ISSN No:-2456-2165

Assessment of the Water Quality Index of River Ethiope for Drinking Water Purposes in Southern Nigeria

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Abstract:- The main purpose of the study is to assess the quality of water from River Ethiope for drinking water purposes by communities located along its course in Southern Nigeria. Water samples were collected on a daily basis from three designated points along the course of the river. The water samples were analyzed based on the standard methods recommended by the World Health Organization (WHO) permissible limit for drinking water quality. The following physico-chemical and biological parameters, TSS, TDS, TOC, THC, COD, temperature, pH, electrical conductivity, turbidity, nitrate, ammonia, chloride and fecal coliform were assessed using the water quality index (WQI) of the Canadian Council of Ministries of the Environment. The calculated value of the Water Quality Index (WQI) of River Ethiope of 36.84 indicates that the quality of water from River Ethiope is impaired and threatened by such parameters as turbidity, DO, BOD, coliform, magnesium, lead, TSS, TOC and THC. The study is therefore of importance to water resources development and also to the Ministry of Health, to help ascertain the quality of river water for human consumption in order to protect the health of the people.

Keywords:- *Water Quality Index, assessment, drinking water, physico-chemical parameter, River Ethiope.*

I. INTRODUCTION

Potable water plays a very significant role in the well-being of all persons on the earth's surface, hence abundant supply of freshwater is essential for a healthy living (Akoto &Adiyiah, 2007; Mohammad, Rmachar&Umamahesh, 2011). Unfortunately in many developing countries of the world including communities in Southern Nigeria, assess to potable water has become a problem, as sources of drinking water have become contaminated and the deteriorated quality of surface and underground water has become a problem to man in many parts of the world (Witek & Jarosiewicz, 2009; Ushurhe, 2014). Water pollution is detrimental to the environment and also to economic and human health (Mohammad, Rmachar&Umamahesh, 2011).

Variations in the physico-chemical and biological indices of water quality are influenced by anthropogenic activities of man (Ushurhe, 2014) and also by the hydrological conditions, topography, climate (Kasiarova&Feszterova, 2010), weathering of crustal materials, and bedrock geoglogy (Nass, Bayrama, Nass & Bulut, 2008) in association with environmental influences (Glinska-Lewczuk, 2006).

Sources of fresh water in Southern Nigeria come from natural rivers, lakes, streams and groundwater aquifers. The sources of water supply for drinking in the area comes mainly from underground water and surface water (Ushurhe, 2014). Abundant water resources exist in Southern Nigeria, but the lack of drinking water from the tap water system is a crucial problem. Man requires water for his daily activities, especially for drinking. An average man of 53kg to 63kg of body weight requires about 3 litres of water daily to keep him healthy (Onweluzo&Akuagbazie, 2010). However, increase in human population has exerted much pressure on the available water, hence potable water especially in the developing countries of the world has become a major problem to the people. Incessant cases of water borne diseases such as cholera, diarrhea, dysentery has become the order of the day.

The importance of potable water for man's daily activities cannot be undermined, hence the need for Water Quality Index (WQI) analysis as it provides an overall water quality assessment at certain location and time based on several water quality parameters. It is on this basis that this study is carried out to assess the Water Quality Index (WQI) of River Ethiope for drinking water purposes in southern Nigeria.

II. PREVAILING TREND

Inadequate and poor management of water resources has directly and indirectly resulted in the degradation of hydrological environment. This has resulted in the prevalence of unsafe drinking water with the attendant problem of water borne diseases. Thus, most of the freshwater bodies are getting polluted.

Freshwater is very important in many areas of human life. It is an effective tool for economic development (Chen, 2007: Reze& Singh, 2010). However, some drinking water sources have become contaminated (Akoto & Adiyah, 2007) and deteriorated surface water quality has become an issue in many parts of the world (Witek &Jarosiewioz, 2009). Water has become a serious environmental, economic and human health problem (Mohammad, Rmachar&Umenanhesh, 2011).

