

# ASSESSMENT OF IRRIGATION WATER QUALITIES OF ABAK RIVER, ABAK, AKWA IBOM STATE, NIGERIA

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## ABSTRACT

Irrigated agriculture is dependent on an adequate water supply of usable quality. Since water quality is very important for any intended use, the Abak River water which is used for irrigation by the Cross River Basin Development Authority and the rural communities around the river bank was assessed for irrigation purposes. The River water samples were assessed for four months (from November, 2016 to February, 2017 for its irrigation water qualities. The water samples were analyzed for major cations:  $\text{Na}^+$ ,  $\text{Ca}^{2+}$ ,  $\text{K}^+$ ,  $\text{Mg}^{2+}$  and anions:  $\text{Cl}^-$ ,  $\text{SO}_4^{2-}$ ,  $\text{HCO}_3^-$ ,  $\text{CO}_3^{2-}$  and  $\text{NO}_3^-$ .

The important constituents that influence the water quality for irrigation such as Electrical Conductivity (EC), Total Dissolved Solid (TDS), Sodium Adsorption Ratio (SAR), Magnesium Adsorption Ratio (MAR), Permeability Index (PI), Kelly's Ratio (KR), Residual Sodium Bicarbonate (RSBC), Soluble Sodium Percentage (SSP), (RSC) Residual Sodium Carbonate and Potential Salinity (PS) were assessed and compared with standard limits. The values of Sodium Adsorption Ratio (0.4 to 0.64), Soluble Sodium Percentage (28.16 to 34.68%), Residual Sodium Bicarbonate (2.82 to 3.15 meq/L), Permeability Index (3.20 to 3.98%), Magnesium Adsorption Ratio (77.78 to 87.59%), Kelly's Ratio (0.13 to 0.161 meq/L), Electrical Conductivity (20.5 to 22.5  $\mu\text{s}/\text{cm}$ ), Total Dissolved Solids (10.20 to 12.60 Mg/l) Residual Sodium Carbonate (0.298 to 0.8 meq/L) and Potential Salinity (1.09 – 1.358 meq/L) were found to be within the safe limits and thus suitable for irrigation purposes, except MAR which is above 50% the safe limit. The river water will thus cause neither salinity hazard nor has an adverse effect on the soil properties of the study area or on crops.

**KEYWORDS:** Abak River, Water Quality Irrigation, Parameters, Assessment.

## INTRODUCTION

The knowledge of irrigation water quality is critical to soil conservation and optimal agricultural productivity. Abak is an urban area that is basically dominated by agricultural activities. Abak River is the only river that is available in Abak suburb. Irrigation is being carried out within the region for all year round vegetable production. Water quality is mostly affected in dry season. Therefore, there is a need to study the quality of the Abak River. This would give an insight into the

quality of the available surface water, since poor irrigation quality water will create a negative impact on the crop and the soil over time which will have an impact on the humans and the environment at large.

Water resource has a unique position among other natural resources and is the most extensively distributed substance in the world (Megersa and Abdulahi, 2015). Water plays a key role in the human life and surrounding environment (Saleh *et. al.*, 2001 and Onoja *et.al.*, 2013). Fresh water is most essential among water resources, it is essential for

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human being's life and activities. The availability of clean fresh water is one of the greatest challenges facing mankind today as millions of people especially in rural areas still lack access to potable water (Dan Hassan *et. al.*, 2012 and Amadi *et. al.*, 2015). About 1.4 billion km<sup>3</sup> water is available on earth. Among them approximately 35 million km<sup>3</sup> fresh water resources are present i.e. about 2.5% of total volume (UNEP, 2001).

