundwater, Asu-River Group, Irrigation, Suitability, Abakaliki

INTRODUCTION

Subsistence agriculture has been a way of life, as 55% of inhabitants of the study area are known to be farmers. They are known for rice, potatoes, corn, cassava farming. One of the major challenges farmer encounter is in adequate water for better productivity. Unlike other parts of the world were irrigation has been a long old tradition in farming, Nigeria is yet to key in fully into irrigation agriculture. Although the state government is trying its best but all hand must be on desk for better productivity of farm produce, as it cannot be left for government alone. For better productivity of farm product water of good quality is required. Groundwater is the only source of water available all year round as most of the surface water dry up during the dry season (Ezeh, et al., 2016). Many factors like leachate from landfill sites, irrigation return flow and domestic and industrial wastes can change the groundwater quality (Moses, et al., 2016). The various land use practices, geology, rainfall patterns, climatological factors affect the groundwater use (Priya, et al., 2014). Groundwater has been on high demand for agricultural in other parts of globe India, Iran, Pakistan and Bangladesh (Reza, et al., 2013; Islam, et al., 2013; Sreenivasa, et al., 2015; Jain, et al., 2012) were
agriculture is the major engine that drives their economy. Availability of groundwater for irrigation has contributed to increase in crop productivity in Bangladesh (Islam, et al., 2013). But that is not case in Nigeria as most research on groundwater is geared towards its quality for drinking and domestic use. In past years research has been focused on quality of groundwater for domestic use within the study area (Ezeh, et al., 2016; Eyankware, et al., 2016a; Obasi, et al., 2015). The research is aimed at determining the quality of groundwater for irrigation. Although there are previous research on surface and groundwater quality of the study area. But research on assessment of water quality for irrigation is limited within south eastern Nigeria (Eyankware, et al., 2016b; Ekpe, et al., 2014). This paper is aim at assisting the state government and non-governmental organization in knowing the suitability of groundwater for irrigation purpose.

**DESCRIPTION OF STUDY AREA**

The study area is located within Abakaliki local government area, Ebonyi State in Southeastern Nigeria. Geographically, the area is located between latitude $6^\circ 15' \text{N} - 6^\circ 22' \text{N}$ and longitude $8^\circ 05' \text{E} - 8^\circ 10' \text{E}$. The area is accessible through network of roads like Nwagu, Agbaja, Obughha Amachi and Ekaeru Inyimagu. (Fig.1).

![Accessibility Map of Study Area Showing Sampled points.](image-url)
Geology of the study area

The study area is of the Lower Benue Trough. The Lower Benue Trough was described by Murat (1972) and Hoque (1977) using the concept of three tectonic sedimentary cycles. Three such cycles of marine transgressions and regressions occurred from the Albian to the Coniacian (Nwajide, 2013). The first marine transgression of the Benue Trough occurred in the middle Albian period, with the deposition of the Asu River Group in the Lower Benue Trough (Murat, 1972) see (Fig.2). Reyment, (1965) pointed out that Asu River Group sediments are predominantly shales, siltstone, sandstone and limestone facies as well as extrusives and intrusives. The Asu River Group has an average thickness of about 2000m and uncomfortably overlies the Precambrian Basement (Benkhelil, et al., 1989). The Santonian tectonic phase resulted in series of fracturing and folding of these rocks, giving rise to chains of anticlines and syncline known as the Abakaliki Anticlinorium (Reyment, 1965). The major fracture system which hosts the lead-zinc forming minerals is in NW- SE and NNW- SE (Farrington, 1952). Agumanu, (1989) further divided the Asu River Group sediment into Abakaliki and Ebonyi Formations. The Abakaliki Formation is predominantly dark grey colored shale (weathered to brownish material in the greater part of the formation), blocky, and indurated in most
locations, yet fissile in some locations. There are presences of intrusive rocks pyroclastic rock within the study area. They outcropped within Onu-ebonyi, Ogbaga, Juju Hill, Strabar quarry, Sharon mines and Azu-iyiokwu river.

