Scientia Africana, Vol. 14 (No.2), December 2015. Pp 22-32
 ISSN 1118 – 1931

DETERMINATION OF WATER QUALITY INDEX AND PORTABILITY OF IGUEDO STREAM IN EDO STATE, NIGERIA.

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Received: 02-07-15
Accepted:02-09-15

ABSTRACT
The water quality index (WQI) and portability of Iguedo Stream in Edo State were determined in this study. The WQI was computed from pH, electrical conductivity, total dissolved solids, chloride, nitrate, sulphate, sodium, magnesium, iron, zinc, copper, lead, manganese, nickel, cadmium and chromium characterized in three designated stations along the stream for a period of six months (January to June, 2014). The Nigerian standards for drinking water quality was used as basis for the computations. With the exception of nickel other physicochemical parameters characterized showed no significant difference (p>0.05) among the stations. Furthermore with the exception of pH and Nickel, the values of the rest of the parameters analyzed complied favourably with Nigerian standards for drinking water quality. The WQI values at stations 1, 2 and 3 were 116.92, 67.22 and 61.87 respectively. These values showed that the water quality at station 1 was poor while stations 2 and 3 were good. Levels of precipitation, weathering and auto-purification capacity of this ecosystem are the natural processes accountable for variations recorded in the WQI values obtained across the stations and study duration. The parameters that most influenced the WQI as depicted by quality rating values include pH, Mn, Ni, Cd and Pb. Application of WQI in this study has been found functional in assessing the water quality of this stream based on the selected parameters.

Key words: Water quality index, physicochemical parameters, Iguedo Stream.

INTRODUCTION
Urbanisation, intensive Agriculture, recreation and the manufacturing industries are affecting water quality throughout the world. Contamination of water bodies by heavy metals have been a global problem especially in developing countries like Nigeria (Alinnor and Obiji (2010). African aquatic environments are increasingly exposed to pollution as a result of the growth in Agricultural and industrial development (Nakayama *et al*., 2010). Water is essential to the continuance of all living organisms on earth but this valued resource is more and more being overused as human populations grow and demand more water of high quality for domestic purposes and economic activities. Water abstraction for domestic use, agricultural production, mining, industrial production,

power generation, and forestry practices can lead to deterioration in water quality and quantity that impact not only the aquatic ecosystem, but also the availability of safe water for human consumption (UNEP GEMS, 2006).This deterioration in water quality and quantity is mostly as a result of poor awareness and civic sense, use of inefficient methods and technology in treatment of waste and the wrong idea that water is a universal receptacle that absorbs all sort of waste. Pollution and deterioration of the earth's water resources is rendering much of the available water unsafe for consumption. In many localities in Nigeria, the usual sources of drinking water are streams, rivers, wells and boreholes which are usually not treated.

Nowadays, pollution and deterioration of aquatic bodies in Nigeria is on increase. This is as a result of inability of the authorities to keep a pragmatic check on this issue and effectively enforce existing laws on pollution control. These increasing imbalances and anomalies create a state of uncertainty on the long term availability of water resources. Accurate information on the condition and trends of water resources quality is one of the basic conditions for economic and social development, and for the development and maintenance of ecosystem integrity.

This study was focused towards evaluation of water quality of Iguedo Stream in Edo State as riverine water quality either directly or indirectly is an important issue for human beings. The specific objectives include monitoring the levels of selected physicochemical parameters with notable health risks and further assessing the portability of the water of the stream using water quality index (WQI) since this stream is the major source of water for drinking and domestic purposes in Iguedo community.