The sources of freshwater in Southern Nigeria exist as rivers, streams, lakes, ponds and groundwater aquifers. The water supply for drinking purposes in the area comes mainly from surface and underground water sources. However, most of these water sources are unsafe for human consumption, hence the need to assess their quality through the Water Quality Index (WQI) analysis; to ascertain the potability of the water for human consumption.

The water quality index (WQI) is a technique developed and formulated based on the comparison of water quality parameters to standards to give a sample value for the water quality of a certain source (Bharti & Katyal, 2011). It thus summarizes a large quantity of water quality data in a comprehensive manner into a single number (Reza & Singh, 2010; Sharms& Kansal, 2011), for the purpose of public consumption, planners, managers and policy makers (Lumb, Doug R. Tribero, 2006; Khan, Khan & Hall, 2005).

Water Quality Index (WQI) is one of the most effective techniques for analysisng water quality (Reza & Singh, 2010; Panduranga &Hosmani, 2009) and can be used as an important tool for the assessment of water sources (Parmar & Parmar, 2010) to evolve water quality over a period of time (Panduranga &Hosmani, 2009; Al-Hesty;Turki& Al-Othman, 2011), hence its application in this study. Therefore, periodic monitoring of water quality is necessary so that appropriate steps can be taken for water resource management practices (Etim, Akpan, Andrew & Edet, 2012) in southern Nigeria. The study therefore assesses the water quality index (WQI) of River Ethiope for drinking water purposes in southern Nigeria in order to safeguard human health for the present and future generations.

III. AIM, OBJECTIVES AND HYPOTHESIS

The aim of the study is to assess the Water Quality Index (WQI) of River Ethiope for drinking water purposes in southern Nigeria. Therefore, the specific objectives are:

- Assess the quality of water from River Ethiope
- Determine the physico-chemical and biological characteristics of the water from River Ethiope.
- Assess the quality of water from the river using the water quality index (WQI).
- Determine the suitability of the water for drinking purposes using the water quality index (WQI).

H_0: The quality of water from River Ethiope does not vary significantly from approved standard for drinking water purposes.

IV. STUDY AREA

The study area is River Ethiope in southern Nigeria. River Ethiope is located within latitudes $5^0 40'$N and $6^0 00'$N of the Equator and longitudes $5^0 39'$E and $6^0 10'$E of the Greenwich meridian. River Ethiope is over 100 kilometers in length (Omo-Irabor & Olobaniyi, 2007) and flows through such settlement as Umuaja, Umutu, Abraka, Oria, Okpara, Sapele among others in Delta region of Southern Nigeria.

V. RESEARCH METHODS

The study adopted the experimental design. This involves field survey and collection of water samples along the course of River Ethiope. Laboratory analysis of the water samples collected were carried out.

The simple random sampling technique was used for choosing the sampled sites along the course of the river for the purpose of collection of water samples.

For the study, three sampling sites were identified, one in the lower course of the river, one in the middle course and one in the upper course for the purpose of sample collection. The water samples were collected twice in each month from January, 2020 to December, 2020. A total of seventy-two (72) water samples were collected, analysed and used for the study.

Water samples were collected directly from the surface and sub-surface of the river. The water samples were collected early in the morning between the hours of 6am and 9am to reduce the effect of temperature on the collected water samples. The water samples were collected using sterilized 2-litre plastic cans fitted with information tags for the purpose of identification. Collected water in plastic cans were securely corked and stored in ice-packed containers before transporting them to the laboratory for analysis. This was done within six hours of collection.

Physico-chemical and biological parameters such as electrical conductivity, temperature, TDS, DO, BOD, COD, nitrate, alkalinity, phosphate, HCO, chloride, sulphate, fecal coliform, sodium, calcium and zinc were analysed using atomic absorption, spectrophotometer (AAS), Digital Meters, Standard Plate Count, including titration methods. The results obtained were compared with the WHO standard for drinking water quality and the Canadian Council of Ministers of the Environment (CCME) Water Quality Index (WQI). The CCMEWQI is a universally applicable and well-accepted model for evaluating water quality index (Sharma &Kansla, 2011; Panduranga &Hosmani, 2009; CCME, 2001; Khan, Paterson & Khan, 2004 & Khan, Husain & Lumba, 2003). The CCMEWQI compares observations to a water quality standard (such as the WHO standard for drinking water quality). For this study the CCMEWQI was compared with the WHO standard for drinking water quality. The CCMEWQI has been used by