However, the way that water has been managed in agriculture has caused wide scale change in land cover with water courses, contributing to ecosystem degradation and undermining the process that supports ecosystem and the provision of a wide range of ecosystem services essential for human well-being. (Megersa and Abdulahi 2015, Malin *et. al.*, 2007, Adelana and Olusehinde, 2003). Water resources are depleting due to exceeding demand and consumption ratio as result of over pumping and demanding human activities thus worsening the water quality resources. Water quality refers to the characteristics of water supply that will influence its suitability for a specific use; that is how well the quality meets the needs of the user. Water quality is defined by physical, chemical and biological characteristics. This classification although primary and simple seems convenient for a more or less broad evaluation to cover the whole spectrum of irrigation water quality for crop production. It is further broadened in order to cover all the physicochemical, biological and microbiological properties of water that may cause any impact on soil, plants, environment and the consumer, human or livestock.

Irrigation waters whether derived from springs, diverted from streams or pumped from well contain appreciable quantities of chemical substances in

#### OBJECTIVE OF THE STUDY

The objective of this study is to assess the irrigation water qualities of Abak River, Abak, Akwa Ibom State, Nigeria

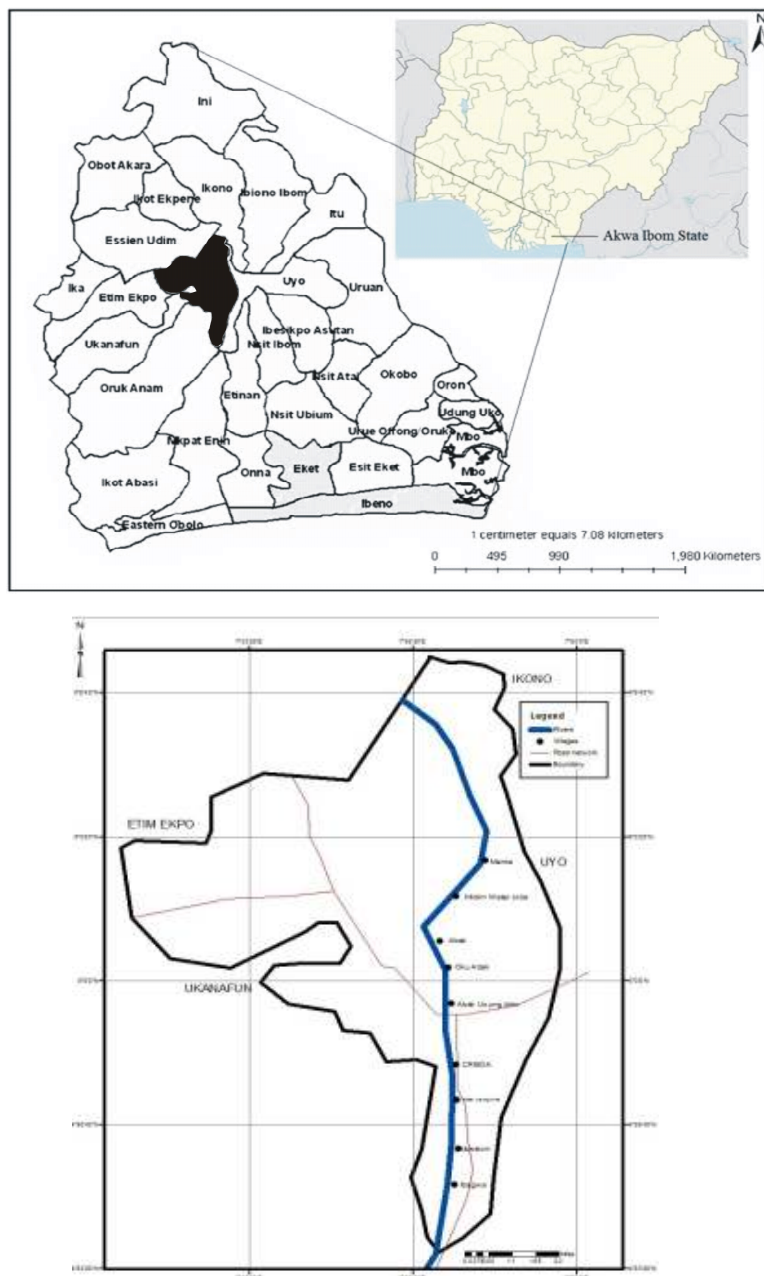
solution that may reduce crop yield and deteriorate soil fertility. Also it may carry substances derived from its natural environment or from the waste products of man's activities (domestic and industrial effluents). Understanding irrigation water quality is critical for sustainability of vegetable production (Dukes *et. al.*, 2015). Water used for irrigation can vary greatly in quality depending upon types and quantity of dissolves salts, these salts are applied with the water and remained behind in the soil as water evaporates or is used by the crop (Tanji, 1990, Longenecker and Lysterly1974). However water quality in irrigated agriculture include salinity hazard (Total Soluble Salt Content), Sodium hazard, (ratio of Sodium (Na<sup>+</sup>) to Calcium (Ca<sup>2+</sup>) and Magnesium (Mg<sup>2+</sup>) ions, water pH, Alkalinity (Carbonate and Bicarbonate) specific ions: Chloride (Cl<sup>-</sup>) Sulfate (So<sub>4</sub><sup>2-</sup>), Boron (Bo) and nitrate – nitrogen (NO<sub>3</sub>N), Organic contaminant (Oil pollutant) and other factors such as heavy metals (Bauder *et. al.*, 2007).