A water quality index is a means to summarize large amounts of water quality data into simple terms (e.g., good) for reporting to management and the public in a consistent manner (Ashwani and Anish, 2009). Similar to other environmental matrix indices, it furnishes us with clear information on whether the overall quality of water bodies poses a potential threat to various uses such as aquaculture practices, irrigation water for agriculture and livestock, recreation and aesthetics, and drinking water supplies. Basically a WQI attempts to provide a mechanism for presenting a cumulatively derived, numerical expression defining a certain level of water quality (Miller *et al.*, 1986). It is one of the most effective tools to communicate information on the quality of water to the concerned populace and policy makers. Assessment of water is not only for suitability for human consumption but also in relation to its agricultural, industrial, recreational, commercial uses and its ability to sustain aquatic life. To underpin its importance, World Health Organisation (WHO), United Nations Environmental Programme (UNEP), United Nations Educational, Scientific and Cultural Organisation (UNESCO) and World Meteorological Organisation (WMO) launched in 1997, a water monitoring programme to collect detailed information on the quality of global ground and surface water. The present water quality monitoring status in Nigeria involves monitoring only ground water once every year by each state's water board using FEPA standards. There is no integrated water quality monitoring scheme in Nigeria (Ekiye and Luo, 2010).

This study was carried out to determine the water quality index (WQI) and portability of Iguedo Stream in Edo State.

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MATERIALS AND METHODS

Study Area

Iguedo Stream (Fig.1) is located within latitudes (N06°42-N06°43) and longitudes (E05°22, E05°22) in the tropical rainforest belt of southern Nigeria. This stream is the major source of water used by the populace of the community for most of their domestic purposes. It is also a source of drinking water for the populace. Other human activities witnessed during the period of this study include washing and processing of farm produce and fishing. The dominant vegetation of this area comprises trees and shrubs particularly Indian bamboo and water hyacinth.

