Quality assessment and classification of Ogbese river using water quality index (WQI) tool

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Abstract

Fourteen (14) water parameters were considered for the Ogbese river quality assessment and water quality index (WQI) tool to classify it and to see if it required treatment before usage. Samples from 20 points at 50 ms interval were collected in February and June 2013 representing dry and wet seasons, respectively, and in accordance with American Public Health Association, APHA (Publications on standard methods for the examination of water and wastewater, pp 123–189, 2005) standard procedures. Most of the parameters were within maximum permissible limits of the World Health Organization (WHO), Food and Agriculture Organization (FAO) and Nigeria Standards for Drinking Water Quality (NSDWQ) with the exception of total dissolved solid, turbidity, electrical conductivity and total coliform in both seasons. Lead, zinc and iron were not detected in dry season, while their traces were recorded in wet season. WQI indicated considerable degrees of pollution with classification numbers of 46.61 and 44.91 for dry and wet seasons, respectively, and falls within Class IV of the general rating scale.

Keywords Cluster analysis · Factor analysis · Water parameters · Ogbese river · WQI

Introduction

Ogbese river is one of the most important rivers in both the central and northern zones of Ondo state, Nigeria (Oyelami et al. 2013). Due to its strategic location within the two zones and availability for agricultural purposes, industrial and commercial consumption, the river has witnessed tremendous change in quality as a result of both human and industrial wastes. Various researches have been carried out on Ogbese river, as it flows through many communities. Orjiekwe et al. (2013) reported the pollution of Ogbese river in Ovia North-East Local Government Area of Edo State, south-east Nigeria and the results showed that most of the pollution indices of the water samples analyzed indicated

that the river water falls within an acceptable range for natural waters according to the World Health Organization (WHO 2004) standards. Okoli et al. (2009) worked on modeling of sediment transport capacities of Ogbese and the study was aimed at developing models which can be used to predict the magnitude and levels of sediment concentration for engineering design purposes. Ololade and Ajayi (2009) investigated the contamination profile of major rivers along the highways of Ondo State using water, surface sediment and African catfish (*Clarias gariepinus*) from Ogbese river as partial environmental indicators.

Rapid deterioration in water quality is due to increasing population pressure, rapid urbanization and industrialization, and inadequate sanitation facilities, with water resources being contaminated by a variety of hazardous chemicals and virulent pathogens (Ogedengbe and Akinbile 2004). These pollutants have been caused mainly by untreated human and animal wastes, garbage, and industrial wastes. Untreated sewage and garbage are intentionally and/or unintentionally drained into open ditches, streams and other waterways, resulting in pollution of freshwater reservoirs, rivers and lakes (FFTC 2008). One vital solution to this pollution problem is monitoring and management to maintain the quality of water as well as the development

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of technologies for its reuse (FFTC 2008). In man's quest to increase his food supplies, obtain uncontaminated and clean water to drink and limit injury to his health and damage to his possessions, the chemical, industrial materials and waste that would have been used to his advantage have turned out to be the silent conqueror and threat to his existence (Ogedengbe and Akinbile 2010). The quality of surface and groundwater resources can significantly affect water use in many regions, especially in those that are arid and semi-arid. In regions where water pollutants from human and industrial activities have seriously degraded water quality, the main issue in water quality management is to control pollution sources and to disseminate appropriate enlightenment. According to the National Bureau of Statistics (NBS 2009), at least 27% Nigerians depended absolutely on streams, ponds, rivers and rainwater for their drinking water source and by 2025, it is projected that most countries will face severe water scarcity and will lose some more from waste water by way of domestic, industrial and other activities. Humans, livestock and aquatic organisms may be affected by poor quality water causing death, sickness or impaired growth. Thus, understanding water quality parameters are essential due to the daily demand for water by the entire ecosystem (Yilmaz 2007).

The need for water quality monitoring is paramount to safeguard the public health and also to protect the water resource in Nigeria. The objective of this study, therefore, is to ascertain the suitability of Ogbese river for municipal and agricultural uses. This was carried out by conducting

physiochemical and microbial (bacteriological assay) analyses, evaluate and classify the river using water quality index (WQI) tool. This became imperative to harness and properly utilize water from Ogbese river for agricultural purposes (irrigation and non-irrigation uses) to increase food production in the region. Also, since industries such as Matna foods processing company, Wood processing company, defunct Benkof beverages company and other small-scale enterprise in Ogbese community depended heavily on the river for their day-to-day utilization, the need to ascertain the level of pollution to recommend the right purification measures becomes imperative, hence this study.