Salts in water or soil reduce water availability to crops which eventually affects crop yield. Relatively high sodium or low calcium content of soil or water reduces the rate at which irrigation water enters the soil to such an extent that sufficient water cannot be infiltrated to supply the crop adequately from one irrigation period to the next. Ions such as those from sodium, chloride or boron from water or soil if accumulated in sensitive crops with high concentration cause damage to the crops and reduce yield of the crops. Also excessive nutrients in irrigation water reduce yield or quality of crops, sprinkler irrigation water with high bicarbonate content cause unsightly deposits on fruit or leaves. The scope of the study is limited to Abak River water quality for irrigation cropping in dry season.

#### METHODOLOGY

##### STUDY LOCATION:

The Abak River is located on the south western part of Uyo, the Akwa Ibom State capital which lies in the rain forest zone of Nigeria. Abak is within the co-ordinates of latitude 4°50<sup>1</sup> and 5°10<sup>1</sup>N, longitude, 7°40<sup>1</sup>E and 7°50<sup>1</sup>E, with an elevation of 30 meter above sea level, having a population of 139,090 with a land mass of 190 Km<sup>2</sup> (2006 National Census, Wikipedia 2016), Attai *et. al.*, (2015).



**Fig 2.1a & b** Map of Nigeria showing Akwa Ibom State and Abak Local Government of Akwa Ibom State

## MATERIALS AND METHODS

### Sampling

The River serves the Cross River Basin Development Authority as a source of irrigation water for her dry season cropping and the rural farmers of Abak Midim, Oku-Abak, Abak Usung Idim and Abak Usung Atai in Abak Local Government of Akwa Ibom State, Nigeria. Abak River water samples were collected in clean 1000ml polyethylene bottle for the Analysis of various physico-chemical parameters on monthly basis from November 2016 to February 2017. Nine samples were

collected for period of four months and a total of thirty-six samples were collected.

### Field Analysis

Parameters such as water temperature and pH were measured on the spot by means of a mercury thermometer and digital pH meter. The samples were then carefully sealed, labeled and taken for analysis.

**Laboratory Analysis**

Chemical analyses were performed in the laboratory of University of Uyo. Atomic Absorption Spectrophotometry for cations and conventional titration for anions (chopra and kanwar, 1980). Ions were converted from milligram per liter to mill equivalent per liter and anions balanced against cations as a control check of the reliability of the analysis of the results.