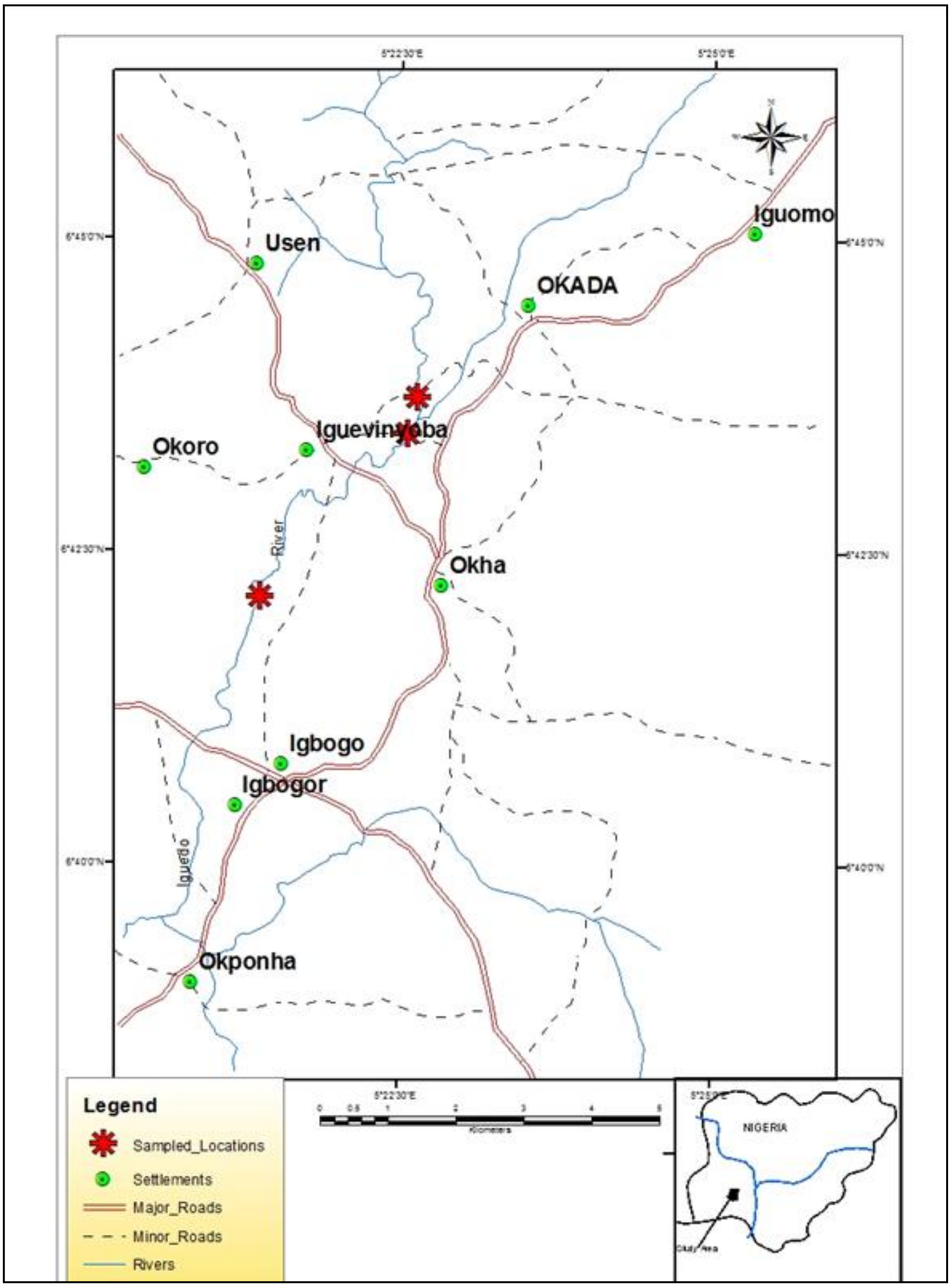

Figure 1: Map of Study Area Showing Sampled Stations

Three sampling stations were selected: Station 1(upstream); Station 2 (midstream) and Station 3 (downstream). At stations 1 and 2, the substrata were sandy with decaying plant particles. The stream at these two stations were partially shaded by Indian bamboo plants. Located close to station 1 is a palm oil mill which channel their effluent to this stream. We were not granted access further head stream of station 1 because of the shrine located therein. At station 2 located downstream of station 1, human activity is restricted to occasional processing and washing farm produce. The substratum at station 3 was muddy with decaying organic matter. The only human activity observed at station 3 was fishing.

Sampling

The water samples were collected from three designated sampling stations along a certain stretch of the stream monthly from January through June, 2013. The stations were visited between the hours of 9:00am and 12:00 noon on each sampling day. pH, electrical conductivity (EC) and total dissolved solids (TDS) were determined in-situ using Extech meter probes (Exstik II). Subsurface water samples for analyses order than heavy metals were collected using a 2 litre capacity plastic container. The water samples for heavy metal analyses were collected in acid washed 1 litre capacity polyethylene bottles. Prior to the sampling, all the containers were labeled properly and while in the field, the labeled bottles were rinsed several times with the water at designated stations and samples were collected at about 50 cm below the water surface. The water samples for heavy metal analyses were acidified with 2 ml of concentrated nitric acid in order to keep the required species of cations in solution, and slow down biological changes. The acid pre-treatment ensured that heavy metals did not get adsorbed to the surface of the container during transportation and storage. All water samples were collected in triplicates and homogenized before being sub-sampled for physico-chemical analyses. Each water sample immediately after collection was placed in an ice chest.

Laboratory Analysis

The water samples were analyzed for selected physico-chemical parameters using standard methods adopted from APHA (1998) and Radajevic and Bashkin (1999). Sulphate (SO_4^{2-}) concentration was determined using spectronic 2ID spectrophotometer. Chloride (Cl^-) and nitrate (NO_3^-) concentrations were determined by Mohr's and colorimetric methods respectively. Technicon auto analyzer flame photometer (IV) was used in determination of Sodium (Na^+) concentration while magnesium (Mg^{2+}) was determined by EDTA titrimetric method.

Heavy metals were determined after digestion of the solution of the samples. Water samples digestion was carried out by taking 10 ml of the sample and adding 4ml Perchloric acid, 20 ml concentrated nitric acid and 2ml concentrated tetraoxosulphate VI acid. This was digested using aluminum block digester 110. The mixture was heated until white fumes evolved and clear solution obtained. After digestion, the samples were allowed to cool and then transferred to 100 ml volumetric flask. This was made up to 100 ml with distilled water and thoroughly mixed. The sample was allowed to stand overnight (in place of centrifuge) to separate insoluble materials. It was then filtered through 0.45 μm Millipore type filter. Iron (Fe), Zinc (Zn), Copper (Cu), Lead (Pb), Manganese (Mn), Nickel (Ni), Cadmium (Cd) and Chromium (Cr) were determined using Unican 929 Atomic Absorption Spectrometry.