Materials and methods

Description of the study site

The study site is Ayede Ogbese river along the Akure-Benin expressway in Ondo state. The area lies within latitude $E6^{\circ}SE8^{\circ}$ and longitude $N4^{\circ}N6^{\circ}E$. The river has its source from Ayede-Ekiti in Ekiti State and flows through Ogbese in Ondo State to Edo State. The Ogbese community is about 10 km east of Akure, the Ondo State capital.

Water sampling and analysis

Twenty (20) sampling points at 50 ms interval were selected along the river course (Fig. 1) and sampling was carried out

Fig. 1 Sampling points along the Ogbese river during experimentation. Courtesy: Google maps (2014)

thrice on each of the sampling points in two seasons (dry and wet) i.e., between the months of February and June in 2013. Some of the activities going on near the river course included an abattoir with indiscriminate waste disposal on the river course, cattle range, farming at subsistence level and some laundry activities by some unemployed youths who depended on the river for their services. Sampling, preservation and analysis was carried out at the University central laboratory and in accordance with the Standard Methods of Water and Wastewater APHA (2005) standard procedures and stored at 4 °C temperature (CPCB 2007) and values obtained were compared with the data published by previous researchers.

Fourteen (14) physicochemical parameters were determined viz: temperature, total dissolved solid (TDS), biochemical oxygen demand (BOD), chemical oxygen demand (COD), dissolved oxygen (DO), turbidity, pH, nitrate (NO₃), phosphate (PO₄) electrical conductivity (EC), lead (Pb), zinc (Zn), iron (Fe) and total coliform count using standard laboratory procedures. Temperature was determined in situ by mercury thermometer, pH was measured by digital pH meter, while COD test was conducted using the COD Vial test tube method. TDS, EC, DO and BOD were measured and computed using HI9828 multiparameter meter (Hanna Instruments). PO₄ and NO₃ contents were measured using Molybdovanadate Method and DR 2008 equipment (code 541P Total HR TNT) for P and (code 395 N Total HR TNT) for N. The presence of iron (Fe), lead (Pb) and zinc (Zn) were determined through the use of Atomic Adsorption Spectrophotometer (AA-7000 series) some of these methods as reported by Akinbile et al. (2013).

Statistical analysis and water quality index (WQI) classification

Fataei (2011) remarked that factor analysis is based on a varimax rotation technique from Statistical Package for the Social Sciences (SPSS version 15.0) which was used to investigate whether a number of variables of interest $Y_1, Y_2, \dots, Y_i$, are linearly related to a smaller number of unobservable factors $F_1, F_2, \dots, F_k$. It is assumed that each Y variable is linearly related to two factors, according to Sharma (1996) as follows:

$$Y_1 = \beta_{10} + \beta_{11}F_1 + \beta_{12}F_2 + e_1, \quad (1)$$

$$Y_2 = \beta_{20} + \beta_{21}F_1 + \beta_{22}F_2 + e_2, \quad (2)$$

$$Y_3 = \beta_{30} + \beta_{31}F_1 + \beta_{32}F_2 + e_3. \quad (3)$$

The error terms e_1, e_2 , and e_3 , serve to indicate that the hypothesized relationships are not exact. In the special vocabulary of factor analysis, the parameters β_{ij} are

referred to as loadings. For example, β_{12} is called the loading of variable Y_1 on factor F_2 . Each observable variable is a linear function of independent factors and error terms, and can be written as:

$$Y_i = \beta_{i0} + \beta_{i1}F_1 + \beta_{i2}F_2 + (1)e_i. \quad (4)$$

This can be written in terms of variance as:

$$\begin{aligned} \text{Var}(Y_i) &= \beta_{i1}^2 \text{Var}(F_1) + \beta_{i2}^2 \text{Var}(F_2) + (1)^2 \text{Var}(e_i) \\ &= \beta_{i1}^2 + \beta_{i2}^2 + \sigma_i^2, \end{aligned} \quad (5)$$

$$\text{Var}(Y_i) = \beta_{i1}^2 + \beta_{i2}^2 + \sigma_i^2, \quad (6)$$

where $\beta_{i1}^2 + \beta_{i2}^2$ = communality, and σ_i^2 = specific variance.

