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Graphic Interpretation and Assessment of Surface Water Quality Index in Ishiagu, Southeastern Nigeria

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Abstract: The improvement in surface water quality in the Ishiagu region was determined by using a modified water quality index. A total of 21 surface water samples were collected from different locations in the study area and analyzed in the laboratory using standard method (APHA, 1995). Cations and anions were dominated in the order of $Ca^{2+} > Na^{+} > Mg^{2+} > K$ for cations, and $HCO_3^{-} > Cl^{-} > SO_4^{2-} > NO_3^{-}$ anions. Ten criteria for measuring the WQI have been considered, such as: pH, electrical conductivity, total dissolved solids, calcium, magnesium, sodium, potassium, chloride, nitrate and sulphate. The calculated WQI shows that 1 percent of the total surface water samples fall in Good category while 99 percent of the samples are in the excellent category. Under normal conditions these waters are good for drinking purposes, and no further action is required for salinity control. Upon careful examination of the results, it was found that most parameters of water quality were below the required limit recommended by NDWQS, making the water safe for human use.

Keywords: Ishiagu**,** Surface water, Anthropogenic, Water quality index, Nigeria Drinking Water Quality Standard.

INTRODUCTION

In daily life, water supplies are becoming increasingly challenging, based on population growth, the pace of development of food stocks and the developing industry. Groundwater is the world's most essential source of fresh water, based on quality and value (Neag, 2000). Alterations in the local topography and drainage system have a significant effect on both surface water quality and quantity (Vasanthavigar et al., 2010). Once the surface water is polluted, its quality cannot be recovered by stopping the contaminants from the source; thus, it is very necessary to track the groundwater quality periodically, and to devise ways and means of preserving it. WQI, a water quality assessment system, is an important method for measuring spatial and temporal improvements in groundwater quality and for transmitting water quality knowledge to the people and policy makers concerned (Mishra and Patel, 2001). WQI is defined as a rating that represents the composite influence of various parameters of water quality, measured from the point of view of the suitability of surface water for consumption by humans. WQI has been applied effectively to evaluate water quality during the last years, as it helps to consider water quality problems by combining diverse data and producing a score reflecting water quality status. WQI is a mathematical method for translating broad data on water quality into a simple cumulatively generated number. This reflects a certain level of water quality, thus removing the subjective quality evaluation (Stambuk-Giljanovic, 1999). The purpose of an index is to turn multidimensional water quality data into basic information which the public can understand and use. It is one of the cumulative indices acknowledged as a ranking that represents the cumulative effect on the entire quality of numbers of specific characteristics of water quality. WQI represents a combined effect of factors contributing to water quality for any water system (Kakati and Sarma, 2007). WQI is a very well-known method and among the most powerful tools for communicating water quality which provides a clear, reliable, replicable unit of measurement and communicates water quality information to policy makers and concerned citizens. Therefore, it is a significant parameter for groundwater appraisal and control (Chauhan et al., 2010). WQI helps to categorize the water, if it is suitable for drinking or not. The water quality index estimation initially started with Horton (1965). The pollutants that physically and chemically change the water quality can be represented entirely in WQI. WQI is a mathematical equation representing water quality by collating water quality parameter indicators (such as pH, nitrate, sulfate, chloride, bicarbonate, calcium, magnesium, etc.).

The aim of this study was to determine the contamination level of the surface water in Ishiagu using the WQI to reveal the irrigation water quality and to determine the relationship among the variables and sources of the contaminants.

STUDY AREA

This study was carried out in the Ishiagu area, located in the Ivo local government area of the Ebonyi State, Southeastern Nigeria. The area, comprising approximately 181 km^2, is bounded within latitudes 5°48'00" N to 6°0'00" N and longitudes 7°26'00" E to 7°38'00" E. The area has a population of about 300,000 inhabitants (2006 census) with major mining industries including Ishiagu Crushrock, Green Field and Palladium Mining Companies. The traditional economic base in the area is Agriculture with over 80% of the people engaged in small scale farming and fishing. The climate is tropical with a temperature range of 25°C in rainy and 32°C in dry seasons respectively. The average annual rainfall varies from 1100 to 1350mm (Inyang, 1985). The study area lies within the tropical rainforest/Guinea Savannah belt of Nigeria (Iloeje, 1978). The study area is characterized by two types of topography; the vast plain lowland areas and elevated highlands which are mostly the hilly areas. The elevation of the area ranges from about 50-100meters above sea.

