USING WATER QUALITY INDEX AND PRINCIPAL COMPONENT ANALYSIS FOR THE ASSESSMENT OF WATER QUALITY OF THE ETHIOPE RIVER, DELTA STATE, NIGERIA

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The surface water quality of Ethiope River was investigated from January 2016 and December 2017. Five stations were sampled from upstream to downstream (Umuaja, Umutu, Obiaruku, Abraka and Eku). Results obtained were analysed using standard methods to determine suitable water quality. A total of thirty-four physico-chemical parameters were analysed and used to obtain the WQI of the surface water using a weighted arithmetic index method across the five designated stations. The results revealed that the mean of the physico-chemical parameters of the surface water were significantly different ($P > 0.05$), except for air temperature, flow rate, pH, salinity, turbidity, dissolved oxygen, potassium, magnesium, ammonium, nitrate nickel, lead, vanadium and total hydrocarbon. Data obtained were compared with the WHO benchmark or standard. The water quality index (WQI) clearly showed that the status (>100) whose mean values were 129.41, 137.03, 173.61, 147.86 and 112.70 revealed that all the stations were affected. The results of this study revealed that the river water is unfit for consumption. This research showed the relevance of WQI and PCA in assessing complex data series of water quality and recommends an effective enforcement of environmental laws by Federal Ministry of Environment on the indiscriminate dumping of sewage, refuse and agriculture effluent discharges in the river. Regular and sustained monitoring is imperative to mitigate ecological and health hazards.

Key words: Anthropogenic activities, physico-chemical parameters, water quality index.

INTRODUCTION

Water quality refers to the biological, physical, radiological and chemical features of water (Diersing, 2009). Water quality of water varies from one river body to another. Water bodies receive different materials from different sources ranging from runoffs, human activities in the water bank and the nature of vegetation which directly or indirectly impact the water quality. The factors include anthropogenic activities and environmental factors. The use of the physico-chemical parameters to assess water quality gives the health status and sustainability of such water body. Water quality varies from non-impacted to severely impacted in Benin River based on the nature of the physico-chemical component present (Ogbeibu et al., 2013). In previous limnological studies done by Omoigberale and Ikponmwosa (2010); Idowu (2013) and Omoigberale et al. (2013), they used used physico-chemical parameters to assess the water quality of lotic water bodies. The observed changes in physico-chemical properties and heavy metals provide useful scientific information on the water quality, source of disparity and their impact on the water bodies. Rotimi and Omoigberale (2005, 2006 and 2011) reported the negative effects of dispersants on the water quality of some selected fresh water bodies. Akujieze and Oteze (2006) reported the impact of physico-chemical variables on the groundwater quality of urban aquifer in Benin City.

There is a dearth of salient scientific information on some selected physico-chemical parameters and Water quality index in Ethiope River, which this research aims to cover. The study aims to analyze the spatial and temporal variations of the physical and chemical parameters of the surface water of Ethiope River using water quality index to provide more salient scientific information and contribute to the existing body of knowledge on the limnology of Ethiope River.

MATERIALS AND METHODS

Study area

Five designated stations were surveyed along the Ethiope River watercourse. Ethiope River is located in Delta State, Nigeria.

Sampling locations

The five sampling stations were visited once monthly from January 2016 – December 2017.

Station 1 (Umuaja): Is the source of the Ethiope River. It lies between lat. 05° 56' 31.4″ N and long. 06°13'58.7″ E, with an elevation of 30 m; it is sited in Ukwuani Local Government Area, Delta State. The human activities done here include sacrifices and bathing.

Station 2 (Umutu): Is located 7 km downstream of station 1. It lies between latitude 05°54'53.1″N and longitude 06° 13'09.5″ E with an elevation of 24 m. The anthropogenic activities done here include agricultural activities, laundering and swimming.

Station 3 (Obiaruku): Lies between latitude. 05°51'29.5″ N and longitude. 006° 09' 30.9″ E, with an elevation of 12 m. Human activities done here include washing of automobiles, recreational activities, laundering, bathing, and fishing.

Station 4 (Abraka): Lies between lat. 05°47'44.6″ N and long. 06° 05' 57 .1″ E, with an elevation of 6 m. It is about 11 km downstream of station 3. There are high human activities carried out here such as laundering, bathing, artisanal fishing, washing off inorganic fertilizers, waste disposal and discharging of petroleum by-products.