From Eq. 6, the variance of Y_i has two parts: first, the communality of the variable is the part that is explained by the common factors F_1 and F_2 . Second, the specific variance is the part of the variance of Y_i that is not accounted by the common factors. If the two factors were perfect predictors of the variables, then $e_1 = e_2 = e_3 = 0$ always, and

$$\sigma_1^2 = \sigma_2^2 = \sigma_3^2 = 0. \quad (7)$$

After identifying the major hidden pollutant sources in the watershed, the next step was to examine the similarity among considered stations for possible zonings according to the level of existing pollution. For this purpose, the cluster analysis was used to decide which of the sampling points (stations) are most similar to each other, considering all of the pollution properties simultaneously. Cluster analysis employs the familiar concept of distance, considering two points, i and j , with coordinates $(X1i; X2i)$ and $(X1j; X2j)$, respectively; the Euclidean distance between the two points is the hypotenuse of the triangle ABC expressed as:

$$D(I, j) = (A^2 + B^2)^{1/2} = \left\{ (X_{1i} - X_{1j})^2 + (X_{2i} - X_{2j})^2 \right\}^{1/2}. \quad (8)$$

After the determining the required physiochemical parameters, water quality index of each station was determined using the WQI tool. Generally, WQI is used for estimating the river's pollution and shows the composite effect of physiochemical and biological parameters. The mathematical expression for WQI was given by Hamed (2012) as:

$$WQI = \sum_{I=1}^p w_i I_i, \quad (9)$$

Where I_i is the sub-index for i_{th} water quality parameters. W_i is the weight (in terms of importance) associated with i_{th} water quality parameter. p is the number of water quality parameters.

Results and discussion

Ogbese river quality parameters

The water quality parameters of Ogbese river for both dry and wet seasons in relation with the spatial difference of the sampling stations and compared with the standard values of the World Health Organization (WHO 2004), the Food and Agriculture Organization (FAO 2012) and the Nigeria Standard for Drinking Water Quality (NSDWQ 2007) were as shown in Table 1.

Temperature varied from 26 to 31 °C and 23 to 29 °C for both dry and wet seasons, respectively, the observed slight difference in the two seasons was due to the fact that temperature tends to be higher in dry season as reported by NIMET (2009). The dry season has the mean value of 28.50 ± 1.51 °C, while the wet season has the mean value of 26.15 ± 1.67 °C (Table 1) and it could be due to weather variations occasioned by the distinctiveness of the two main seasons in Nigeria. With the exception of the FAO values (25 °C), average temperature was within permissible limits of WHO and NSDWQ. This observation is in accordance with the findings of Igbinosa et al. (2012). The results of total dissolved solid (TDS), biochemical oxygen demand (BOD), chemical oxygen demand (COD), and dissolved oxygen (DO) were as shown in Table 1. TDS varied from 750 to 3800 mg/L with mean value of 1356.35 ± 45.43 mg/L for dry season and also varied from 11 to 720 mg/L for the wet season with mean value of 198.85 ± 20.85 mg/L; the values were above WHO value

of 250 mg/L and NSDWQ value of 500 mg/L but below that of the FAO 2000 mg/L. This is in agreement with the study of Raman et al. (2009). Similar observations were recorded for BOD which ranged from 2.0 to 28 mg/L and 1.25 to 9.20 mg/L and average values of 13.29 ± 5.74 and 2.82 ± 2.30 for dry and wet seasons, respectively. Mean BOD values were within permissible limits for the WHO, FAO and NSDWQ standards, but slightly higher during dry season with value of 13.29 ± 5.74 mg/L. The observed low values might not be unconnected to the infiltration of industrial wastes into the river which might result in the death of aquatic lives triggered by the oxygen depletion and is in accordance with findings of Ololade and Ajayi (2009). COD values varied from 18 to 49 mg/L with average value of 35.70 ± 7.63 during the dry season and from 5.7 to 20.4 mg/L with mean values of 11.84 ± 3.57 during the wet season, respectively. However, COD values were within the permissible limits of WHO, FAO and NSDWQ and the results were similar to the findings of Akinbile et al. (2013) and an indication that the water was considered very polluted. Higher COD value indicated the ability of water to consume more oxygen during decomposition and the amount of organic pollutants was also high since more decomposition process occurred. DO variations ranged from 4.7 to 16.0 mg/L with mean value of 10.23 ± 3.70 mg/L for dry season and 3.3 to 7.0 mg/L with mean value of 4.44 ± 0.91 mg/L for wet season, respectively. DO values were within WHO and NSDWQ permissible limits but above FAO value of 2 mg/L, the slight reduction in DO during the wet season might be due to the higher influx of wastes thereby reducing the biological

