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River Water Quality Assessment for Agricultural Use in Ishiagu, Southeastern Nigeria

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ABSTRACT

Accelerated industrialization and overpopulation are placing tremendous pressure on the country's water supplies. Demand for surface water has risen because of insufficient groundwater. Twenty-one surface water samples were obtained during rainy and dry seasons and analyzed for different parameters such as sodium, calcium, magnesium and bicarbonate etc. Irrigation indices such as sodium adsorption ratio (SAR), permeability index (PI), sodium percentage (Na percent) have been calculated to evaluate surface water's suitability for irrigation. Some of the indices showed that the water reached the allowable limits.

Keywords: *Ishiagu, Sodium adsorption ratio, Permeability index, Sodium percentage, irrigation.*

INTRODUCTION

Water is a divine liquid which is necessary to sustain life. Water is not just one of the most important resources in our daily life, but also plays an important role in the cycles of economic and social development. While the total quantity of water available in the world is constant and

is commonly said to be sufficient to satisfy all human demands, its consistency and supply across different regions of the world is unequal, causing problems of availability and appropriateness. Therefore, it is essential that man rationally and properly use and handle this scarce commodity. Sadly, more than one in six people in developing world lack reliable access to this valuable resource.

Many physical, chemical, and biological criteria (APHA, 2005) are used to determine water body quality. The emphasis is placed on the chemical and physical characteristics of water for evaluation of irrigation-water quality. The water quality assessment requirements for irrigation purposes include the calculation of (1) salinity hazard in terms of electrical conductivity (EC); (2) sodium threat measured in terms of sodium adsorption ratio (SAR); (3) specific ions (i.e. sodium, chloride, borate, sulphate and nitrate) causing plant ionic imbalance or phytotoxicity; (4) sodium carbonate residual (SCR); and (5) Trace elements (Fe, Mn, Zn, Cu, Pb, Cd, Cr, Ni and F) toxicity (Ayers and Westcot, 1994).

Agricultural operations in the study area are facilitated by surface water supplied. Until now, we have been unable to find information on the surface water quality particularly for agricultural purposes. Hence, it is necessary to assess the water quality of the surface water in Ishiagu area, especially for agricultural purposes by monitoring SAR, PI and Na% values (USDA 1954).

MATERIALS AND METHODS

Study Area

Ishiagu is situated between 5°50' to 6°00'N latitudes and 7°27' to 7°39'E longitudes with an area of approximately 672.22km^2. It is surrounded by Awgu in Enugu State in the north, Lokpa-Lekwesi in Abia State in the west, Obinagu in the south and Aka-Eze in Ebonyi State in the east.

It witnesses two seasons each year; dry November through March, and rainy March through October (Udo, 1970). The mean annual temperature is between 25°C and 37°C with average rainfall of approximately 1200mm to 2000mm. In the area the inhabitants participate in moderate farming activities. The Savanna is the forest.

Geology and Hydrogeology

Two rock formations, as shown in the geological map of the study area, underlie the study area (Figure 1). The oldest is Abakaliki Formation, which consists of two mappable shale, limestoneand sandstone units. Ezepue (1984), named the shale unit as Ivo Shale and this includes clay, siltstones and dark gray calcareous shales, whereas the sandstone unit comprises of fine to medium grain calcareous sandstone. The two units dip NW and SE between 15° and 20° respectively. A sandstone member of the Ezeaku Formation unconformably overlays the Abakaliki Formation. McConnell (1949), dated this sandstone member of Ezeaku Formation to Turonian. It ranges from siltstone to fine-medium grained sandstone with dips from 10° to 22° SE. Ezepue (1984), identified a collection of fractures in the region that run NW to SW. These fractures, he stated, run across the axis of the fold and may have been due to the tectonic activities that folded the rocks. However, scattered intermediate intrusive rocks of various sizes and forms also occur commonly in the area.