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Data Analysis

Measures of central tendency (mean) and dispersion (standard deviation and range) were adopted in analysing the data obtained from field and laboratory. One way analysis of Variance with Duncan multiple range post hoc was used for the statistical analysis of results obtained at 95% confidence level. These analyses were computed using the computer application SPSS 16.0 and Microsoft Excel - 2007 for windows.

Water Quality Index

In current study, Water Quality Index (WQI) was calculated by using the Weighted Arithmetic Index method as described by (Cude, 2001). In this model, different water quality components are multiplied by a weighting factor and are then aggregated using simple arithmetic mean.

For assessing the quality of water in this study, firstly, the quality rating scale (ø) for each parameter was calculated by using the following equation;

ø = {[(Å – Ï) / (Ş – Ï)] * 100} --- Equation 1

Where

- ø = Quality rating of nth parameter for a total of n water quality parameters.
- Å = Actual value of the water quality parameter obtained from laboratory analysis.
- Ï = Ideal value of that water quality parameter which can be obtained from the standard Tables. Ï for pH = 7 and for other parameters it is equalling to zero, but for DO, Ï = 14.6 mg/L
- Ş = Nigerian Industrial Standard – NIS (2007). Nigerian Standard for Drinking Water Quality

Then, after calculating the quality rating scale (ø), the Relative (unit) weight (Ŧ) was calculated by a value inversely proportional to the recommended standard (Ş) for the corresponding parameter using the following expression;

Ŧ = 1/ Ş -------- Equation 2

Where,

- Ŧ = Relative (unit) weight for nth parameter
- Ş = Standard permissible value for nth parameter
- 1= Proportionality constant.

Finally, the overall WQI was calculated by aggregating the quality rating with the unit weight linearly by using the following equation:

WQI = Σ Ŧ ø / Σ Ŧ ------- Equation 3

Where,

- ø = Quality rating
- Ŧ = Relative weight

Table 1: Grades of Water Quality Index (WQI) and status of water quality (Modified from Ramakrishniah *et al.*, 2009)

Water Quality Index Levels	Description
< 50	Excellent
51 – 99	Good
100 – 199	Poor
200 – 299	Very poor (bad) water
> 300	Unsuitable (unfit)for drinking

RESULTS

Table 2 shows the summary of the characterized physico-chemical parameters across the three stations, the mean, standard deviation, range, level of significance and NIS standard for drinking water are inclusive in the table. The water was slightly acidic and pH values ranged from 5.32-5.95 across stations. The highest level of variability in terms of EC and TDS was recorded at station 1; this station in turn recorded the highest mean concentrations of these parameters. Across the stations, the anions decreased as follows: Cl^-> SO_4^{2-} > NO_3^-. Na and Mg were the alkali and alkali earth metals respectively which were characterized in this study. Their concentrations decreased as the water flowed downstream. Thus the highest and lowest concentrations of these metals were recorded at stations 1 and 3 respectively. The mean values of the heavy metals were similar across the stations.

Table 2: Summary of the characterized physico-chemical parameters across the three stations.