Robert and Pirro (2013) and they achieved significant results, hence its application in this study. The analysis of variance (ANOVA) statistical technique was used to test the posited hypothesis. The analysis of variance (F-ratio) is a standard parametric technique that enables researchers to test for the significance of variance between three or more sample means, hence its application in this study. The SPSS computer package was used in the ANOVA statistics to determine the F-ratio.

VI. CALCULATION OF WATER QUALITY INDEX (CCMEWQI)

The scope (F_1), frequency (F_2) and the amplitudes (F_3) are three measures of water quality variance that makes up the CCME model (Khan, Annette, Paterson, Haseen & Richard, 2005). The scope (F_1) represents the percentage of variables that do not meet their standard; while frequency (F_2)represents the percentage of individual tests that do not meet standards, and the amplitude (F_3) refers to the amount by which failed test values do not meet their standard. These three factors combine together to produce a value between 0 and 100 that represents the overall water quality standard, where '0' represents the worst water quality and 100 represents the best water quality (Panduranga &Hosmani, 2009; Al-Haety, Tunki& Al-Othman, 2011; Lumb, Doug & Tribeni, 2006; Khan, Khan & Hall, 2005 & CCME, 2001). The CCMEWQI values are then converted into rankings by using the index categorization scheme (Khan, Annette, Paterson, Haseen & Richard, 2005) modified Khan, Paterson & Khan (2004) as presented in Table 1.

Table 1: CCMEWQI categorization scheme

Rank	WQI value	Description
Excellent	95 – 100	Water quality is protected with a virtual absence of threat or impairment conditions very close to natural or pristine levels.
Very Good	89 – 94	Water quality is protected with slight presence of threat or impairment conditions close to natural or pristine levels.
Good	80 – 88	Water quality is protected with only minor degree of threat or impairment conditions rarely depart from natural or desirable levels.
Fair	65 – 79	Water quality is usually protected but occasionally threatened or impaired conditions, sometimes depart from natural or desirable levels.
Marginal	45 – 64	Water quality is frequently threatened or impaired, conditions often depart from natural or desirable levels.
Poor	0- 44	Water quality is almost always threatened or impaired, conditions usually depart from natural or desirable levels.

Source: Khan, Paterson & Khan (2004).

Water quality index (CCMEWQI) was determined by the following equations:

$$\text{CCMEWQI} = 100 - \left(\frac{\sqrt{F1^2+F2^2+F3^2}}{1.732}\right) \text{ ---------- (1)}$$

Where:

$$F_1 = \frac{\text{number of failed variable}}{\text{total number of variables}} \times 100 \quad \ldots\ldots (2)$$

$$F_2 = \frac{\text{number of failed test}}{\text{total number of test}} \times 100 \quad \ldots\ldots (3)$$

And F_3 is calculated in three steps as:

$$\text{Excursion}_i = \left(\frac{\text{failed test value } i}{\text{standard } j}\right) - 1 \text{ ---------- (4)}$$

Where, excursion is the number of times by which an individual concentration is greater than the standard.

$$\text{Thus nSe} = \frac{\sum_{i=1}^{n} \text{excursion } i}{\sum \text{of test}} \quad \ldots\ldots (5)$$

Where nSe is the normalized sum of excursions

F_3 is thus calculated as:

$$F_3 = \left(\frac{nSe}{0.01\, nSe + 0.01}\right) \text{ ---------- (6)}$$

Table 2: Mean values of analyzed Physico-chemical parameters (January – December, 2020) along River Ethiope.