Station 5 (Eku): Lies between lat. 05°45'19.2″ N and long. 05°58'57.3″ E, with an elevation of 15 m. The human activities here include farming, fishing, logging and timber transportation, laundering, bathing and washing of automobiles

Sampling techniques

Surface water samples for the determination of physico-chemical parameters were collected simultaneously monthly from January (2016) to December (2017) from each of the five sampling stations. Samples were collected on each sampling day starting from station 1 and to station 5. At each location, air and surface water temperatures, flow rate and depth were determined *in-situ*. Surface water samples were collected by immersing a one litre plastic bottle about 50 cm below the water surface and allowed to fill up. It was stored in an ice chest and taken to the laboratory for analysis using standard methods

Determination of water physico-chemical parameters

Air and water temperatures were taken in the field with mercury-in-glass thermometer ranging from 0-100°C (Krisson Model 59). Flow rates were determined using floatation method by timing a float as it moved over a distance of 10 m (Gordon et al., 2004). Depths were measured in each station using a Calibrated meter ruler; pH was obtained using a buffered electronic pH meter (Kent, 7020). Colour was measured in Platinum-Cobalt (Pt/Co) and determined using the visible spectrophotometer VS72IG at 455 nm (APHA, 2005). Electrical conductivity and total solids were measured with an Extech, meter (Model Exstik, Ec 400) as recommended by Clesceri et al. (1998). Turbidity was measured with Spectronic 21-D) turbidmeter (APHA, 2005). Total suspended solids were obtained using TDS meter (Analytic TDS meter) (APHA, 2005). DO and BOD were determined using winker's method (APHA, 2005). Chemical oxygen demand was analysed in the laboratory using dichromate method (APHA, 2005). Sulphate and nitrate were determined using a spectrophotometer (APHA, 2005) and PO_4^{2-} was determined by the ascorbic acid method 880 nm (APHA, 2005). Chloride was determined by MOHR's method (APHA, 2005) and bicarbonates were determined in the laboratory. Determinations of exchangeable bases (Sodium, Potassium, Calcium and Magnesium) were determined using the Technicon auto analyzed flame photometer (APHA, 2005). Ammonium nitrogen was obtained spectrophotometrically (APHA, 2005) and total hydrocarbon contents were determined in water spectronic 20D^{+} spectrophotometer (APHA, 2005).

Water quality index

The water quality index (WQI) was calculated by using the Weighted Arimetic Index method as described by Cude (2001). In this model, different water quality components were 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 (Qi) for each parameter was calculated by using the following equation;

$$\text{Qi} = \left\{\left[\frac{(\text{V actual} - \text{V ideal})}{\text{V standard} - \text{V ideal}}\right] \times 100\right\} \quad (1)$$

Qi = Quality rating of nth parameter for a total of n water quality parameters

V actual = Actual value of the water quality parameter obtained from laboratory analysis

V ideal = Ideal value of the water quality parameter can be obtained from the standard tables. V ideal for pH = 7 and for other parameters that are equal to zero; but for DO V ideal = 14.6 mg/L

V standard = Recommended Federal Ministry of Environment permissible limits standard of the water quality parameter.

Then, after calculating the quality rating scale (Qi), the relative (unit) weight (Wi) was calculated by a value inversely proportional to the recommended standard (Si) for the corresponding parameter using the following expression;

$$\text{Wi} = \frac{1}{\text{Si}} \quad (2)$$

Where,

Wi = Relative (unit) weight for nth parameter

Si= 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:

$$\text{WQI} = \frac{\sum \text{WiQi}}{\sum \text{Wi}} \quad (3)$$

Where,

Qi = Quality rating

Wi = Relative weight

Analysis of water samples for heavy metals

Water samples were digested using aluminum block digester 110. Water sample digestion was carried out by taking one hundred milliliters of the sample and adding four milliliters Perchloric acid, twenty milliliters concentrated nitric acid and two milliliters concentrated tetraoxosulphate VI acid. The heavy metals analyzed in this study were Iron, Manganese, zinc, Copper, Chromium, Calcium, Nickel, lead and Vanadium using an atomic Absorption Spectrophotometer (AAS) (Unican 929 model) (APHA, 2005).