A diverse aquifer unit is the product of the interlayering of the Eze Aku Formation shale and sand units, which provide substantial aquifer units, and also the yield is enhanced by the availability of fine to medium grained sandstone (Ismael, 1990). Asu River Group's weathered shale/sandstones and Ebonyi River Basin alluvial deposits make up the aquifer for the water table. Abakaliki's broken shales form the semi-confined aquifer and Eze Aku Formation's

sandstone groups, which overlap with sandy shale and mudstone, form a multi-aquifer network, often confined or semi-confined, resulting in weathered aquifer areas, fractures zone aquifer, aquifer deposits of alluvium, sandstone and calcareous layers within Eze Aku Shale, and shale-intrusive borders (Ismeal, 1990).

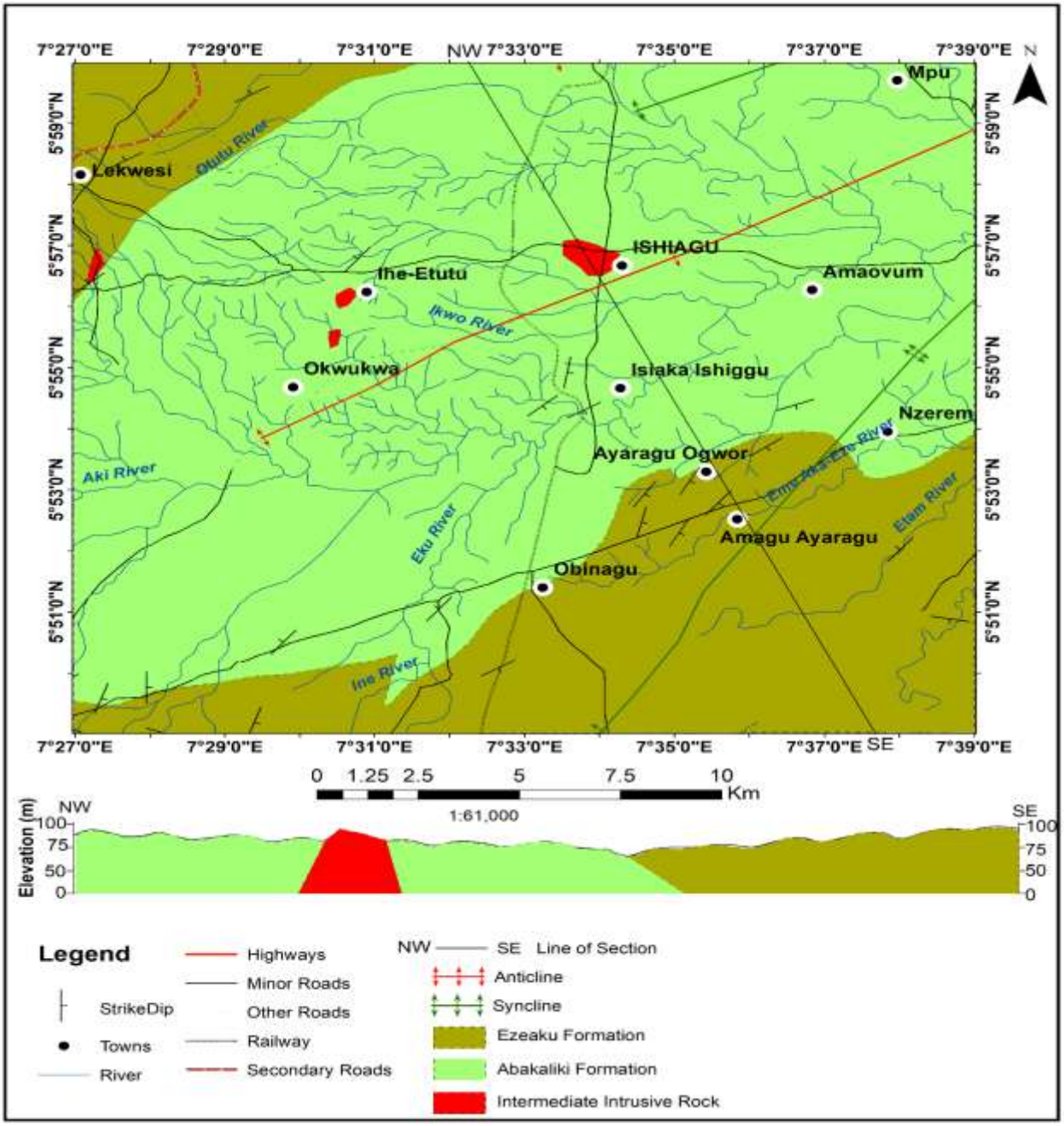

Figure 1: Geologic map of the study area.

Sample Collection

Total of 21 samples were collected from different surface waters covering the entire area with 1 litre polyethylene bottles.The sample containers were soaked for 24 hours in 10 per cent HNO_3 and scrubbed with deionized water many times before use. The bottles were thoroughly washed at each sampling site with the water to be collected before collection, tightly closed leaving air bubble below the stopper, appropriately labeled and placed in a cooler. Within 24 hours of collection the samples were sent to the laboratory for chemical analysis. And this was done for both rainy and dry seasons.

Analytical methods

Water samples were tested for pH, electrical conductivity (EC), dissolved solids (TDS), total calcium (Ca^{2+}), magnesium (Mg^{2+}), sodium (Na^{+}), potassium (K^{+}), chloride (Cl^{-}),bicarbonate (HCO_3^{-}) and sulphate (SO_4^{2-}). All reagents used in this analysis were of analytical reagent quality and were used for experimental purposes. All the measures for sampling and analysis were taken as set out in APHA, AWWA, WPCF (2003).

Sodium Adsorption Ratio (SAR)