**Hydrogeology**

Studies by Cocker (1995); Hook (2005); Pazand, et al., (2011) showed that hydrochemistry of surface and groundwater are principally controlled by the rocks and sediments through which these waters flow through. Background geochemistry is an important tool which can be applied to evaluate the hydrochemistry of water and plan the monitoring of water quality. Generally the movement and storage of groundwater within the area is controlled by three major factor namely; lithology, thickness and structure of rock formation (predominantly shales of the Asu River Group).

**METHODOLOGY**

**Sample Collection and Analysis**

Six water samples were collected from boreholes, hand-dug wells and surface water (Figure 1). These samples were labeled EBY/01- EBY/06 as shown in Table. 1. The water sample were analyzed for physical and chemical parameters. For quality assurance, 500ml polythene-free bottles were used for the collection. These bottles were washed with soap and rinsed thoroughly with distilled water. They were also vigorously rinsed at the sample collection point with water from the sources of collection. 2-3 drops of dilute hydrochloric acid was added to avoid metal oxidation and was subsequently caped and labeled. The water samples were persevered and immediately transported to the laboratory for analyzed within 48hours of collection. Physical parameters were determined in situ with measuring kits standard methods. pH of the water samples were measured by electrometric method using laboratory pH meter according to America Public Health Association (APHA) 2005 guideline, Model DDS-307. Mercury thermometer was used to determine the temperatures of the water samples, METRO HM644 conductivity meter was used to measure electrical conductivity, turbidity of the samples were measured using turbidity meter. Major ions (cations and anions) were determined using their various stand methods. Cation were analyzed using Fast sequential Atomic Absorption Spectrophotometer, Varian 240 AA was used. Anions were analyzed using Ultra Violet spectroscopy, PV 300 opel was used. Minor/trace ions were determined by titration. Heavy metal analysis was done using varian AA240 Absorption spectrophotometer (ASS) according to APHA (1995) guidelines.

**Statistical analyses**

Relevant statistical packages (SPSS Version 17, Microsoft Excel 2007 Statistical Tool Pack) was used to analyze the data obtained. Descriptive statistics were some of the analyses carried out in this study.
RESULT AND DISCUSSION

Hydrogeochemical Facies

The values obtained from the groundwater samples analysis, from Piper and Schoeller diagrams (Fig. 3 and 4) it reveals that sample EBY/01 is of Mg-Cl-HCO$_3$ water type, samples EBY/02 is of Cl-HCO$_3$, sample EBY/03 is of Mg-Ca-Cl water type, samples EBY/04, is of Ca-Na-Cl, sample EBY/05 is of Mg-Cl water type, while samples EBY/06 is of Ca-Cl. The dominant ionic species in the study area is Cl from the Piper plot.

Figure 3: Piper Trilinear diagram for water characterization of the study Area.
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) and Permeability Index (PI).

Magnesium Adsorption Ratio (MAR).

Magnesium content of water is considered as one of the most important qualitative criteria in determining quality of water for irrigation. 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 11.71 to 536.84 with mean value of 71.83. Based on the value of MAR sample EBY/01, EBY/02, EBY/03, EBY/03 is not fit for irrigation. While for sample EBY/04 and EBY/05 is considered suitable for irrigation. EBY/06 is considered fairly suitable for irrigation (Table 3). More magnesium in water will adversely affect crop yields as the soils become more alkaline. MAR less than the acceptable limit of 50 (Ayers &
Westcot, 1994). The Magnesium Adsorption Ratio was calculated using the following equation (Raghunath, 1987):

$$\text{MAR} = \frac{\text{Mg}^{++} \times 100}{\text{Mg}^{++} + \text{Ca}^{++}}$$  \hspace{1cm} (eqn 1)

Where all ionic concentration are expressed in meq/L.

Figure 5a: Wilcox Diagram for groundwater in the study Area.

**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 0.28 to 0.78 with mean value of 0.18 (Table 3). The water samples are suitable for irrigation purpose because SSP value is less than the set standard (Table 3). SSP calculated by using Todd, (1980).
SSP = \frac{\text{Na}^+ \times 100}{\text{Ca}^{++} + \text{Mg}^{++} + \text{Na}^+} \quad (eqn \ 2)

Where all ionic concentration are expressed in meq/L.

From the Wilcox diagram EBY/01 to EBY/05 can classified under excellent to permissible (Fig: 5a). This implies that the samples are fit for irrigation purpose based Wilcox SSP diagram.