Ishiagu area is located in the sedimentary basin of Southeastern Nigeria, and forms part of the Afikpo Basin in the Southern Benue Trough. Ishiagu is underlain by the oldest sedimentary sequences of southern Nigeria. These include the following formations: Asu River Group (Albian) Eze-Aku Group (Turonian) and Awgu Group (Coniacian). Scattered intermediate intrusive rocks of various sizes and forms also occur commonly (Figure 1).

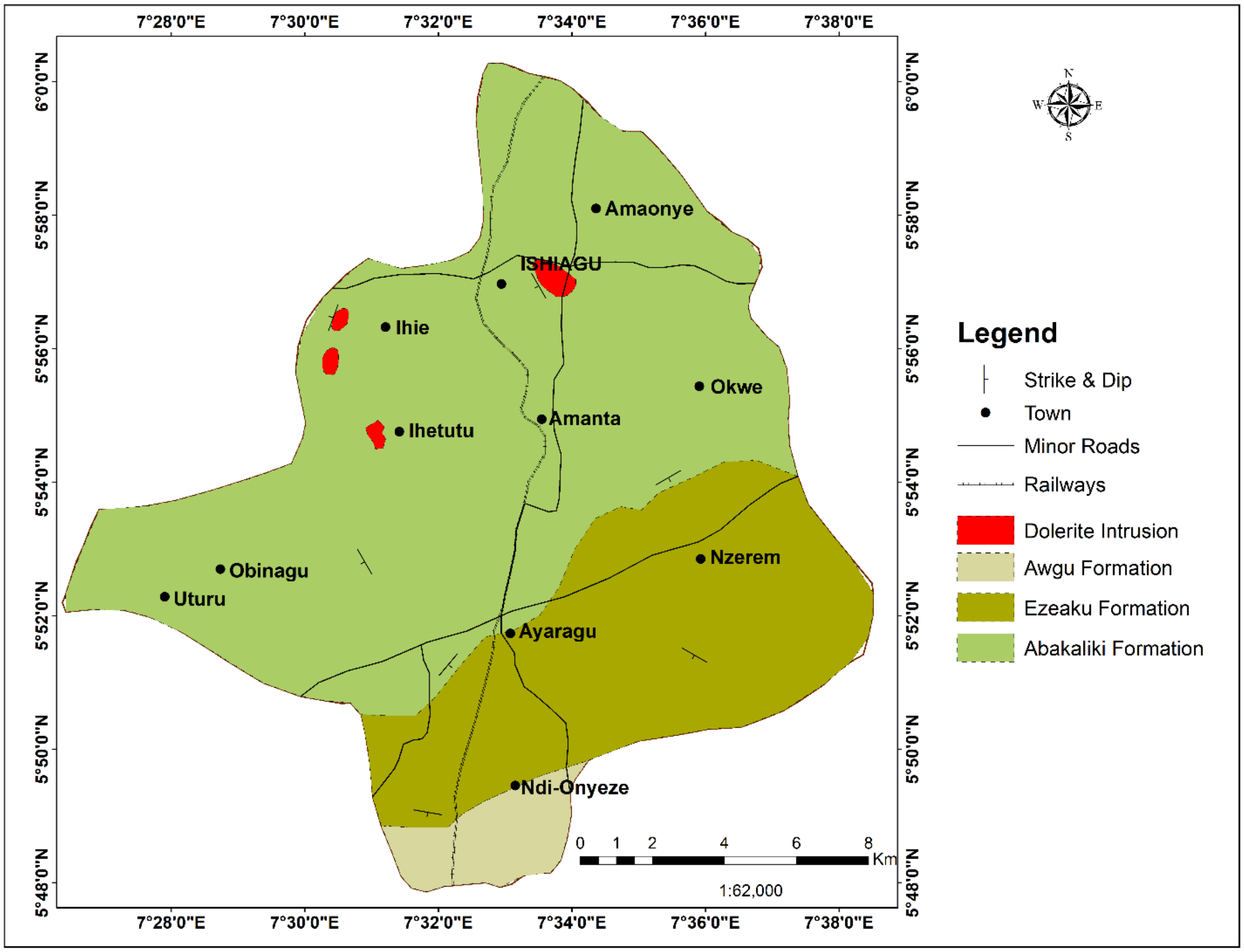

Figure 1: Geologic map of the study area.

MATERIALS AND METHODS

Systematic sampling was conducted during rainy and dry seasons, 2017 to 2018, to determine surface water quality in Ishiagu. Twenty-one surface water samples from the rivers were obtained in the area (Figure 2). The surface water samples were obtained in pre-washed polyethylene bottles. A portable conductivity and pH meter were used to calculate the electrical conductivity (EC) and pH values in the field. In the laboratory the water samples were filtered to isolate suspended particles using 0.45 lm Millipore membrane filters. The APHA (1996) approved standard was the employed laboratory physicochemical analysis method.