SAR is a critical parameter for assessing the competency of irrigation water, excess sodium in water causes the unwanted effects of increasing soil properties and decreasing soil permeability. Owing to excess SAR (Richards, 1954), the soil is dense and impervious in nature. SAR is the sodium concentration ratio of the average calcium square root plus magnesium concentration in either irrigation water or the soil solution (Miller and Gardiner, 2007). Multiple studies indicate that irrigation water-related solubility issues as permeability.

$$\text{SAR} = \frac{Na^{+}}{\sqrt{Ca^{2+} + Mg^{2+}/2}} \quad - \quad - \quad - \quad - \quad - \quad - \quad (1)$$

(Concentrations are in Meq/L)

Permeability Index (PI)

The appropriateness of the irrigation water was dependent on PI. The PI can be listed as orders Class I, Class II and Class III. Class I and Class II water has been classified as good for irrigation with a maximum permeability of 75 per cent. At 25 per cent gross permeability, Class III was unsuitable (Doneen, 1964).

This was determined using equation (Domenico, 1990), as follows:

$$PI = \frac{Na + \sqrt{HCO_3}}{Ca + Mg + Na} \; x \; 100 \quad - \quad - \quad - \quad - \quad - \quad (2)$$

(Concentrations are in Meq/L).

Sodium Percentage (Na%)

This is known as the sodium ratio in epm to the total epm multiplied by 100 cations. Water with a sodium percentage greater than 60 percent will result in accumulations of sodium that will cause a breakdown in the physical properties of the soil.

This was determined using the equation (Todd, 1995), as follows:

$$Na\% = Na+/ (Ca^{2+} + Mg^{2+} + Na^{+} + K^{+}) \times 100 \quad - \quad - \quad - \quad (3)$$

(Concentrations are in Meq/L).

The accumulation of both carbonate and bicarbonate influences the appropriateness of water for irrigation uses. The chemical composition of sodium over alkaline earth as regards excessive carbonate and bicarbonate often influences the appropriateness of water for irrigation purposes and this excess is characterized by residual sodium carbonate (Richards, 1954).