Figure 5b: Rating of groundwater samples on the basis of electrical conductivity and percent sodium (after Wilcox, 1955).

**Sodium Percentage (SP)**

Sodium percentage is an important criterion for defining the type of irrigation. Sodium percent is another important factor to study sodium hazard. The value of Na% ranges from 14.05 to 39.02 with mean value of 26.81 (Table 3). Na % was calculated by using (Doneen, 1964) formula:

$$Na\% = \frac{\text{Na}^+ \times 100}{\text{Ca}^{++} + \text{Mg}^{++}} \quad (eqn \ 3)$$

Where all ionic concentration are expressed in meq/L.
The Wilcox, (1955) diagram relating sodium percentage and electrical conductivity shows that 90% of the groundwater samples fall within excellent to good (EBY/01, 02, 04, 05 and 06). While EBY/03 fall within good to permissible as shown in Fig.5b.

![Diagram](image)

**Figure 5c**: Doneen’s, (1964) Chart for P.I. values of groundwater.

**Permeability Index (P.I.)**
Doneen evolved a criterion for assessing the suitability of water for irrigation based on the permeability index. The value of PI ranges from 0.40 to 1.00 with mean value of 0.62 (Table 3). Based on value range of PI it is fit for irrigation purpose (Table 3). PI is classified under Class I (>75% permeability), Class II (25-75% permeability) and Class III (<75% permeability) orders. Class I and Class II waters are categorized as good for irrigation and Class III waters are unsuitable with 25% of maximum permeability, EBY/01 and 06 is classified under Class I, while EBY/02, 03, 04 and 05 are classified under Class II. (Fig. 5c). PI was calculated based on Domenico, et al., (1990).

\[
\text{PI} = \text{Na}^+ + \sqrt{\text{HCO}_3^-} 
\]  
(eqn 4)
Ca$^{++}$ + Mg$^{++}$ + Na$^+$

Where all ionic concentration are expressed in meq/L.

**Total Hardness (TH)**

TH value ranges from 41 to 95 with mean value of 71.83 (Table 3). Hence the water can be classified as soft water based on Sawyer, et al., (1967) see Table. 3. TH was calculated by the following equation (Raghunath, 1987):

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

(eqn 5)

Where all ionic concentration are expressed in meq/L.

<table>
<thead>
<tr>
<th>Total hardness as CaCO$_3$ (mg/l)</th>
<th>Water Class</th>
<th>Number of Samples</th>
<th>Percentage of sample (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;75</td>
<td>Soft</td>
<td>3 (EBY/01,05 and 06)</td>
<td>38.97</td>
</tr>
<tr>
<td>75 – 150</td>
<td>Moderately Hard</td>
<td>3 (EBY/02, 03 and 04)</td>
<td>61.02</td>
</tr>
<tr>
<td>150 – 300</td>
<td>Hard</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>&gt;300</td>
<td>Very Hard</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

**Residual Sodium Bi-carbonate (RSBC)**

Residual sodium bicarbonate (RSBC) exists in irrigation water when the bicarbonate (HCO3) content exceeds the calcium (Ca) content of the water. Where the water RSBC is high (>2.5meq/L), extended use of that water for irrigation will lead to an accumulation of sodium (Na) in the soil. This may results in (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 and water movement (SAI, 2010; Naseem, et al., 2010). The RSBC value of the study area is between -1.43 to 0.6 with mean -0.45 (Table 3) indicating good quality for irrigation purpose. RSBC was calculated according to proposed formula by Gupta and Gupta (1987):

$$RSBC = HCO_3^- – Ca^{++}$$

(eqn 6)

**Kelly Ratio (KR).**

The Kelly’s ratio of equal to or less than 1 is indicative of good quality water for irrigation whereas above 1 is suggestive of unsuitability for agricultural purpose due to alkali hazards (Karanth, 1987). The value of KR ranges from 0.14 to 0.39 with mean value of 0.28. Based on the value the water is fit for irrigation purpose (Table 3). This was calculated employing the equation (Kelly, 1963) as:
\[ KR = \frac{Na^+}{Ca^{++} + Mg^{++}} \]  

(eqns 7).  

Where all ionic concentration are expressed in meq/L.