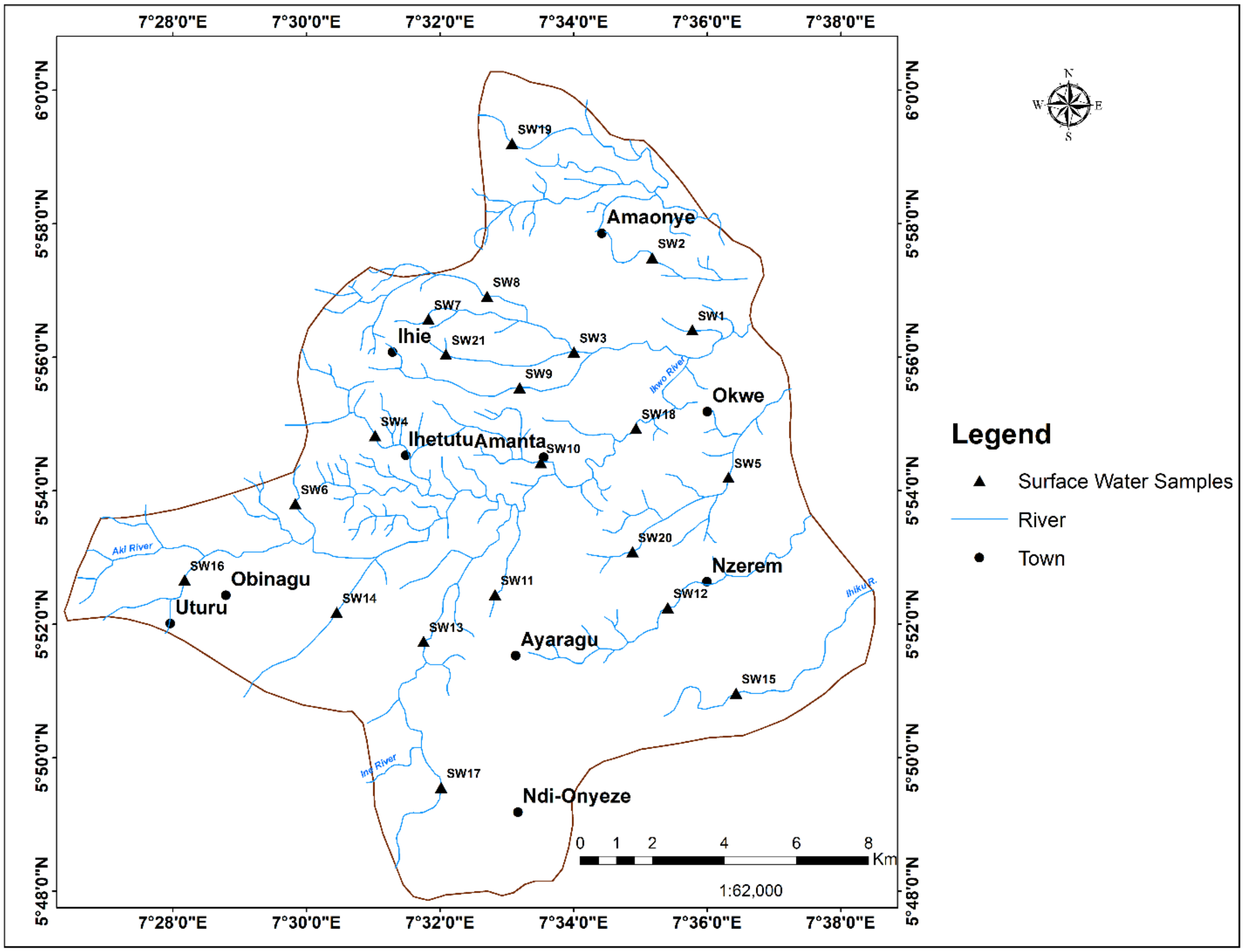

Figure 2: Surface water sampling map of the study area.

RESULTS AND DISCUSSION

Table 1 summarizes the physicochemical parameters of the examined surface water samples. Surface water of the study area varied from strongly acidic to slightly alkaline with pH values ranging from 3.78 to 7.18 and from 2.87 to 6.8 for both rainy and dry seasons respectively. The electrical conductivity (EC) value of the water samples varies from 82 to 310µs/cm and from 280 to 980µs/cm. The surface water samples show a total dissolved solids (TDS) content within the range 38-120mg/l in the rainy season and from 110 to 467mg/ during dry season. Calcium was among the main cations with the dominant ions forming an average of 39 per cent of the total cations for both rainy and dry seasons. Sodium and magnesium ions were of secondary importance, representing respectively on average 31 and 25 per cent of total cations. Potassium was the least prevalent cation and represented 5% of the total cations. Cation abundance was ordered $Ca^{2+} > Na^{+} > Mg^{2+} > K^{+}$ (Figure 3). Bicarbonate was typically dominant among the major anions and comprised 61 per cent of the total anions for both rainy and dry season. Chloride is the next predominant anion, comprising 23 per cent of total anions. sulphate was less effective ions and contributed 7 per cent respectively to total anions. Nitrate is the less powerful anion of the overall anion. The ordering of the surface occurrence of anions has been found as $HCO_3^- > Cl^- > SO_4^{2-} > NO_3^-$.

Table 1: Analyzed physicochemical parameters of the study area.

Sample ID	**pH**		**EC (µs/cm)**		**TDS (mg/l)**		**Ca^{2+} (mg/l)**		**Mg^{2+} (mg/l)**		**Na^{+} (mg/l)**		**K^{+} (mg/l)**		**Cl^{-} (mg/l)**		**HCO_3^{-} (mg/l)**		**SO_4^{2-} (mg/l)**		**NO_3^{-} (mg/l)**	
	RS	DS	RS	DS	RS	DS	RS	DS	RS	DS	RS	DS	RS	DS	RS	DS	RS	DS	RS	DS	RS	DS
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	2.65	3.68
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	8.61	2.44
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	1.89	3.68
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	7.12	3.47
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	4.12	2.65
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	6.24	6.11
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	1.78	3.68
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	2.68	3.47
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	1.41	3.89
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	1.78	1.89
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	2.65	1.78
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	1.41	3.46
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	2.68	2.44
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	3.68	3.2
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	4.81	4.1
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	4.1	3.2
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	5.61	3.68
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	2.65	2.65
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	1.41	3.55
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	2.65	3.2