This was determined using equation (Eaton, 1950), as follows:

$$RSC = (CO_3^{2-} + HCO_3^{-}) - (Ca^{2+} + Mg^{2+}) \quad - \quad - \quad - \quad - \quad (4)$$

Table 1 provided classification of water based on irrigation indices.

Table 1: The water quality condition of the various irrigation indices.

SAR	Class	PI	Class	Na%	Class
<10	Excellent	75%	Class I	>20	Excellent
10 – 18	Good	75%	Class II	20 – 40	Good
18 – 26	Fair	25%	Class III	40 – 60	Permissible
>26	Poor			60 – 80	Doubtful
				>80	Unsuitable

RESULTS AND DISCUSSION

Table 2 gives an overview of the surface water physicochemical data in the area of study. During both rainy and dry seasons, the chemical composition of the surface water varies across a wide range and this suggests that surface water in the study area is not standardized, but differs considerably in salinity and ionic composition.The concentration of surface water in the study area is quite heterogeneous and low mineralised (TDS < 500mg/l). The dominant cation is calcium, whichhas a concentration of 21.9 and 21.79mg/l for both rainy and dry seasons, followed bysodium with concentration of 5.1mg/lduring the rainy season and 8.8mg/l in the dry season andthen by magnesium and potassium. In 89% of the surface water samples, calcium is the dominantcation, while sodium dominates in 21% of thesamples. HCO3 is the main anion with a mean concentration of 75.56mg/l, followed by NO3 (mean concentration of 17,28mg/l) and then SO_4^{2-} and Cl (mean 8.00 and 5.65mg/l). The groundwater pH varies from 4.3 to 7.9, with a mean of 5.8, an indicator that the dissolved carbonates are primarily in HCO3 form (Adams et al. 2001).

Table 2: Analyzed physicochemical parameters of the study area.

Sample ID	pH		EC		TDS		Ca^{2+}		Mg^{2+}		Na^{+}		K^{+}		Cl^{-}		HCO_3^{-}		SO_4^{2-}	
	Rainy	Dry	Rainy	Dry	Rainy	Dry	Rainy	Dry	Rainy	Dry	Rainy	Dry	Rainy	Dry	Rainy	Dry	Rainy	Dry	Rainy	Dry
ACI/SW1	5.97	5.5	310	430	100	250	21.32	14.39	1.02	1.68	5.11	5.3	1.03	3.92	22	20	33.6	36.12	15	11
ACI/SW2	6.02	4.04	215	520	75	280	15	13.2	2.2	5.4	2.51	6.3	13	6.5	20	25	36.56	30.94	20	38
ACI/SW3	5.91	5.73	125	420	82	200	20.68	18.67	0.96	1.69	4.01	6.8	1.01	1.37	25	22	36.32	25.12	10	11
ACI/SW4	4.03	3.33	180	980	120	467	14	10.54	2.6	2.5	3.1	5.5	1.2	2.4	22	33	33.6	11.5	10	10
ACI/SW5	3.78	2.87	180	890	82	460	18	18.54	2.5	3.1	1.92	8.5	1.5	2.6	20	20	36.12	33.54	10	14
ACI/SW6	4.06	3.03	190	780	73	380	20	18	1.5	3.2	1.8	6.2	10	3.6	26	22	31.94	27.4	15	10
ACI/SW7	6.11	4.88	125	450	56	290	15.2	21.79	1.01	2.01	3.86	7.3	1.22	3.92	10	30	29.54	28.6	18	10
ACI/SW8	5.82	4.06	170	610	54	300	18.3	21.63	0.91	1.08	2.91	6.6	1.5	2.5	22	35	23.6	10.32	10	15
ACI/SW9	5.81	5.73	90	420	38	220	16.8	16	1.02	2.01	2.86	8.8	1.6	4.31	25	32	10.6	11.6	18	12
ACI/SW10	6.32	5.13	110	510	80	265	10.9	12.05	1.08	2.68	3.01	6.81	1.37	1.22	10	18	12.56	18.12	15	15
ACI/SW11	7.18	6.5	100	430	52	225	11.2	12.03	1.81	2.22	2.61	5.8	0.89	1.66	16	25	12.09	12.09	16	10
ACI/SW12	6.23	5.87	125	320	53	185	21.9	15.67	2.32	4.31	1.92	8.3	1.37	1.22	20	25	19.54	23.6	15	20
ACI/SW13	5.32	6.8	215	480	42	230	12.9	14.39	1.08	2.12	2.08	8.61	0.99	1.5	16	21	18.4	17.6	10	15
ACI/SW14	5.87	5.13	300	520	48	240	18.1	18.05	2.12	2.89	1.92	4.92	1.5	1.6	30	24	13.6	18.56	12	12
ACI/SW15	7.12	4.36	280	480	100	220	15.1	15.8	2.1	3	2.21	6.3	1.1	2.5	20	25	13.6	16.22	15	10
ACI/SW16	5.37	5.61	125	325	82	182	18.01	10.03	1.01	1.21	2.01	6.6	0.23	2.5	20	10	13.22	13.8	12	15
ACI/SW17	4.97	4.06	85	380	41	200	13.22	16.4	1.01	1.45	1.08	6.8	1.5	2.5	15	25	16.08	16.22	15	10
ACI/SW18	5.82	4.37	190	410	100	200	15.86	13.3	0.81	2.22	1.68	6.32	1.01	4.31	20	21	13.8	24.3	16	10
ACI/SW19	5.32	3.87	120	380	55	180	14.02	12.03	1.02	2.01	0.91	4.65	0.91	1.37	20	14	12.32	16.6	10	15
ACI/SW20	5.82	5.71	100	300	44	150	13.01	10.79	1.01	0.98	1.02	0.51	1.91	1.39	21	10	10.08	17.09	10	10
ACI/SW21	5.17	5.81	82	280	40	110	20.01	10.05	1.01	1.69	1.01	1.26	1.73	1.37	20	10	10.09	12.03	12	16