**Sodium Adsorption Ratio (SAR).**

SAR is an easily measured property that gives information on the comparative concentrations of \(Na^+, Ca^{++},\) and \(Mg^{++}\) in the water samples (Talabi, et al., 2014). The 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 0.28 to 0.78 with mean value of 0.57 (Table 3). Based on this the value of SAR is fit for irrigation purpose. This was calculated employing the equation (Raghunath, 1987) as:

\[ SAR = \sqrt[2]{\frac{Na^+}{(Ca^{++} + Mg^{++})}} \]  

(eqns 8).  

Where all ionic concentration are expressed in meq/L.

**Electrical Conductivity (EC)**

Electrical conductivity is a good measure of salinity hazard to crops as it reflects the TDS in groundwater (Sawid, et al., 2015). The value of EC ranges from 126.24 to 752.43 \(\mu/\text{Scm}\).

**Table 2: Classification of Groundwater Based on EC**

<table>
<thead>
<tr>
<th>Salinity Hazard (Class)</th>
<th>EC (\mu/\text{Scm})</th>
<th>Sampling Points</th>
</tr>
</thead>
<tbody>
<tr>
<td>Excellent(C1)</td>
<td>&lt;250</td>
<td>EBY/02 and 06</td>
</tr>
<tr>
<td>Good (C2)</td>
<td>250 -750</td>
<td>EBY/01, 04 and 05</td>
</tr>
<tr>
<td>Doubtful(C3)</td>
<td>750 -2250</td>
<td>EBY/03</td>
</tr>
<tr>
<td>Unsuitable(C4)</td>
<td>&gt;2,250</td>
<td></td>
</tr>
</tbody>
</table>

From the US Salinity diagram EBY/01, 04 and 05 can group in C2 (Good) based on Fig.3, while EBY/02 and 06 are group into C1 (Excellent) Fig. 3d. And finally EBY/03 is group into C3 (Doubtful) based on CGWB and CPCB (2000) (Fig.5d and Table 2 and 5).
Fig. 5d: Classification of Groundwater based on US salinity diagram.

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

For geochemical classification, a diagram after Chadha plot has been used. The rectangular field of the plot describes the primary character of the water including the permanent and temporary hardness domain. The rectangular field is divided into eight sub-fields, each of which represents a water type and hardness domain (Fig. 6), which are as follows: (1) Alkaline earths exceed alkali metals. (2) Alkali metals exceed alkaline earths. (3) Weak acidic anions exceed strong acidic anions. (4) Strong acidic anions exceed weak acidic anions. (5) Alkaline earths and weak acidic anions exceed both alkali metals and strong acidic anions, respectively. The positions of data points in this domain represent Ca\(^{2+}\) - Mg\(^{2+}\) - HCO\(_3\)\(^-\) water type. (6) Alkaline earths exceed alkali metals and strong acidic anions exceed weak acidic anions. Such water has permanent hardness and does not deposit residual sodium carbonate in irrigation use. The positions of data points in this domain represent Ca\(^{2+}\) - Mg\(^{2+}\) - Cl\(^-\) type of waters. (7) Alkali metals exceed alkaline earths and strong acidic anions exceed weak acidic anions. Such water generally creates salinity problems both in irrigation and drinking uses. The positions of data points in this domain represent Na\(^+\) - Cl\(^-\) type and Na\(^+\) - SO\(_4\)\(^{2-}\) type of waters. (8) Alkali metals exceed alkaline earths and weak acidic anions exceed strong acidic anions. Such waters deposit residual sodium carbonate during irrigation use and cause foaming problems. The positions of data points in this region represent Na\(^+\) - HCO\(_3\)\(^-\) type waters (Chakraborthy, et al. 2012). The plot shows that all of the groundwater samples fall under the
Alkaline earths exceed alkali metals and strong acidic anions exceed weak acidic anions. Such water has permanent hardness and does not deposit residual sodium carbonate in irrigation use.