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	1.41	4.11

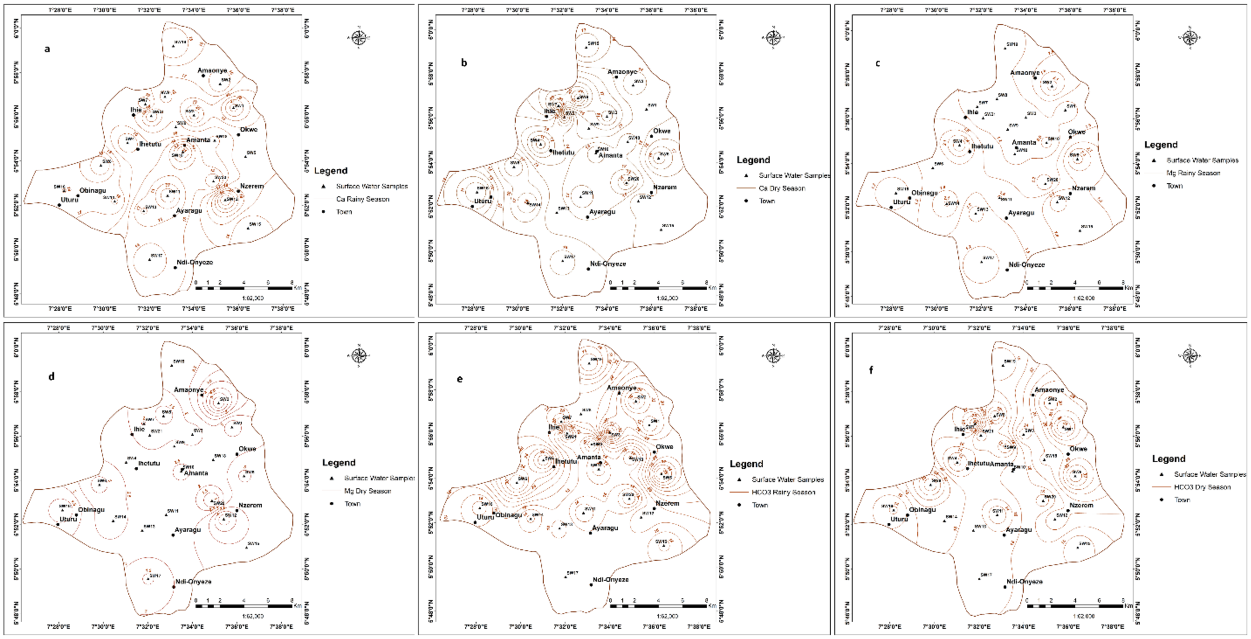

Figure 3: Spatial distribution map of physicochemical parameters. **a, b,** Ca^{2+}**; c, d,** Mg^{2+}: **d, f,** HCO$_3^-$

WATER QUALITY INDEX (WQI)

The water quality index is among the most important tools for both surface and groundwater monitoring. It can be used effectively in implementing programs for upgrading water quality. The purposes of an index are to translate highly complex water quality data into simple information that the public can understand and use. It is among the aggregate indices agreed as a ranking which represents the effect of the composite on the general quality of numbers of specific water quality types. Water quality index offers rating scale information from zero to hundred. WQI's higher value suggests better water quality, and the lower value demonstrates poor water quality. WQI is classified as a rating which represents the composite impact of various water quality parameters, calculated from the perspective of groundwater suitability for human consumption. The WQI framework was first used by Horton (1965), then improved by Brown et al. (1970) and further refined by Deininger (1975, Department of Scottish Development). WQI is a well-known method and one of the most valuable tools for transmitting water quality, providing a simple, reliable, reproducible unit of measurement and communicating water quality information to policy-makers and concerned citizens (Singh et al., 2013).