	Station 1	Station 2	Station 3		
Parameters	$\bar{X}$± SD	$\bar{X}$± SD	$\bar{X}$± SD	P-Value	NIS
pH	5.53±0.18 (5.32-5.71)	5.75±0.14 (5s.55-5.95)	5.67±0.19 (5.41-5.87)	p>0.05	6.50-8.50
EC (µS/cm)	135.50±43.81 (81.00-198.00)	119.58±41.83 (66.00-172.00)	94.92±40.83 (43.00-144.00)	p>0.05	1000.00
TDS (mg/l)	67.75±21.91 (40.50-99.00)	59.79±20.92 (33.00-86.00)	47.46±20.41 (21.50-72.00)	p>0.05	500.00
Cl^- (mg/l)	40.65±13.14 (24.30-59.40)	35.88±12.55 (19.80-51.60)	28.48±12.25 (12.90-43.20)	p>0.05	200.00
SO_4^{2-} (mg/l)	0.40±0.15 (0.25-0.61)	0.35±0.14 (0.20-0.53)	0.27±0.13 (0.13-0.45)	p>0.05	100.00
NO_3^- (mg/l)	0.30±0.10 (0.18-0.44)	0.26±0.09 (0.15-0.38)	0.21±0.09 (0.09-0.32)	p>0.05	50.00
Na^+ (mg/l)	0.58±0.19 (0.32-0.79)	0.37±0.24 (0.13-0.71)	0.30±0.24 (0.09-0.66)	p>0.05	200.00
Mg^{2+} (mg/l)	0.32±0.11 (0.18-0.44)	0.29±0.11 (0.15-0.42)	0.23±0.12 (0.09-0.39)	p>0.05	20.00
Fe^{3+} (mg/l)	0.36±0.39 (0.12-1.15)	0.32±0.41 (0.08-1.14)	0.28±0.41 (0.05-1.12)	p>0.05	3.00
Zn^{2+} (mg/l)	0.10±0.04 (0.05-0.15)	0.09±0.04 (0.04-0.15)	0.07±0.04 (0.03-0.14)	p>0.05	3.00
Mn^{2+} (mg/l)	0.10±0.21 (0.01-0.53)	0.10±0.21 (0.01-0.53)	0.10±0.21 (0.00-0.53)	p>0.05	0.10
Cu^{2+} (mg/l)	0.02±0.01 (0.01-0.05)	0.02±0.01 (0.01-0.05)	0.02±0.02 (0.01-0.05)	p>0.05	2.00
Ni^{2+} (mg/l)	0.06±0.09 (0.02-0.24)	0.06±0.09 (0.01-0.24)	0.06±0.09 (0.01-0.24)	p>0.05	0.02
Cd^{2+} (mg/l)	0.00^a ±0.00 (0.00-0.00)	0.00^b ±0.00 (0.00-0.00)	0.00^b ±0.00 (0.00-0.00)	p<0.01	0.003
Cr^{6+} (mg/l)	0.01±0.00 (0.01-0.02)	0.01±0.00 (0.00-0.02)	0.01±0.00 (0.00-0.02)	p>0.05	0.05
Pb^{2+} (mg/l)	0.02±0.01 (0.00-0.04)	0.02±0.02 (0.01-0.05)	0.02±0.02 (0.01-0.05)	p>0.05	0.01

p>0.05- No significant Difference; p<0.01 – Highly Significant Difference. Similar Superscript among the Means in a Row - No significant Difference.

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Table 3: Summary of WQI across the stations

	Stations 1	Stations 2	Stations 3	
	$\bar{X}$± SD (Min-Max)	$\bar{X}$± SD (Min-Max)	$\bar{X}$± SD (Min-Max)	Bench Mark
WQI	116.92±68.21 (59.57-240.95)	67.22±77.55 (19.99-223.33)	61.87±81.60 (17.69-226.21)	100.00

Fig. 2 shows the variations recorded in water quality index adopted in assessing the quality of water in this stream. All the parameters characterized across the months were used in assessing the water quality of this stream. At station 1 the highest level of WQI was recorded in the month of March while at stations 2 and 3, this occurred in January. After these peaks, the quality of the water became better as the months went –by. From the computations of WQI it can be seen that the grades of water quality index at stations 1, 2 and 3 varied from 59.57-240.95, 19.99-223.33 and 17.69-226.21 respectively. The mean values of WQI at stations 1, 2 and 3 were 116.92, 67.22 and 61.87 respectively.