Table 1 Water quality parameters of Ogbese River with selected standard values

Parameters	Dry season			Wet season			Standards		
	Min	Max	Mean $\pm$ SD	Min	Max	Mean $\pm$ SD	WHO	FAO	NSDWQ
Temp (°C)	26.00	31.00	28.50 ± 1.51	23.00	29.00	26.15 ± 1.67	30	25	30
TDS	750.00	3800.00	1356.35 ± 45.43	11.00	720.00	198.85 ± 20.85	250	2000	500
BOD	2.00	28.00	13.29 ± 5.74	1.25	9.20	2.82 ± 2.30	10	10	10
COD	18.00	49.00	35.70 ± 7.63	5.70	20.40	11.84 ± 3.57	40	350	40
DO	4.70	16.00	10.23 ± 3.70	3.30	7.00	4.44 ± 0.91	10	2	10
Turbidity (NTU)	24.00	33.00	29.35 ± 2.01	2.10	28.50	8.98 ± 8.16	5	–	5
pH	7.20	8.40	7.76 ± 0.34	4.00	8.20	6.10 ± 0.85	6.50–8.50	6.50–8.50	6.50–8.50
Nitrate	0.01	0.03	0.02 ± 0.01	0.02	2.30	0.51 ± 0.63	50	10	50
Phosphate	0.02	0.09	0.03 ± 0.02	0.01	2.10	0.34 ± 0.47	0.70	3	0.70
EC (μ S/cm)	620.00	1780.00	1102.75 ± 414.53	400.00	614.00	473.30 ± 57.99	250	500	1000
Lead	ND	ND	ND	0.01	0.20	0.03 ± 0.05	0.01	0.01	0.1
Zinc	ND	ND	ND	0.1	0.30	0.07 ± 0.06	4.00	0.01	3
Iron	ND	ND	ND	0.1	3.14	1.72 ± 0.68	0.30	0.30	0.30
Total coliform (cfu/l)	9200.00	11000.00	9975.00 ± 690.44	17100.00	18200.00	17950.00 ± 291.10	1.00	10	10

Unless otherwise stated, all units are in mg/L. Values are means of triplicates reading and standard deviation

ND not detected

life of the river which agreed with the findings of Hassan et al. (2013). The implications of this were that the water would not be suitable for public/domestic supply and recreational purposes, and that it would weaken the activities of aquatic organisms in the river and the DO reduction will also prevent the establishment or distortion of the usual flora and fauna of Ogbese River. Turbidity varied from 24 to 33 NTU for the dry season and 2.1 to 28.5 NTU for the wet season with mean values of 29.35 ± 2.01 and 8.98 ± 8.16 for the two seasons, respectively. These agreed with the findings of Eloskkay and Abukila (2014). Turbidity values were above WHO and NSDWQ standard values of 5 NTU. Higher turbidity values recorded during the wet season may be due to increase in water level resulting from increased precipitation, increased soil detachment and increased transportation of detached soil particles and at this level, water bodies might lose their ability to support the diversity of aquatic life. Increased turbidity has a significant effect on aquatic ecosystems, as the most obvious effect is a reduction in the light available for photosynthesis. This reduces the amount of the plant growth and in turn limits the number of aquatic organisms that feed on these plants and finally fish community that rely on aquatic organisms as a food source are affected. The pH showed relative variation of 7.2 to 8.4 for the dry season, this can be considered basic and might be unsuitable for domestic consumption with mean value of 7.76 ± 0.34 , while the pH range for wet season was between 4.0 and 8.0 and mean value of 6.10 ± 0.85 which might be due to the multi-variable activities on the river course by the farmers and the habitats of the region at those seasons of the year and conformed reasonably with standard limits. These results were similar to the findings of Charkhabi and Sakizadeh (2006).