	Field code	pH	Elec. Conductivity (us/cm)	Temp (°C)	Salinity (%)	TDS (mgl)	TSS (mgl)	Turb. (NTU)	DO (mgl)	BOD (mgl)	NH_2N (mgl)	NO_3N (mg/l)	TOC (mgl)	THC (mgl)	COD (mgl)	Alkali (mgl)	Total phosp. (mgl)	HCO_2 (mgl)	CL^{-1} (mgl)	SO4 (mgl)	Coliform (Count/ 100)	Na (PPM)	K (PPM)	Mg (PPM)	Ca (PPM)	Pb (PPM)	Zn (PPM)	Fe (PPM)
1.	Jan.	5.18	90.10	29.10	5.41	10.12	*16.14	4.20	*6.85	*4.26	0.04	1.26	*15.14	*4.22	45.12	1.61	0.43	4.26	0.61	4.26	*68.00	6.45	2.75	*5.21	4.25	0.001	0.04	<0.01
2.	Feb.	5.28	81.00	29.50	6.26	24.10	*15.12	3.95	*7.14	*5.12	0.20	1.00	*12.14	*3.22	36.14	1.82	0.26	3.42	0.52	3.49	*28.00	6.15	2.18	*5.60	4.14	0.002	0.21	<0.01
3.	Mar.	5.72	69.50	*30.15	7.42	27.10	*21.24	*6.14	*8.23	*4.85	0.21	1.26	*10.21	*2.21	50.14	1.45	0.27	3.50	0.61	1.76	*25.10	5.97	2.14	*4.32	3.75	0.007	0.36	0.01
4.	Apr.	6.40	65.00	27.00	18.14	42.10	*24.14	*7.28	*9.14	*5.58	*1.56	0.46	*7.21	*3.04	13.14	0.96	*1.21	2.41	0.71	0.62	*25.10	3.46	5.20	*3.36	2.16	0.001	0.46	0.02
5.	May	6.15	61.00	26.81	17.15	52.10	*17.14	*10.21	*15.21	*10.14	*2.10	0.01	*6.51	*4.23	15.21	0.81	*1.36	1.76	0.62	0.51	*15.14	3.45	4.56	*2.76	2.14	*0.02	0.51	0.05
6.	June	6.45	59.41	26.56	20.14	71.10	*16.15	*16.16	*18.14	*16.12	*1.76	0.54	*6.49	*5.01	18.21	0.76	*2.00	1.80	0.85	0.42	*21.00	2.92	5.20	*3.46	2.10	0.001	0.41	0.04
7.	July	7.20	84.00	28.00	21.61	36.99	*18.30	*13.26	*11.60	*12.90	1.24	0.04	*7.21	*4.22	15.16	1.30	*1.48	2.40	0.81	0.72	*24.00	2.98	6.10	*2.41	1.67	*0.027	0.41	<0.001
8.	Aug.	7.05	75.20	27.10	25.12	38.14	*19.46	*12.15	*15.20	*10.21	1.32	0.03	*9.10	*3.21	10.12	1.21	*2.10	2.14	0.96	0.96	*25.10	3.96	5.21	*2.56	1.24	0.001	0.36	0.07
9.	Sep.	6.90	81.12	27.42	8.36	42.10	*20.41	*10.12	*13.14	*10.14	0.76	0.01	*8.21	*3.43	16.04	1.16	0.96	3.36	0.21	0.76	*10.25	4.14	4.59	*3.42	1.67	0.010	0.01	0.01
10.	Oct.	6.75	62.00	26.16	9.41	6.71	*21.46	3.48	*7.43	*5.21	0.51	0.76	*13.10	*2.21	32.12	1.00	0.94	2.42	0.31	3.49	*15.25	5.16	3.75	*3.10	3.14	0.010	0.01	0.03
11.	Nov.	6.72	90.00	27.15	6.52	6.42	*16.41	4.76	*8.43	*5.23	0.41	0.81	*14.12	*2.01	31.16	1.04	0.18	1.75	0.49	4.28	*46.00	5.45	3.95	*4.36	3.54	*0.020	0.01	0.01
12.	Dec.	6.90	92.00	29.00	5.21	0.96	*17.30	*5.21	*13.40	1.50	0.06	0.96	*15.16	*0.96	28.19	1.50	0.15	2.40	0.46	5.10	*52.00	6.42	2.96	*5.14	4.14	*0.020	0.02	0.02
13.	Range	2.02	32.59	3.62	19.91	70.14	9.02	11.68	11.29	14.52	2.06	1.25	8.67	4.05	40.02	1.06	1.95	2.51	0.75	4.68	57.75	3.53	3.19	3.19	3.02	0.009	0.50	0.06
14.	X	6.39	77.52	27.97	12.56	30.52	18.58	7.99	11.15	7.60	0.84	0.59	10.37	3.49	25.89	1.21	0.94	2.63	0.59	2.19	29.57	4.70	4.02	3.80	2.62	0.01	0.23	0.02
15.	WHO	6.5–8.5	100	29.80	500	500	5.00	5.00	5.00	3.00	1.50	10	5.00	0.007	100	50	1.00	50	250	200	10	200	NA	0.00	75	0.01	3.00	0.30
16.	NIS	6.5-8.5	100	-	-	500	5.00	5.00	5.00	-	-	10	5.00	0.007	100	-	-	-	250	100	10	200	-	0.20	-	0.01	3.00	0.30
17.	USEPA 2008	-	-	-	-	500	-	-	-	-	-	10	-	-	-	-	-	-	-	-	10	-	-	-	-	0.015	5	0.30