The SAR values within the acceptable range were found. Water samples were obtained in one-liter bottles of precleaned, sterilized polyethylene. At Eku River in dry season, the highest SAR was 0.56. All the sampling stations were found using Class III permeability index as shown in Table 1. RSC values were found to be small in all the sampling stations and water from Table 1 was found to be sufficient as per RSC standards. The sodium percentage values were observed to be higher in most of the sampling stations and were classified as good and excellent. Figure 2 and 3 provided the variations of four indices of all sampling stations for two seasons at both rainy and dry.

Table 3: Irrigation indices (All values are expressed in Meq/L).

Sample ID	**SAR**		**PI**		**Na%**		**RSC**	
	Rainy	Dry	Rainy	Dry	Rainy	Dry	Rainy	Dry
ACI/SW1	0.29	0.35	39.7	52.9	17.9	21.0	11.26	20.05
ACI/SW2	0.16	0.37	43.4	47.6	7.7	20.1	19.36	12.34
ACI/SW3	0.23	0.40	39.1	43.5	15.0	23.8	14.68	4.76
ACI/SW4	0.20	0.40	45.2	48.0	14.8	26.3	17	-1.54
ACI/SW5	0.11	0.48	35.4	47.4	8.0	26.0	15.62	11.9
ACI/SW6	0.10	0.35	32.0	41.7	5.4	20	10.44	6.2
ACI/SW7	0.30	0.40	46.3	40.7	18.1	20.8	13.33	4.8
ACI/SW8	0.18	0.38	35.1	33.5	12.3	20.7	4.39	-12.39
ACI/SW9	0.18	0.55	29.6	45.5	12.8	28.3	-7.22	-6.41
ACI/SW10	0.23	0.46	43.7	51.4	18.4	29.9	0.58	3.39
ACI/SW11	0.19	0.40	39.0	46.3	15.8	26.7	-0.92	-2.16
ACI/SW12	0.10	0.48	24.3	46.5	7.0	28.1	-4.68	3.62
ACI/SW13	0.15	0.56	39.7	51.0	12.2	32.3	4.42	1.09
ACI/SW14	0.11	0.28	25.3	35.7	8.1	17.9	-6.62	-2.38
ACI/SW15	0.14	0.38	30.4	41.1	10.8	22.8	-3.6	-2.58
ACI/SW16	0.12	0.52	26.8	57.8	9.5	32.4	-5.8	2.56
ACI/SW17	0.10	0.43	33.2	43.9	6.4	25.0	1.85	-1.63
ACI/SW18	0.11	0.42	29.4	51.5	8.7	24.2	-2.87	8.78
ACI/SW19	0.06	0.33	27.7	46.7	5.4	23.2	-2.72	2.56
ACI/SW20	0.07	0.04	27.9	37.8	6.0	3.7	-3.94	5.32
ACI/SW21	0.06	0.10	19.0	36.4	4.3	8.8	-10.93	0.29