Nitrate (NO_3) values varied from 0.01 to 0.03 mg/L and 0.02 to 2.30 mg/L with mean values of 0.02 ± 0.01 and 0.51 ± 0.63 mg/L for dry and wet seasons, respectively. The values were within the WHO, FAO and NSDWQ standard permissible limits, the sharp contrast in NO for the wet season was as the result of infiltration of applied fertilizer from cultivated land into the river and the influx of domestic wastes dumped into the river, these results agreed with the findings of Karaman (2013). Phosphate (PO_4) varied from 0.02 to 0.09 mg/L and 0.01 to 2.1 mg/L with mean values of 0.03 ± 0.02 and 0.34 ± 0.47 for dry and wet seasons, respectively. The EC of Ogbese river was higher in the dry season with the mean value of 1102.75 ± 414.53 μscm , minimum value of 620 μscm and maximum value of 780 μscm when compared with the wet season with mean value of 473.30 ± 57.99 μscm , SD of 57.99 μscm , minimum value of 400.30 μscm and maximum of 614 μscm for the dry season which agreed with the findings of Anwar et al. (2011), EC mean values were

above the WHO and FAO values but within the NSDWQ value. High EC values in dry season might be due to the lower volume of the river and higher temperature which favored ionization (Chikogu et al. 2012).

Heavy metals in water samples

Heavy metals such as lead (Pb), zinc (Zn) and iron (Fe) were tested for in the river and were not detected during the dry season but were present in traceable quantities during the wet season (Table 1). Presence of Pb, Zn and Fe varied from 0.01 to 0.2 mg/L, 0.1 to 0.3 and 0.1 and 3.14 mg/L with mean values of 0.03 ± 0.05 , 0.07 ± 0.06 and 1.72 ± 0.68 mg/L, respectively. The presence of these metals were very minute and were within the recommended values of WHO, FAO and NSDWQ which might be from seepage of industrial wastes and percolation of water through iron-containing rocks nearby before flowing into the river in accordance with the study of Akinbile et al. (2013); Ayodele and Percy (2011). Total coliform count values ranged from 9200MPN to 1100MPN and from 17100MPN to 18200MPN with mean values of 9975.00 ± 690.44 MPN and 17950.00 ± 291.10 MPN for both dry and wet seasons, respectively. These values were much higher than the WHO, FAO and NSDWQ values which implied that the water quality under study fell short of recommended standard and could pose health risk (especially of contracting gastro-intestinal illnesses such as diarrhea and gastro-intestinal diseases) to both humans and animals that use these water bodies and the findings are consistent with that of Akinbile (2012); Alatishe and Adeboye (2008).

Table 2 Varimax rotation output and extraction communality for dry season

	Factor 1	Factor 2	Factor 3	Communality
TEMPdr	−0.215	0.143	0.900	0.876
TDSdr	0.920	0.285	0.015	0.928
BODdr	0.855	0.195	0.181	0.801
CODdr	0.610	0.724	0.071	0.900
DOdr	0.555	0.779	0.111	0.927
TURBIDITYdr	0.148	0.914	0.236	0.914
PHdr	0.549	0.706	0.118	0.814
NOdr	0.922	0.296	−0.054	0.940
POdr	0.502	0.201	0.671	0.742
ECdr	0.863	0.446	0.047	0.947
Pbdr	0.849	0.361	−0.229	0.903
Zndr	0.799	0.480	0.024	0.869
Fedr	0.919	0.304	0.052	0.940
T.COLIdr	0.763	0.501	0.177	0.866

Pollution structure

In Table 2, three rotated factors were identified with their respective community level for the dry season. Factor 1 is positively loaded with twelve parameters TDS, BOD, COD, DO, pH, NO_3^- , PO_3^- , EC, Pb, Zn, Fe and total coliform as opposed to temperature (negative loading) which accounted for 51.9% of the rotated variance. Temperature reduction is advantageous to the river pollution with nitrate, TDS and Fe having highest explainable community. Stations 19 and 20 had the highest score in factor 1, which implied that these stations are extremely polluted and might be points of entrance of the pollutants in the dry season. Table 3 showed three rotated factors and community for wet season with seven pollutants (TDS, BOD, DO, pH, NO_3^- , PO_3^- and Pb) having highest positive loading in Factor 1, while Fe and total coliform are negatively loading, all these accounted for 36.36% of rotated variance. Stations 4, 5, 6, 19 and 20 had the highest in the first factor. The fact that stations 4, 5, and 6 are loaded in NO_3^- and PO_3^- during the wet season implied that the source is from seepage from applied fertilizer to the surrounding farming soil.