Estimation of WQI

The Water Quality Index (WQI) is defined as a rating procedure that gives the composite effect of individual water quality parameters on the general water quality (Singh et al., 2013). WQI is a mathematical formula used to turn a considerable number of data regarding water quality into a single number (Stambuk-Giljanovic, 1999). For decision-makers it is simple and easy to understand about the efficiency and future uses of any water body (Bordalo et al., 2001). The water quality data of the analyzed samples were matched with the recommended drinking water level of NDWQS (2007) for the measurement of the WQI in order to evaluate the eligibility of drinking water. Nigeria Drinking Water Quality Standard (NDWQS, 2007) for drinking water along with its respective WQI status categories. Three measures are taken when computing the

WQI. In the first stage, a weight (wi) was assigned to each of the 10 parameters (pH, EC, TDS, Ca^{2+}, Mg^{2+}, Na^{+}, K^{+}, Cl^{-}, SO_4^{2-} and NO_3^{-}) as per its significance for the overall quality of drinking water (Table 2). The maximum weight of 5 was allocated to parameters like TDS, Na^{+}, Cl^{-}, NO_3^{-} and SO_4^{2-} according to their great importance in the determination of water quality (Vasanthavigar et al., 2010). K^{+} has a minimum weight of 1. Other parameters, such as pH, EC, Ca^{2+}, Mg^{2+}, were given a weight (wi) of 3 to 4 depending on their significance in determining water quality. In the second step, the relative weight (Wi) is determined from the following equation, since it plays relevant role in the assessment of water quality.

$$Wi = \frac{wi}{\sum_{i=1}^{n} wi} \quad - \quad - \quad - \quad - (1)$$

Where:

Wi is the relative weight, wi is the weight of each parameter, and n is the number of parameters.

Table 2: Chemical parameters corresponding to the NDWQS (2007).

Chemical parameters	**Standards (NDWQS)**	**Weight (wi)**	**Relative weight (Wi)**
pH	8.5	4	0.11
EC	1000	3	0.08
TDS	500	5	0.14
Ca^{2+}	75	3	0.08
Mg^{2+}	30	3	0.08
Na^{+}	200	5	0.14
K^{+}	100	1	0.03
Cl^{-}	250	5	0.14
SO_4^{2-}	100	5	0.14
NO_3^{-}	45	5	0.14
		$\sum W_i = 36$	$\sum W_i = 1.08$

All concentration in mg/l, except pH and EC (µs/cm).

In Table 2 the calculated relative weight (Wi) values for each parameter are given. In the third step a quality rating scale (qi) is given for each parameter by dividing its concentration in each water sample by its respective norm according to the regulations set out in the NDWQS (2007) and multiplying the result by 100.

$$q_i = (C_i/S_i) \times 100 \quad - \quad - \quad - \quad - \quad - (2)$$

Where qi is the quality ranking, Ci is the mg/l concentration of each chemical parameter in each water sample, and Si is the mg/l NDWQS norm for each chemical parameter in compliance with the NDWQS guidelines (2007).

$$SI_i = W_i \times q_i \quad - \quad - \quad - \quad - \quad - \quad - (3)$$

$$WQI = \sum SI_{i-n} \quad - \quad - \quad - \quad - \quad - (4)$$

The SI is first calculated for each chemical parameter for calculating the WQI, which is then used to calculate the WQI according to the following equation where the SIi is the sub-index of the ith parameter, qi is the concentration-based rating of the ith parameter and n is the number of parameters. Class of water quality, was calculated on the basis of the WQI. Classification of WQI distribution and water level is represented Tables 3.

Figure 4 indicates the spatial distribution of the water forms during rainy and dry seasons, respectively. From the WQI maps the area covered by different types of water is estimated and given in Table 4. The water types distribution shows that the majority of the region is filled

in rainy and dry season by " Excellent water " respectively.
“Good water " emerges in few regions during both seasons.

Table 3: Classification of WQI range and category of water.

WQI	**Status**
<50	Excellent water
50 – 100	Good water
100 – 200	Poor water
200 – 300	Very Poor water
>300	Unfit for drinking purpose

Table 4: Water quality index for surface water in Ishiagu.