**Data Analysis**

The data were analyzed statistically using the standard methods of mean and standard deviation methods from the data obtained. The analytical results were compared with the standard specification (WHO, 2006).

$$\bar{x} = \frac{\sum x}{N} \quad 2.1$$

$\bar{x}$  = mean  
 $\sum x$  = the sum of  $x$   
 $N$  = Number of data

$$\sigma = \sqrt{\frac{\sum (x - \bar{x})^2}{n}} \quad 2.2$$

$\sigma$  = Standard deviation  
 $\sum$  = Sum of  
 $x$  = each value in the data set  
 $\bar{x}$  = Mean of all values in the data set  
 $n$  = Number of value in the data set

**Table 2.1 Showing the Irrigation Water Parameters and their Respective Formulas**

Parameters	Formula	References
Sodium Adsorption Ratio (SAR)	$\frac{Na^+}{\left(\frac{\sqrt{Ca^{2+} + Mg^{2+}}}{2}\right)}$	Richards (1954)
Soluble Sodium Percentage (SSP)	$\frac{(Na^+ + K^+) \times 100}{Ca^{2+} + Mg^{2+} + Na^+ + K^+}$	Todd (1995)
Residual Sodium Bicarbonate (RSBC)	$HCO_3^- - Ca^{2+}$	Gupta and Gupta (1987)
permeability Index (PI)	$\frac{Na + \sqrt{HCO_3^- \times 100}}{Ca^{2+} + Mg^{2+} + Na^+}$	Doneen (1964)
Magnesium Adsorption Ratio (MAR)	$\frac{Mg^{2+} \times 100}{Ca^{2+} + Mg^{2+}}$	Raghunath (1987)
Kelly's Ratio (KR)	$\frac{Na^+}{Ca^{2+} + Mg^{2+}}$	Kelly (1963)
Residual Sodium Carbonate (RSC)	$(HCO_3^- + CO_3^{2-}) - (Ca^{2+} + Mg^{2+})$	Richards (1954)
Potential Salinity	$Cl^- + \frac{1}{2} SO_4^{2-}$	Doneen (1961)

All ions are expressed in meq/L

## RESULT AND DISCUSSION

The analyzed physicochemical qualities of Abak River water is as indicated in table 3.1 with effect from November 2016 to February, 2017.

**TABLE 3.1: RESULT OF PHYSICO CHEMICAL ANALYSIS OF ABAK RIVER**

Parameters	Months				Statistics				WHO
	Nov	Dec	Jan	Feb	Min	Max	Mean	SD	
Temperature	26.20	27.00	25.80	27.80	25.80	27.80	26.70	0.89	30
pH	6.51	6.30	6.18	6.20	6.18	6.51	6.30	0.15	6.5 – 8.5
EC	22.00	21.20	20.5	22.5	20.50	22.50	21.55	0.88	3
TDS	11.70	10.20	11.20	12.60	10.20	12.60	11.43	1.00	2000
Na	20.06	15.8	14.72	13.8	13.80	20.06	16.10	2.77	200
K	49.07	64.00	65.29	50.83	49.07	65.29	57.30	8.53	45
Ca	14.86	15.00	10.8	20.00	10.80	20.00	15.17	3.77	400
Mg	57.13	48.20	46.48	42.7	42.70	57.13	48.63	6.12	60
B	0.34	0.31	0.35	0.37	0.31	0.37	0.34	0.03	
Cl	39.28	38.10	37.28	36.57	36.57	39.28	37.81	1.16	1100
SO <sub>4</sub>	22.64	18.12	20.64	5.76	5.76	22.64	16.79	7.58	1000
HCO <sub>3</sub>	227.09	220.00	225.09	233.02	220.00	233.02	226.30	5.38	600
CO <sub>3</sub>	66.4	45	43.8	39.00	39.00	66.40	48.55	12.18	
NO <sub>3</sub>	1.05	28.52	1.05	8.06	1.05	28.52	9.67	13.00	10

All units are in mg/l except Temp (°c) EC µs/cm, and pH (no unit)