SOURCE: Fieldwork, 2020
*Values above WHO drinking water standard

Table 2 shows the data collected and analyzed from water samples along River Ethiope and used for the calculation of CCMEWQI as shown:

Total parameters = 27
Failed parameter = 12
Total test = 324
Failed test = 104

$F_1 = (\frac{Fp}{Tp} X \frac{100}{1}) = (\frac{12}{27} X \frac{100}{1})$

$F_1 = 44.44$

$F_2 = (\frac{Ft}{Tt} X \frac{100}{1}) = (\frac{104}{324} X \frac{100}{1})$

$F_2 = 32.1$

$F_3 = \text{Excursion}_i = (\frac{failed\ test\ value\ i}{standard\ j}) - 1$

$nSe = \frac{\sum_{i=1}^{n} excursion\ i}{\sum of\ test}$

$nSe = \frac{5743.461}{324}$

$nSe = 17.727$

$F_3 = (\frac{nSe}{0.01\ nSe+0.01})$

$F_3 = (\frac{17.73}{0.01\ x\ 17.73\ +0.01})$

$F_3 = (\frac{17.73}{0.1873})$

$F_3 = 94.66$

$WQI = 100 – (\frac{VF12+F22+F32}{1.732})$

$WQI = 100 – (\frac{\sqrt{44.442+32.12+94.662}}{1.732})$

$WQI = 100 – (\frac{\sqrt{1974.9136+1029.7681+8960.5156}}{1.732})$

$WQI = 100 – (\frac{\sqrt{11965.1973}}{1.732})$

$WQI = 100 – (\frac{109.386}{1.732})$

$WQI = 100 – 63.156$

$WQI = 36.844 \approx 36.84$

The calculated value are shown in Table 3.

Table 3: Calculated Values of WQI of River Ethiope

S/N	Terms of index	Value	Rating of Water Quality
1.	Scope = F_1	44.44	Water quality is threatened or impaired and its condition departs from natural or desirable levels.
2.	Frequency = F_2	32.1	
3.	nSe	17.73	
4.	Amplitude = F_3	94.66	
5.	WQI	36.84	

VII. RESULTS AND DISCUSSION

The mean physico-chemical and biological parameters of the analyzed water samples collected from the sampled sites along River Ethiope from January, 2020 to December, 2020 are shown in Table 2 and discussed.

pH, electrical conductivity, temperature, salinity and total dissolved solids (TDS) are within the WHO permissible limit for drinking water quality except for temperature in the month of March which was 30.150C. a value which was above the permissible limit of WHO. while TSS, turbidity, DO, BOD, Ammonia, TOC and THC values were above the WHO permissible value for drinking water quality except for the months of January, February, October and November for turbidity and the months of January, February, March, July, August, September, October, November and December for Ammonia, whose values were above the WHO permissible limit for drinking water quality. However, nitrate values which range between 0.01mg/l to 1.26mg/l are within the WHO permissible value for drinking water quality. Also, all the values of COD, alkalinity, phosphate, HCO, chloride, sulphate, sodium, potassium, calcium, lead, zinc and iron were within the WHO values for drinking water quality except in the months of April, May, June, July and August for phosphate with values above the WHO standard and May, July, November and December for lead, whose values were above the WHO limit for drinking water quality.