**Figure 6:** Chadha, (1999) Plot for Groundwater of the study area.

The concentration of dissolved ions in groundwater samples are generally governed by lithology, nature of geochemical reactions and solubility of interaction rocks. The functional sources of dissolved ions can be broadly assessed by plotting the samples, according to the variation in the ratio of Na/(Na+Ca) and Cl/(Cl+HCO₃) as a function of TDS(Gibb’s, 1970). The Gibbs plot of data from study area (Fig.7) indicates that rock is the dominant processes controlling the major ion composition of groundwater.
Conclusion

The value of Electrical conductivity ranges from (126.24 to 752.43 µScm), Total Dissolved Solid (90.32 to 855.27 mg L\(^{-1}\)), Total Hardness (41.00 to 95.00mg/L\(^{-1}\)) Sodium Adsorption Ratio (0.28 to 0.78), Magnesium Adsorption Ratio (11.7 to 536.8%), permeability Index (0.40 to 1.00%), Kelly Ratio (0.14 to 0.39meq/L), Residual Sodium Bicarbonate (-1.43 to 0.6 meq/L), Sodium percentage (14.00 to 39.02%), Soluble Sodium Percentage (0.28 to 0.78%). From Piper and Schoeller diagrams (Fig. 3 and 4) it reveals that sample EBY/01 is of Mg- Cl - HCO\(_3\) water type, samples EBY/02 is of Cl - HCO\(_3\), sample EBY/03 is of Mg- Ca –Cl water type, samples EBY/04, is of Ca-Na- Cl, sample EBY/05 is of Mg-Cl water type, while samples EBY/06 is of Ca-Cl. The dominat ionic species in the study area is Cl from the Piper plot. Based on the value of MAR sample EBY/01, EBY/ 02, EBY/03, EBY/03 is not fit for irrigation. While for sample EBY/04 and EBY/05 is considered suitable for irrigation. EBY/06 is considered fairly suitable for irrigation. From Gibb’s plot, rock water interaction is the dominant processes controlling the major ions in groundwater.
Acknowledgment

The author is grateful to two anonymous reviewers and Dr. Mrs. O. O. Omo- Irabor of the department of Earth Science Federal University of Petroleum Resources, Effurn Delta State. Nigeria.

References


### Table 1: Result of Analyzed Physical and Chemical Parameters

<table>
<thead>
<tr>
<th>PARAMETERS</th>
<th>EBY/01 Obugha Amachi I</th>
<th>EBY/02 Obugha Amachi II</th>
<th>EBY/03 Ndechi Igbeagu</th>
<th>EBY/04 Sharon Junction</th>
<th>EBY/05 New Layout</th>
<th>EBY/06 Water Works</th>
</tr>
</thead>
<tbody>
<tr>
<td>pH</td>
<td>8.01</td>
<td>7.43</td>
<td>7.05</td>
<td>6.7</td>
<td>6.08</td>
<td>7.5</td>
</tr>
<tr>
<td>TDS (mg L⁻¹)</td>
<td>90.32</td>
<td>623.54</td>
<td>115.44</td>
<td>855.27</td>
<td>617.34</td>
<td>113.95</td>
</tr>
<tr>
<td>E.C μ/Scm</td>
<td>325.08</td>
<td>148.65</td>
<td>752.43</td>
<td>524.7</td>
<td>282.65</td>
<td>126.24</td>
</tr>
<tr>
<td>SO₄²⁻ (mg L⁻¹)</td>
<td>8.43</td>
<td>14.05</td>
<td>6.09</td>
<td>9.56</td>
<td>6.76</td>
<td>14.54</td>
</tr>
<tr>
<td>HCO₃⁻ (mg L⁻¹)</td>
<td>43</td>
<td>78</td>
<td>22.04</td>
<td>15.32</td>
<td>28.45</td>
<td>14.34</td>
</tr>
<tr>
<td>K⁺ (mg L⁻¹)</td>
<td>1.06</td>
<td>0.02</td>
<td>1.98</td>
<td>2.18</td>
<td>1.40</td>
<td>1.40</td>
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<tr>
<td>Mg²⁺ (mg L⁻¹)</td>
<td>8.45</td>
<td>10.28</td>
<td>12.43</td>
<td>2.76</td>
<td>9.23</td>
<td>1.65</td>
</tr>
<tr>
<td>Na⁺ (mg L⁻¹)</td>
<td>7.42</td>
<td>10.01</td>
<td>6.07</td>
<td>12.65</td>
<td>9.32</td>
<td>8.94</td>
</tr>
<tr>
<td>Ca²⁺ (mg L⁻¹)</td>
<td>4.04</td>
<td>13.44</td>
<td>16.65</td>
<td>33.81</td>
<td>6.83</td>
<td>28.54</td>
</tr>
<tr>
<td>Cl⁻ (mg L⁻¹)</td>
<td>78</td>
<td>213</td>
<td>35</td>
<td>16.6</td>
<td>101</td>
<td>154</td>
</tr>
<tr>
<td>NO₃⁻ (mg L⁻¹)</td>
<td>4.32</td>
<td>3.92</td>
<td>5.54</td>
<td>4.54</td>
<td>2.00</td>
<td>6.07</td>
</tr>
</tbody>
</table>