**TABLE 3.2: IONS AND THEIR MILLIEQUIVALENT (NOVEMBER, 2016 – FEBRUARY, 2017) MONTHLY VALUES**

IONS	NOVEMBER	DECEMBER	JANUARY	FEBRUARY
Ca <sup>2+</sup>	0.743	0.75	0.54	1.00
Mg <sup>2+</sup>	4.682	3.95	3.81	3.50
Na <sup>+</sup>	0.872	0.68	0.64	0.60
K <sup>+</sup>	1.255	1.64	1.67	1.30
Cl <sup>-</sup>	1.122	1.07	1.06	1.03
SO <sub>4</sub> <sup>2-</sup>	0.472	0.38	0.43	0.12
HCO <sub>3</sub> <sup>-</sup>	3.723	3.61	3.69	3.82
CO <sub>3</sub> <sup>2-</sup>	2.213	1.50	1.46	1.30
NO <sub>3</sub> <sup>-</sup>	0.017	0.46	0.02	0.13

The ions were converted from milligram per litre (mg/l) to milliequivalent per liter (meq/L) as presented in table 3.2

**TABLE 3.3: WATER QUALITYPARAMETER INDICES FOR ABAK RIVER AND ITS SUSTAINABILITY IN IRRIGATION (NOVEMBER, 2016 – FEBRUARY, 2017)**

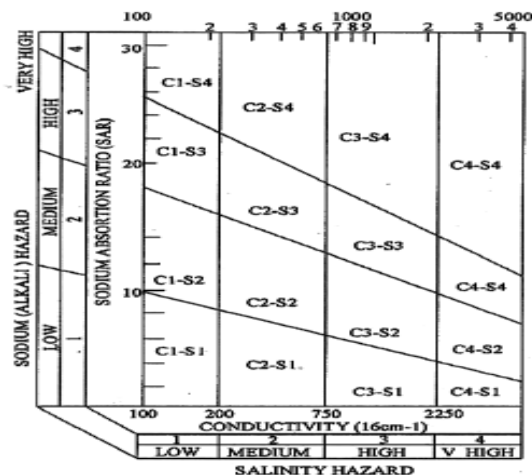
Parameters	Months				Statistics			
	Nov	Dec	Jan	Feb	Min	Max	Mean	SD
SAR (Unit )	0.64	0.58	0.44	0.4	0.4	0.64	0.515	0.098
SSP (%)	28.16	33.05	34.68	29.69	28.16	34.68	31.395	2.593
RSBC (meq/L)	2.98	2.86	3.15	2.82	2.82	3.15	2.953	0.128
PI (%)	3.20	3.66	3.98	3.95	3.20	3.98	3.698	0.313
MAR (%)	86.34	84	87.59	77.78	77.78	87.59	83.928	3.776
KR (meq/L)	0.161	0.15	0.15	0.13	0.13	0.161	0.148	0.011
EC ( $\mu$ S/cm)	22.00	21.20	20.5	22.5	20.5	22.5	21.55	0.763
TDS (Mg/l)	11.70	10.20	11.20	12.60	10.20	12.60	11.425	0.867
RSC (meq/L)	0.30	0.41	0.80	0.62	0.298	0.80	0.532	0.193
PS (meq/L)	1.36	1.26	1.28	1.09	1.09	1.36	1.246	0.097

The results of the different irrigation indices for assessing irrigation water quality of Abak River are summarized and in presented table 3.

#### **SODIUM ADSORPTION RATIO (SAR)**

The Sodium Adsorption Ratio gives a clear idea about the adsorption of sodium by the soil. It is the proportion of sodium to calcium and magnesium which affect the availability of the water to crop. The

sodium adsorption ratio of Abak River obtained in the present study within the four months (Nov. 2016 - Feb. 2017) are generally less than 9 and fall under the category of C1S1 indicating low alkali hazards and excellent irrigation water as shown on Table 3.4, Fig 3.1 Salinity Laboratory's Staff (1954)



**Fig. 3.1:** Classification of the analyzed water sample with respect to sodium adsorption ratio and salinity hazard (After US Salinity Lab. (1954).