Statistical analysis

The results of the physico-chemical parameters of surface water obtained from the study stations of the Ethiope River are summarized in Table 1. The mean, standard deviation, minimum and maximum values for each parameter are presented. Also shown in the table are the p-values of the one-way analysis of variance (ANOVA). The superscripts representing *post hoc* Duncan Multiple Range (DMR) tests appear in cases where the ANOVA indicated significant differences. Principal component Analysis (PCA) for water was based upon the correlation matrix among the physico-chemical parameters and to determine the controlling variables in data series, which play significant roles in the variation across the sampled stations

$$PC_{ab} = \text{Z}_{\text{a1}}\text{K}_{\text{1b}} + \text{Z}_{\text{a2}}\text{K}_{\text{2b}} \ldots + \text{Z}_{\text{ai}}\text{K}_{\text{ib}} \quad (4)$$

Where *PC* is the component score, Z is the component loading, a is the component number and b is the sample number. Varimax rotation of results obtained can be interpreted. Varimax

Table 1. Summary of physical and chemical parameters of the water from the study stations (January, 2016 to December, 2017).

Parameter	Station 1 $\bar{X}$±SE (min-max)	Station 2 $\bar{X}$±SE (min-max)	Station 3 $\bar{X}$±SE (min-max)	Station 4 $\bar{X}$±SE (min-max)	Station 5 $\bar{X}$±SE (min-max)	P-Value	*Sig.
Air temperature (°C)	26.42± 0.64 (21.0-34.0)^{b}	27.04±0.62 (21.0- 33.0)^{b}	29.04±0.61 (23.0- 35.0)^{a}	28.96±0.56 (24.0- 33.0)^{a}	29.95±0.49 (25.0 - 34. 0)^{a}	0.454	P<0.05
Surface water temperature (°C)	24.5± 0.45 (20.0- 29.0)^{b}	24.54±0.49 (20.0- 28.0)^{b}	25.83 ± 0.37 (22.0- 29.0)^{a}	25.75±0.50 (22.0- 30.0)^{a}	26.82±0.34 (24.0- 31.0)^{a}	0.051	P>0.05
Flow rate (ms^{-1})	1.04 ± 0.16 (0.0- 3.0)^{a}	1.83±0.23 (0.85- 6.0)^{a}	1.66 ± 0.13 (0. 0- 3.0)^{b}	1.87±0.19 (0.0- 3.0)^{a}	0.28±0.19 (0.79- 4.0)^{a}	0.100	P>0.05
Depth (m)	1.21± 0.12^{a} (0.0- 2.0)	1.11±0.11^{a} (0.0- 2.0)	0.67± 0.12^{b} (0.0 -2.0)	0.96±0.22^{a} (2.0-5.0)	1.09±0.06^{a} (1.00- 2.0)	0.138	P<0.05
Ph	5.56± 0.13 (4.0- 6.0)	5.46±0.13 (4.0- 7.0)	5.42 ± 0.12 (4.0- 6.0)	5.63±0.13 (5.0- 7.0)	5.41±0.14 (4.0- 7.0)	0.313	P>0.05
Electrical conductivity (μSm^{-1})	114.58± 14.02^{a} (6.0- 290.0)	106.25±7.97^{a} (47.0- 209.0)	113.54± 1.0^{a} (38.0- 198.0)	126.0±0.52^{a} (59.0- 196.0)	88.45±7.08^{b} (32.0- 161.0)	0.090	P<0.05
Salinity (g/L)	0.13± 0.13 (0.0- 3.0)	0.0±0.00 (0.0- 0.0)	0.0±0.00 (0.0- 0.0)	0.0±0.00 (0.0- 0.0)	0.0±0.00 (0.0- 0.0)	0.170	P>0.05
Colour (Pt.Co)	3.5± 0.32^{b} (1.0- 6.0)	3.82±0.41^{a} (2.0- 8.0)	4.21 ± 0.50^{a} (2.0- 10.0)	5.08±0.68^{a} (2.0- 16.00)	3.40±0.28^{b} (2.0- 6. 0)	0.0282	P<0.05
Turbidity (NTU)	2.82± 0.30 (1.0- 6.0)	2.86±0.34 (1.0- 7.0)	2.83 ± 0.45 (1.00- 8.0)	3.58±0.47 (1. 0- 11. 0)	2.45±0.30 (1.00- 6.0)	0.068	P>0.05
Total Suspended Solid (mg/L)	0.4± 0.73^{b} (2.0- 19.0)	5.92±0.54^{b} (2.0- 12.0)	7.13 ± 0.40^{a} (3.0- 15.0)	9.13±1.23 ^{a} (3.0- 26. 0)	6.27±0.61^{b} (2.0- 15. 0)	0.340	P<0.05
Total Dissolved Solid (mg/L)	56.42± 7.48^{a} (6.0- 148.0)	53.33±3.95^{a} (24.0- 97.0)	55.96± 4.70^{a} (20.0- 100.0)	62.0±4.16^{a} (29.0- 98.0)	43.77±3.356^{b} (16.0- 70.0)	0.105	P<0.05
Dissolved Oxygen (mg/L)	5.63± 0.22 (2.0- 7.0)	5.67±0.12 (4.0- 6.0)	5.63± 0.10 (5.0- 6.0)	5.50±0.13 (4.0- 7.0)	5.60±0.14 (4.0- 7.0)	0.486	P>0.05
Biochemical Oxygen Demand (mg/L)	2.46± 0.31 (1.0- 8.0)	2.71±0.19 (1.0- 4.0)	2.63± 0.20 (1.0- 4.0)	2.46±0.19 (1.0- 4.0)	2.05±0.14 (1.00- 3.0)	0.053	P<0.05
Chemical Oxygen Demand (mg/L)	10.92± 1.06^{b} (5.0- 28.0)	12.83±0.81^{a} (5.0- 23.0)	15.13 ± 1.18^{a} (6.0- 29.0)	16.17±1.78^{a} (5.0- 36.0)	10.14±0. 70^{b} (4.00- 16.0)	0.131	P>0.05
Bicarbonate (mg/L)	24.08± 2.92^{b} (0.0- 58.0)	25.38±2.10^{b} (6. 0- 49.0)	30.58± 2.07^{a} (12.0- 53.0)	33.58±2.33^{a} (18.0- 51.0)	18.41±1.40^{c} (6.0- 30.0)	0.054	P>0.05
Sodium (mg/L)	0.96± 0.11^{a} (0.0- 2.0)	1.00±0.06^{a} (0.0- 2.0)	1.08 ± 0.08^{a} (0.0- 2.0)	1.13±0.67^{a} (1.0- 2.0)	0.86±0.07^{b} (0.0- 1.0)	0.087	P>0.05
Potassium (mg/L)	0.04± 0.04 (0.0- 1.0)	0.0±0.0 (0.0- 0.0)	0.0±0.0 (0.0- 0.0)	0.0±0.0 (0.0- 0.0)	0.0±0.0 (0.0- 0.0)	0.172	P>0.05