Zoning of the river system

Cluster analysis was performed on the mean values of the parameters for each of the stations for both dry and wet seasons. Figure 2 showed the results of four separated clusters along the river in the dry season, the first cluster comprises stations 2, 3, 6 and 7 which were towards the downstream and were less polluted with elevated river shore, stations 1, 12, 13, 9, 10 and 8 were moderately polluted and very close to the access high-way bridge constructed across the

Fig. 2 Dendrogram of hierarchical cluster analysis for all the stations in dry season

river, the third cluster was made up of station 14 and 15 which were more polluted than second cluster and served as intermediate between second and fourth clusters which consisted stations 14, 15, 17, 18, 16, 20 and 19, this cluster was the most polluted cluster and was the point of pollution source to the downstream. Figure 3 showed the five clusters for the wet season, stations 9, 10, 8, 11, 2 and 13 in the first cluster which were averagely polluted and easily accessible for people nearby. Second cluster contained stations 6, 7, 14, 5, 15, 4 and 3; this cluster is similar to the first cluster and the stations were very close to farming land. The third

Table 3 Varimax rotation output and extraction communality for wet season

	Factor 1	Factor 2	Factor 3	Communality
TEMPwt	0.487	0.309	0.443	0.529
TDSwt	0.767	0.573	0.186	0.951
BODwt	0.709	0.443	0.358	0.827
CODwt	0.474	0.562	0.578	0.875
DOwt	0.544	-0.038	0.491	0.538
TURBIDIYwt	0.290	0.759	0.413	0.831
PHwt	0.882	0.067	-0.142	0.803
NOwt	0.935	0.270	0.010	0.947
POwt	0.579	0.747	-0.244	0.951
ECwt	0.790	0.287	0.196	0.745
Pbwt	0.675	0.721	-0.027	0.976
Znwt	0.283	0.791	-0.315	0.804
Fewt	-0.041	0.920	0.309	0.943
T.COLIwt	-0.095	-0.018	0.790	0.633

Fig. 3 Dendrogram of hierarchical cluster analysis for all the stations in wet season

Table 4 Qualification of water quality index

Qualification	Rating Range
Very good	90–100
Good	70–90
Normal	50–70
Bad	25–50
Very bad	0–25

cluster had stations 16, 17 and 18 which were more polluted than the first and second clusters, the fourth cluster was the most polluted cluster and consisted station 19 and 20, the fifth cluster consisted station 1 and 2 which were similar to the first cluster as shown in Fig. 3.

Water quality index

The Water quality index (WQI) of Ogbese river was calculated, using Elisabeta et al. (2010) and Pradyusa et al. (2009) techniques from nine water quality parameters sub-index for dry and wet seasons and it showed that dry season index was calculated to be 46.61 which can be classified as bad. This is as shown in Table 4 and wet season which was 44.91 was also rated bad, the detailed general rating scale of WQI and uses are shown in Table 5. From the comparative analysis of the results of the water quality index for dry and wet seasons using ANOVA, since the obtained *F* value exceeded the probability at 18 and 1 degrees of freedom, it can be said that the WQI of Ogbese river is significant at 0.05 level of confidence and is similar to the observations of Park et al. (2014) and Simeonov et al. (2010).

Conclusions

The analysis of water quality at Ogbese river was carried out as a requirement for classification. Using the WQI, the evaluated result was 46.61 for dry season and 44.91 for wet season and it was classified in water class IV indicating significant pollution and requiring considerable degree of treatment depending on the desired mode of usage. Pollutants such as nitrate and phosphate among many others were majorly from the application of inorganic fertilizer to the cultivated farmland along the river banks. However, the study has revealed that there was an undesirable impact on the physicochemical characteristics of the river at the upstream near a dumpsite as a result of the discharge of untreated waste entering into the watershed from municipalities and surrounding industries. This poses serious health risk to rural communities that rely on the water body for domestic and recreational purposes. The other parameters for microbiological water quality assessment such as *E. Coli*

Table 5 General rating scale of WQI and uses

QWI	10	20	30	40	50	60	70	80	90	100
General	Very polluted									
Water classes	V									
Public water supply	Not acceptable				IV Doubtful	III Necessary treatment becoming more expensive	Slightly polluted		II Minor purification required	I Purification not necessary
Recreation	Not acceptable		Obvious pollution appear	Only for boating	Doubtful for water Contact	Becoming polluted still acceptable bacteria count	Acceptable for all sports			
Marginal for Trout Navigation	Acceptable for all fishes Not acceptable			Coarse fish only Obvious pollution appear	Handy fish only Acceptable	Doubtful for sensitive fish				

and fecal coliform needed to be ascertained periodically to assist water resource managers in restoring the impaired water resources.

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