### Table 2: Analyzed Physical and Chemical Parameters

<table>
<thead>
<tr>
<th>PARAMETERS</th>
<th>EBY/01 Obugha Amachi I</th>
<th>EBY/02 Obugha Amachi II</th>
<th>EBY/03 Ndechi Igbeagu</th>
<th>EBY/04 Sharon Junction</th>
<th>EBY/05 New Layout</th>
<th>EBY/06 Water Works</th>
</tr>
</thead>
<tbody>
<tr>
<td>SO₄²⁻ (meq/L)</td>
<td>0.17</td>
<td>0.29</td>
<td>0.12</td>
<td>0.19</td>
<td>0.14</td>
<td>0.30</td>
</tr>
<tr>
<td>HCO₃⁻ (meq/L)</td>
<td>0.70</td>
<td>1.27</td>
<td>0.36</td>
<td>0.25</td>
<td>0.46</td>
<td>0.23</td>
</tr>
<tr>
<td>K⁺ (meq/L)</td>
<td>0.02</td>
<td>0.00</td>
<td>0.05</td>
<td>0.05</td>
<td>0.15</td>
<td>0.03</td>
</tr>
<tr>
<td>Mg²⁺ (meq/L)</td>
<td>0.69</td>
<td>0.84</td>
<td>1.02</td>
<td>0.22</td>
<td>0.75</td>
<td>0.13</td>
</tr>
<tr>
<td>Na⁺ (meq/L)</td>
<td>0.32</td>
<td>0.43</td>
<td>0.26</td>
<td>0.55</td>
<td>0.40</td>
<td>0.38</td>
</tr>
<tr>
<td>Ca²⁺ (meq/L)</td>
<td>0.20</td>
<td>0.67</td>
<td>0.83</td>
<td>1.68</td>
<td>0.34</td>
<td>1.42</td>
</tr>
<tr>
<td>Cl⁻ (meq/L)</td>
<td>2.20</td>
<td>6.00</td>
<td>0.98</td>
<td>0.46</td>
<td>2.84</td>
<td>4.34</td>
</tr>
<tr>
<td>NO₃⁻ (meq/L)</td>
<td>0.06</td>
<td>0.06</td>
<td>0.08</td>
<td>0.07</td>
<td>0.03</td>
<td>0.09</td>
</tr>
</tbody>
</table>

Note: Concentration are in **meq/L**
Table 3: Value of Irrigation Parameters.