However, all the values for coliform and magnesium in the analyzed water samples were above the WHO limit for drinking water quality. Thus, there was high concentration of coliform, magnesium, TSS, turbidity, DO, BOD, TOC and THC in the analyzed water samples in the area. Also, presence of ammonia, phosphate, and lead in some months were above WHO permissible limit for drinking water quality.

Accordingly, twenty-seven (27) physico-chemical and biological parameters were examined (Table 2) and calculated for water quality using the CCMEWQI. The total number of individual tests were three hundred and twenty-four (324). The number of parameters not meeting the standard were twelve (12) and the number of failed test were one hundred and four (104). The calculated values and ratings of WQI are presented in Table 3.

The WQI of 36.84 shows that drinking water quality of River Ethiope in Southern Nigeria is poor (Table 1). The poor quality can be attributed to the measured TSS, turbidity, DO, BOD, TOC, THC, coliform, Mg and parts of ammonia, phosphate and lead that exceeded the WHO permissible limit for drinking water quality. It reflects to a large extent the impairment of the water by anthropogenic activities of man and its departure from natural/desirable levels.

A. *Test of Hypothesis*

The analysis of variance (ANOVA) statistical technique was used to test the posited hypothesis. The analysis of variance (F-ratio test) is a standard parametric technique that enables researchers test for the significance of variance between three or more sample means, hence its application in the study. The SPSS statistical package was used in the ANOVA statistics to determine the F-ratio.

Table 4: ANOVA statistical calculation

	SS	DF	MS	F	P
Between groups	13115.724	9	457.303	307.746	0.005
Within groups	520.894	110	4.735		
Total	13636.618	119			

From Table 4, the calculated F (307.746) is greater than the critical table value (3.1693) at $P < 0.005$. Thus, the model is significant. This implies that Ho is rejected and H1 is accepted. The implication is that there is variation in the quality of water from River Ethiope from month to month for drinking water purposes.

B. *Findings*

- There is significant variation in water quality for domestic purposes from month to month along the course of River Ethiope at $P < 0.005$.
- Some of the parameters examined such as TSS, turbidity, DO, BOD, TOC, THC, coliform, Magnesium showed significant increase in concentration from January to December, hence are above the permissible limit of WHO drinking water quality.
- The WQI of River Ethiope is 36.84. This implies that the water is impaired and threatened by anthropogenic activities of man.

- Anthropogenic activities of man are factors identified as being responsible for increase or decrease in the physico-chemical and biological parameters examined.
- The water from the river is a departure from natural or desirable levels as a result of man's anthropogenic activities.

VIII. RECOMMENDATIONS

- Surface water, especially those serving the needs of communities along their courses should be tested regularly to identify impairment and hence safeguard the health of people.
- There should be monitoring of human activities along the course of the river in order to address impairment arising from anthropogenic activities.
- The water from the river should be treated before usage; especially before drinking.
- Risk assessment of water sources and catchment areas including the hydrogeology of contaminants at the surface and sub-surface be carried out.
- Wastewater run-off and other activities detrimental to the quality of water from the river be checked from time to time.

IX. CONCLUSION

The study assessed the water quality index of River Ethiope in southern Nigeria for drinking water purposes using the CCMEWQI. The water quality used for rating the water along the course of River Ethiope indicates that the quality is "poor", (CCMEWQI) for the period under examination. TSS, DO, BOD, TOC, THC, coliform, Mg, turbidity, lead, phosphate and ammonia exceeded the WHO standard for drinking water quality. Thus, there is variation in the quality of water along the course of the river caused by run-offs, geologic and anthropogenic activities of man. Surface water in Nigeria should be checked through improved monitoring, testing and control to safeguard its potability for human consumption.

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