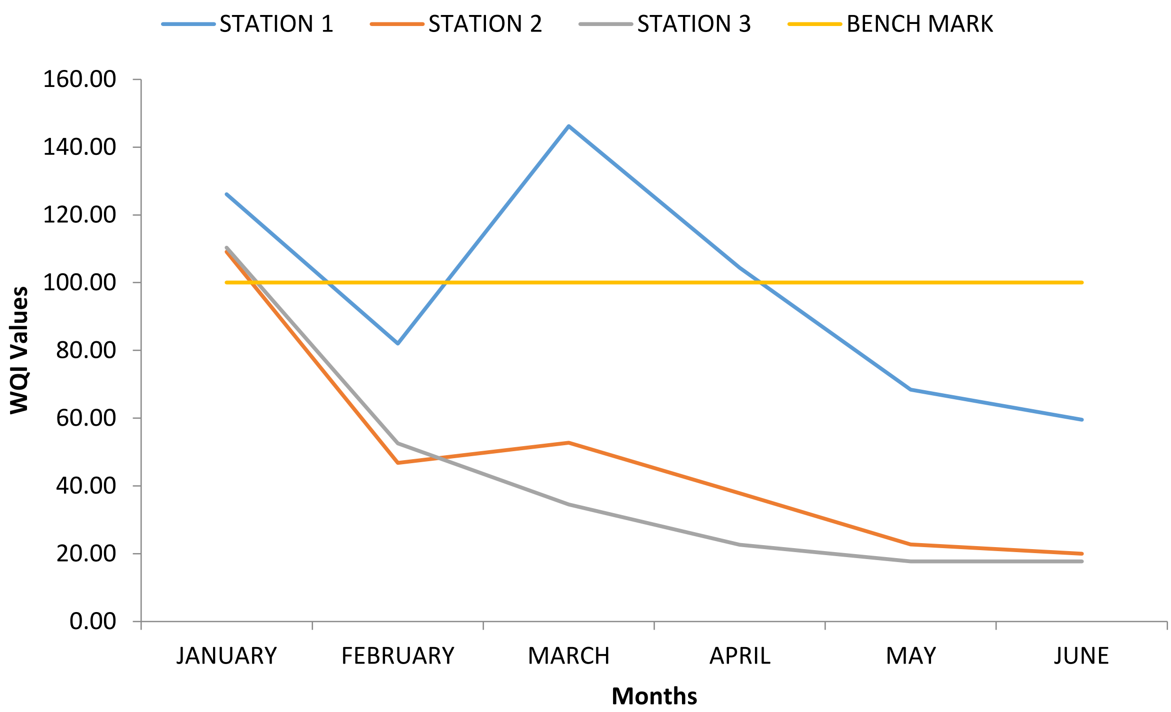

Fig 2: Spatial and monthly variations in WQI

Tables 4, 5 and 6 show the temporal variations in quality rating (ø) for the individual parameters at stations 1, 2 and 3 respectively.

Table 4: Quality rating (ø) across the months at station 1

	January	February	March	April	May	June	July
pH	311	330	258	264	336	265	294
EC	13	17	20	14	9	8	14
TDS	13	17	20	14	9	8	14
Cl	20	25	30	21	14	12	20
NO_3	1	1	1	1	0	0	1
SO_4	0	0	0	0	0	0	0
Na	0	0	0	0	0	0	0
Mg	2	2	2	2	1	1	2
Fe	38	8	10	7	5	4	12
Zn	5	3	4	3	2	2	3
Mn	531	18	22	16	10	9	101
Cu	2	1	1	1	1	0	1
Ni	1208	165	200	142	93	81	315
Cd	50	100	133	95	62	54	82
Cr	31	20	28	20	13	11	20
Pb	410	0	200	145	95	83	155

Table 5: Quality rating (ø) across the months at station 2

	January	February	March	April	May	June	July
pH	270	248	230	290	252	210	250
EC	13	15	17	13	8	7	12
TDS	13	15	17	13	8	7	12
Cl	19	23	26	19	11	10	18
NO_3	1	1	1	1	0	0	1
SO_4	0	0	0	0	0	0	0
Na	0	0	0	0	0	0	0
Mg	2	2	2	1	1	1	1
Fe	38	8	7	5	3	3	11
Zn	5	3	4	3	2	1	3
Mn	530	17	19	14	8	7	99
Cu	2	1	1	1	1	0	1
Ni	1200	150	170	125	75	66	298
Cd	0	0	0	0	0	0	0
Cr	30	18	20	15	9	8	17
Pb	490	160	180	128	77	67	184