<table>
<thead>
<tr>
<th>SAMPLED LOCATION</th>
<th>RSBC</th>
<th>MAR</th>
<th>TH</th>
<th>SAR</th>
<th>SP</th>
<th>SPP</th>
<th>SAR</th>
<th>PI</th>
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<tr>
<td>EBY/01</td>
<td>0.5</td>
<td>147.6</td>
<td>41</td>
<td>0.39</td>
<td>39.02</td>
<td>28.07</td>
<td>0.78</td>
<td>1.00</td>
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<td>494.7</td>
<td>75.5</td>
<td>0.28</td>
<td>28.47</td>
<td>22.16</td>
<td>0.57</td>
<td>0.79</td>
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<tr>
<td>EBY/03</td>
<td>-1.32</td>
<td>536.84</td>
<td>92.5</td>
<td>0.14</td>
<td>14.05</td>
<td>12.32</td>
<td>0.28</td>
<td>0.40</td>
</tr>
<tr>
<td>EBY/04</td>
<td>-1.43</td>
<td>20.54</td>
<td>95</td>
<td>0.30</td>
<td>28.94</td>
<td>22.44</td>
<td>0.57</td>
<td>0.42</td>
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<td>74.07</td>
<td>54.5</td>
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<td>36.69</td>
<td>26.84</td>
<td>0.74</td>
<td>0.71</td>
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<tr>
<td>EBY/06</td>
<td>-1.19</td>
<td>11.71</td>
<td>72.5</td>
<td>0.24</td>
<td>24.51</td>
<td>19.68</td>
<td>0.49</td>
<td>0.44</td>
</tr>
<tr>
<td>Minimum</td>
<td>-1.43</td>
<td>11.71</td>
<td>41</td>
<td>0.14</td>
<td>14.05</td>
<td>12.32</td>
<td>0.28</td>
<td>0.4</td>
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<tr>
<td>Maximum</td>
<td>0.6</td>
<td>536.84</td>
<td>95</td>
<td>0.39</td>
<td>39.02</td>
<td>28.07</td>
<td>0.78</td>
<td>1.0</td>
</tr>
<tr>
<td>Mean</td>
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<td>214.24</td>
<td>71.83</td>
<td>0.28</td>
<td>26.81</td>
<td>21.91</td>
<td>0.57</td>
<td>0.62</td>
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<tr>
<td>STDEV</td>
<td>0.95</td>
<td>238.89</td>
<td>21.11</td>
<td>0.08</td>
<td>8.97</td>
<td>5.64</td>
<td>0.18</td>
<td>0.24</td>
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Table 4: Table Showing Sampling Points

<table>
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<tr>
<th>Co-ordinate</th>
<th>Sampling Code</th>
<th>Sampling Location</th>
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<tbody>
<tr>
<td>N8°09'57&quot;. E 006°17'13&quot;</td>
<td>EBY/01</td>
<td>Obugha Amachi I</td>
</tr>
<tr>
<td>N8°09'57&quot;. E 006°16'51&quot;</td>
<td>EBY/02</td>
<td>Obugha Amachi II</td>
</tr>
<tr>
<td>N8°08'09&quot;. E 006°18'24&quot;</td>
<td>EBY/03</td>
<td>Ndechi Igbeagu</td>
</tr>
<tr>
<td>N8°06'51&quot;. E 006°21'10&quot;</td>
<td>EBY/04</td>
<td>Close to Vanco Junction</td>
</tr>
<tr>
<td>N8°06'15&quot;. E 006°21'45&quot;</td>
<td>EBY/05</td>
<td>Close to New Layout</td>
</tr>
<tr>
<td>N8°07'03&quot;. E 006°21'44&quot;</td>
<td>EBY/06</td>
<td>Close to Ekaeru Inyimagu</td>
</tr>
</tbody>
</table>

Table 5: Guidelines for evaluation of irrigation water quality. Source: Modified after CGWB and CPCB (2000).

<table>
<thead>
<tr>
<th>Water Class</th>
<th>Na%</th>
<th>SAR</th>
<th>MAR</th>
<th>PI</th>
<th>SSP</th>
<th>KR</th>
<th>EC (µS/cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Excellent</td>
<td>&lt;20</td>
<td>&lt;10</td>
<td>&lt;50</td>
<td>&lt;80</td>
<td>50</td>
<td>&lt;1.0</td>
<td>&lt;250</td>
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<tr>
<td>Good</td>
<td>20-40</td>
<td>10-18</td>
<td>&lt;50</td>
<td></td>
<td></td>
<td></td>
<td>250-750</td>
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<tr>
<td>Medium</td>
<td>40-60</td>
<td>18-26</td>
<td>80-100</td>
<td></td>
<td>100-120</td>
<td></td>
<td>750-2250</td>
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<tr>
<td>Bad</td>
<td>60-80</td>
<td>&gt;26</td>
<td>&gt;50</td>
<td></td>
<td></td>
<td>&gt;1.0</td>
<td>2250-4000</td>
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<tr>
<td>Very Bad</td>
<td>&gt;80</td>
<td>&gt;26</td>
<td>&gt;50</td>
<td></td>
<td></td>
<td></td>
<td>&gt;4000</td>
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</tbody>
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