**TABLE 3.4: LIMITS OF SOME PARAMETER INDICES FOR RATING WATER QUALITY AND ITS SUSTAINABILITY IN IRRIGATION**

CATEGORY	EC( $\mu$ MHOS/CM)	SAR	SSP %	SUSTAINABILITY FOR IRRIGATION
1.	< 117 - 503	< 10	< 20	Excellent
2.	117 - 503. 61	10 - 18	20 - 40	Good
3.	503. 61	18 - 26	40 - 80	Fair
4.	> 503. 61	> 26	> 80	Poor

#### SOLUBLE SODIUM PERCENTAGE (SSP)

Sodium percentage is an important factor for rating sodium hazard. It is also used for adjudging the quality of water for agricultural purposes. High percentage sodium water for irrigation purpose may stunt the plant growth, and reduces soil permeability (Joshi *et al.*, 2009). The soluble sodium percentage values of Abak River Water in the study area ranged between 28.16-34.69% indicating class II and good irrigation water quality (Wilcox (1950) as shown on Table 3.4.

#### RESIDUAL SODIUM BICARBONATE (RSBC)

The concentration of bicarbonate and carbonate influence the suitability of water for irrigation purposes. The water with high RSBC has high pH. Therefore, land irrigated with such water is rendered infertile owing to the deposition of Sodium Carbonate

(Eaton, 1950). The residual sodium bicarbonate values of water from the study area vary 2.82 to 3.15 meq/L (Table 3.4). The residual sodium bicarbonate values are less than 5Meq/Land are therefore considered safe for irrigation (Gupta 1987, Oladeji *et al.*, 2012).

#### PERMEABILITY INDEX (PI)

The soil permeability is characterized by the long-term use of irrigated water and the influencing constituents are the total dissolved solids, sodium bicarbonate and the type of soil. During the present study, the permeability index values range between 3.20% to 3.98% (av. 3.698) as contained in table 3.3.

The results therefore suggest that the water sample fall within class I and class II and can be regarded as good irrigation water Doneen,1964; obtained from fig 3.2

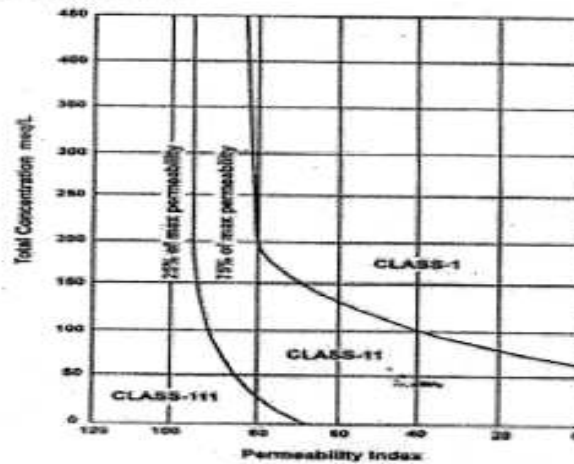


Fig.3.2: Showing Doneen's Chart of Permeability Index (after Doneen, 1964)

### MAGNESIUM ADSORPTION RATIO (MAR)

Magnesium content of water is very important criteria in determining irrigation water quality. Basically, calcium and magnesium maintain a state of equilibrium in most water. Excess content of magnesium in water for irrigation will adversely affect crop yields as the soils become more saline (Joshi *et al.*, 2009).

The values of the magnesium adsorption ratio of Abak river water sample in the present study varies from 77.78 to 87.59% (Table 3.3) showing that it is above the acceptable limit of 50% (Ayers and West cot, 1985). The water is therefore considered unsuitable. This is because high magnesium adsorption ratio causes a harmful effect to soil when it exceeds 50%.

### KELLY'S RATIO (KR)

The Kelly's Ratio (KR) values of the study water sample ranged between 0.13 and 0.161% (av. 0.148, Table 3.3).

This indicates that the Abak river water sample falls within the permissible limit of 1.0 and is considered suitable for irrigation purposes.