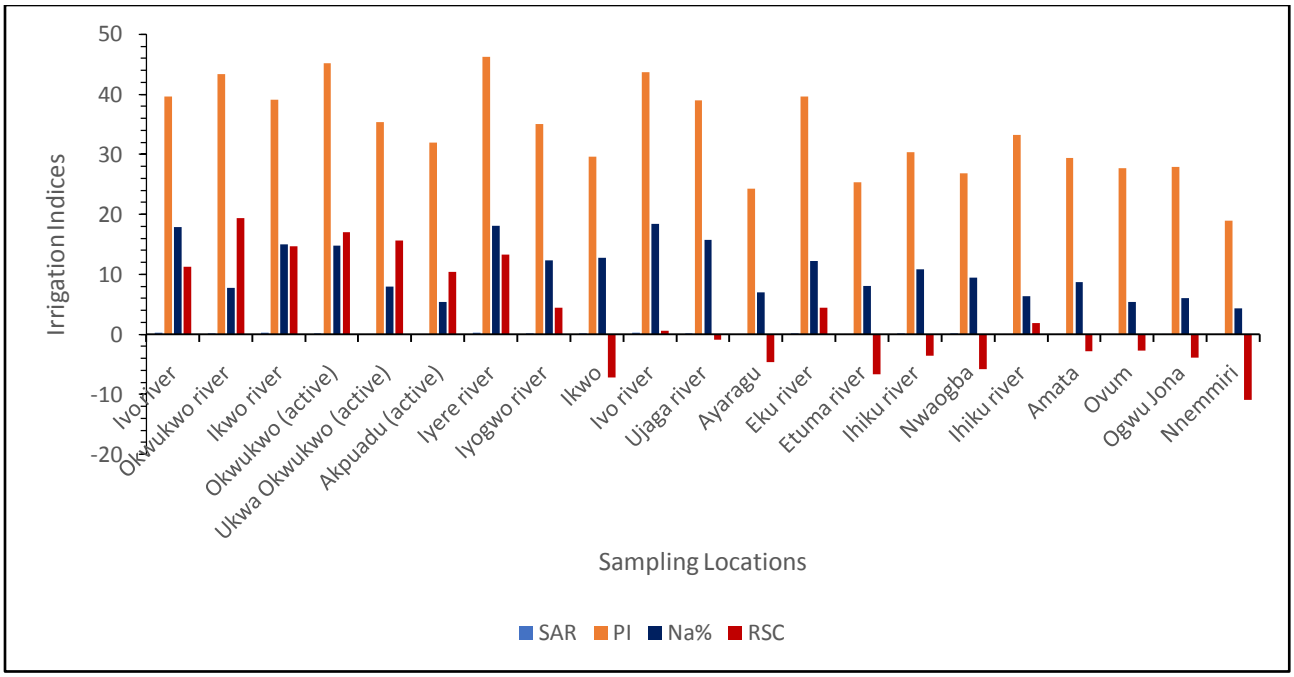

Figure 2: Variation of irrigation indices of sampling stations (rainy season).