Sample ID	**WQI**		**Status**
	Rainy Season	**Dry Season**	
ACI/SW1	19.1974	26.0984	Excellent water quality
ACI/SW2	48.2305	52.1325	Poor water quality
ACI/SW3	17.4795	15.4091	Excellent water quality
ACI/SW4	17.0006	19.4116	Excellent water quality
ACI/SW5	15.0718	14.3217	Excellent water quality
ACI/SW6	37.4911	53.4024	Good water quality
ACI/SW7	17.1508	56.5071	Good water quality
ACI/SW8	17.1966	20.2363	Excellent water quality
ACI/SW9	16.9469	18.5518	Excellent water quality
ACI/SW10	17.7164	14.2970	Excellent water quality
ACI/SW11	16.8413	16.1933	Excellent water quality
ACI/SW12	17.7925	23.3597	Excellent water quality
ACI/SW13	15.3861	17.1068	Excellent water quality
ACI/SW14	19.1014	50.3019	Good water quality
ACI/SW15	20.4093	20.9126	Excellent water quality
ACI/SW16	14.4494	16.2433	Excellent water quality
ACI/SW17	16.0589	18.1059	Excellent water quality
ACI/SW18	17.2823	15.1853	Excellent water quality
ACI/SW19	14.3296	16.5246	Excellent water quality
ACI/SW20	16.9394	23.4990	Excellent water quality
ACI/SW21	15.1419	15.3649	Excellent water quality

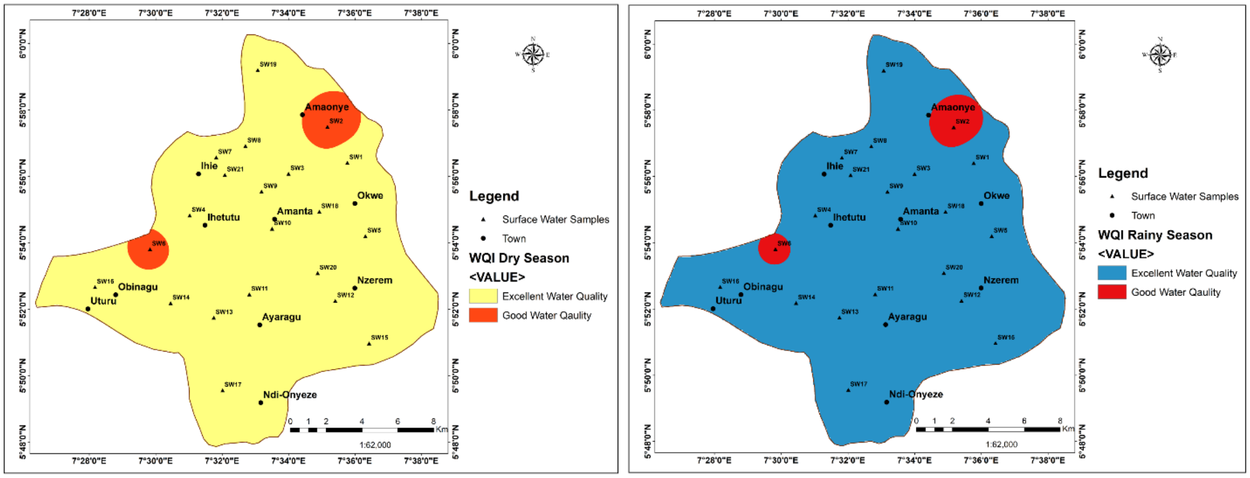

Figure 4: Water quality index (WQI) map for both rainy and dry seasons.

CONCLUSION

This paper presents the surface water quality assessment of Ishiagu. Twenty-one samples were taken from various sites within the field. The field of research, surface water is mildly alkaline in nature. Surface water chemistry is dominated by Ca^{2+}, Na^{+} and HCO_3^{-}, as well as SO_4^{2-}. The evaluated parameters are well within the appropriate limits in most samples, and water is potable for drinking. Various natural causes such as rock weathering and anthropogenic sources, such as mining activity and agricultural waste may be responsible for the little increase of Ca^{2+}, HCO_3^{-}, and SO_4^{2-} in the surface water of this region. The WQI values showed higher low category rate. This indicates that the water is fit for immediate use and requires no treatment prior to its use.

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