### ELECTRICAL CONDUCTIVITY (EC)

Electrical conductivity is the most influential water quality guideline on crop productivity as it measures the salinity hazard of the water. The primary effect of water with high EC on crop productivity is the inability of the plant to compete with ions in the soil solution for water (physiological drought). The higher the EC the less water is available to plants though the soil may appear wet. Since plants can only transpire water (pure water) usable plant water in the soil solution decreases drastically as EC increases (Amadi *et al.*, 2013).

On the basis of electrical conductivity, classification for Abak water sample under the present study for irrigation water quality the electrical conductivity values vary from 20.5 to 22.5  $\mu\text{s}/\text{cm}$  (av. 21.55) Table 3.3. The sample falls within the irrigation water categories as excellent category as shown on table 3.4.

### TOTAL DISSOLVED SOLIDS

Salts of calcium, magnesium, sodium and potassium present in the irrigation water may prove to be injurious when present in excessive quantities. They reduce the osmotic activities of the plants and may prevent adequate aeration. The TDS values vary from 10.20 to 12.60 Mg/l (av. 11.425 Mg/l). The water can be classified as excellent irrigation water according to the determined values in table 3.4.

### RESIDUAL SODIUM CARBONATE (RSC)

Residual sodium carbonate (RSC) is used to determine the hazard effects of carbonate and bicarbonate on quality of water for irrigation and is expressed by the equation:

$$\text{RSC} = (\text{HCO}_3^- + \text{CO}_3^{2-}) - (\text{Ca}^{2+} + \text{Mg}^{2+})$$

Where all ionic concentrations are expressed in meq/L. The classification of irrigation water according to the RSC is presented in table 3.5 (Richards, 1954). Water containing more than 2.5 meq/L of RSC is not suitable for irrigation while those having less than 1.25 meq/L are good for irrigation (Taqveen and Abbasi, 2013). The calculated RSC values of the water samples from the study area ranged from 0.298 to 0.8 meq/L with an average value of 0.532 meq/L (Table 3.3)

Hence, the river water of Abak River, the study center is safe for irrigation. (Table 3.5)



TABLE 3.5: WATER CLASSES BASED ON RSC (AFTER RICHARDS 1954)

RSC VALUES	WATER QUALITY
Less than 1.25	Suitable
1.25 – 2.5	Marginal
More than 2.5	Not suitable

**POTENTIAL SALINITY (P.S)**

On the basis of Potential Salinity which is an important parameter for assessing the suitability of water for irrigation uses, the water samples from the study center ranged from 1.09 meq/L to 1.358 meq/L with

an average of 1.246 meq/L. This indicates that the water samples from the study area are good for irrigation purposes and on soil of low permeability and on class I (Table 3.6).

TABLE 3.6: CLASSIFICATION OF IRRIGATION WATER BASED ON POTENTIAL SALINITY

CLASS OF WATER/ SOIL CHARACTERISTICS	CLASS I	CLASS II	CLASS III
Soil of low permeability	< 3	3 – 5	> 5
Soil of medium permeability	< 5	5 – 10	> 10
Soil of high permeability	< 7	7 – 15	> 15

**CONCLUSION**

The Abak River water quality for irrigation used by the Cross River Basin Development Authority was assessed for its irrigational suitability.

The values of Sodium Adsorption Ratio (0.4 to 0.64), soluble sodium percentage (28.16 to 34.68%), Residual sodium bicarbonate (2.82 to 3.15 meq/L), Permeability index (3.20 to 3.98%) Kelly’s ratio (0.13 to 0.161 meq/L), Electrical conductivity (20.5 to 22.5  $\mu$ s/cm) Total dissolve solids (10.20 to 12.60 Mg/l), Residual Sodium Carbonate (0.298 to 0.8 meq/l), and Potential Salinity (1.09 – 1.358 meq/l) were obtained for Abak river water sample, and were found to be within the safe limit except magnesium adsorption ratio with the value ranging from 77.78 to 87.59% as compared to the safe limit of 50% (Ayers and West cot,1985).

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