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Table 6: Quality rating (ø) across the months at station 3

	January	February	March	April	May	June	July
pH	259	226	298	318	268	268	266
EC	12	13	8	6	4	4	9
TDS	12	13	8	6	4	4	9
Cl	17	19	13	8	6	6	14
NO_3	1	1	0	0	0	0	0
SO_4	0	0	0	0	0	0	0
Na	0	0	0	0	0	0	0
Mg	2	1	1	1	0	0	1
Fe	37	6	3	2	2	2	9
Zn	5	3	2	1	1	1	2
Mn	529	14	9	6	5	5	96
Cu	2	1	1	0	0	0	1
Ni	1220	190	126	83	65	65	316
Cd	0	0	0	0	0	0	0
Cr	30	18	12	8	6	6	16
Pb	495	170	111	73	57	57	183

DISCUSSION

The parameters characterized in this study have been adopted worldwide in assessment of water quality. Among the physico-chemicals characterized in this study, pH is an important parameter which determines the suitability of water for various purposes. In this study, the pH values recorded all through the study period were slightly acidic. Furthermore these values did not comply favourably with NIS recommended range of 6.50-8.50 for drinking water. Acidic environment with pH < 6 or alkaline environment with pH > 8 is more corrosive than an environment with pH values from 6 to 8 (Bradford, 1993). The acidic pH may have resulted from humic acid formed from decaying organic matter (leaves). The solubility of heavy metals is influenced by pH. Low pH increases the solubility of heavy metals (Radojevic, and Bashkin, 1999). Agbaire and Obi (2009) reported that the pH and other physicochemical parameters studied in River Ethiope water, Southern Nigeria for both wet and dry seasons were within the WHO standard of 6.50-8.50. They concluded that River Ethiope, which is one of the main sources of drinking water in that area was portable and unpolluted.

Aghoghovwia (2011) reported that the levels of heavy metals and other physicochemical parameters (chemical oxygen demand, biological oxygen demand, pH, TDS and temperature exceeded stipulated permissible limits of effluents discharged into the River from identified anthropogenic sources. In this study the exception of Nickel, the values other parameters analyzed complied favourably with Nigerian standards for drinking water quality. Slightly high concentrations of Nickel observed in the water may have originated from re-suspension this heavy metal species from the sediment. Other factors such as input via anthropogenic activity can be considered.

Adopting WQI, the quality of water in Iguedo stream at stations 2 and 3 is good for human consumption as at the time this was conducted. The WQI values at stations 2 and 3 attended the highest values which were more than the bench mark of 100 in January. At station 1 the bench mark was exceeded. The trends observed in Figure 2 show that the quality of water in this ecosystem was influenced by both anthropogenic and natural processes. The natural process such as precipitation brought in dilution of solutes input in this stream. The trend observed in station 1 most especially in March typifies the influence of anthropogenic activities. This afterwards was conditioned by precipitation. Precipitation on WQI values has widely been documented (Yogendra. and Puttaiah, 2008; Ashwani and Anish, 2009; Khwakaram *et al*., 2012)
The results obtained from the quality rating (**ø**) showed that pH made a significant input in the computed values of WQI across the stations and months. Other parameters of importance included Mn, Ni, Cd and Pb. These trends of variation further buttress the influence of pH on solubility of heavy metal.

Application of WQI in this study has been found functional in assessing the water quality of Iguedo stream based on the characterized parameters. This method appears to be more systematic and gives comparative evaluation of the water quality at each station. From the application of WQI, it is clear the quality of Iguedo Stream is most suitable for consumption during the rainy season and advisable to source water for domestic purposes from points upstream of station 1 or far downstream. As exemplified in this study periodic monitoring of water sources for domestic purposes using WQI is essential in safeguarding the health of the populace.

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