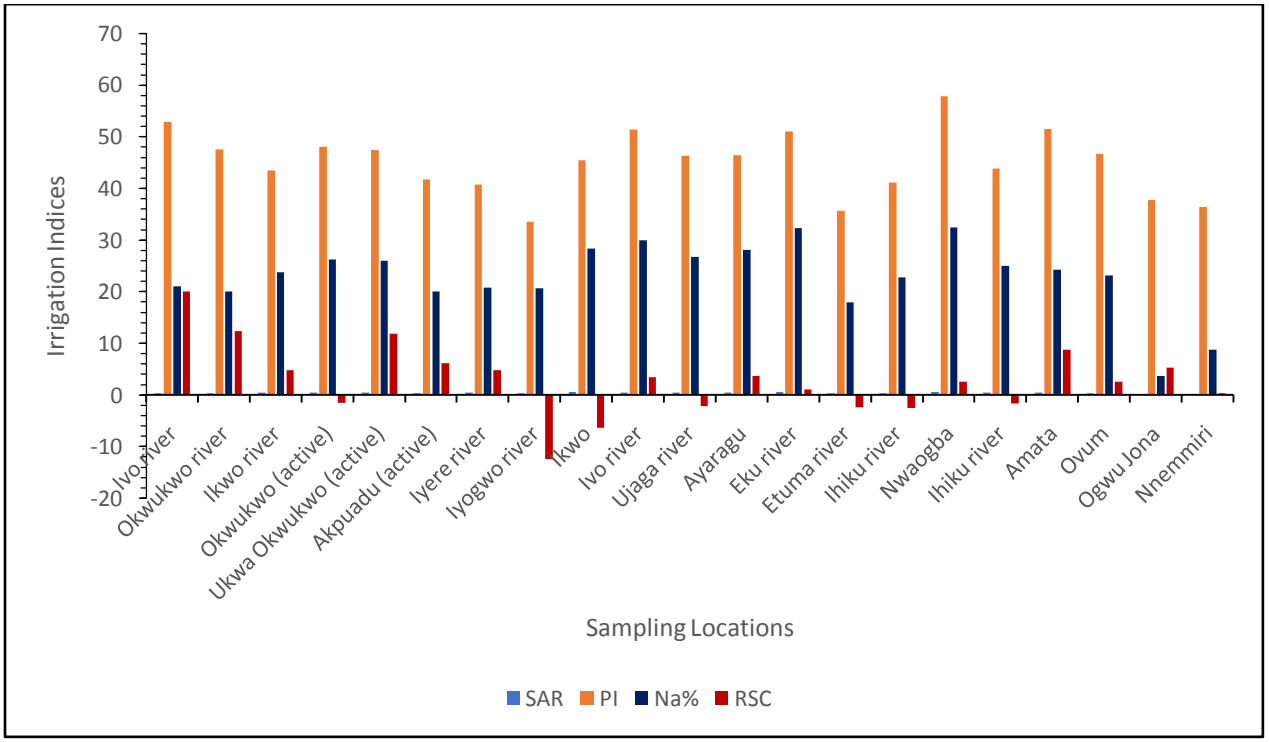

Figure 3: Variation of irrigation indices of sampling stations (dry season).

CONCLUSION

Evaluation of surface water quality for irrigation was carried out using four indices like SAR, PI, RSC and Na%. The values of SAR and PI were found to be within permissible range. The value of RSC was found to vary from -0.92 to 20.05 and was extremely suitable. The values of Na% were found between good to excellent class. Therefore, the water quality was found to be suitable for irrigation purpose as per SAR and PI, RSC and Na%. The water is recommended to be checked further for other indices and has to be confirmed if the same could be used for irrigation purpose.

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