Table 1 Continue

Calcium (mg/L)	**1.79± 0.23 (0.0- 6.0)**	**1.86±0.15 (1.0- 4.0)**	**2.13± 0.19 (1.0- 5.0)**	**2.63±0.22 (1.0- 5.0)**	**1.41±1.11 (1.0- 2.0)**	**0.079**	**P<0.05**
Magnesium (mg/L)	1.17± 0.65 (0.0- 16.0)	0.63±0.10 (0.0- 1.0)	0.71± 0.11 (0.0- 2.0)	0.75±0.09 (0.0- 1.0)	0.36±0.10 (0.0- 1.0)	0.105	P>0.05
Chlorine (mg/L)	32.71± 3.51 (8.0- 69. 0)	33.92±1.94 (15.0- 53.0)	40.71± 3.21 (19.0- 90.0)	48.04±4.01 (21.0- 88.0)	27.68±2.47 (6.0- 52.0)	0.090	P<0.05
Phosphorus (mg/L)	0.79± 0.13 (0.0- 2.0)	0.08±0.10 (0.0- 2.0)	1.08 ± 0.13 (0.0- 3.0)	1.17±0.17 (0.0- 4.0)	0.86±0.12 (0.0- 2.0)	0.079	P<0.05
Ammonium Nitrogen (mg/L)	0.04± 0.04 (0.0- 1.0)	0.0±0.0 (0.0- 0.0)	0.0±0.0 (0.0- 0.0)	0.0±0.0 (0.0- 0.0)	0.0±0.0 (0.0- 0.0)	0.172	P>0.05
Nitrate (mg/L)	1.42 ± 0.17 (0.0- 3.0)	1.50±0.16 (1.0- 4.0)	1.92± 0.23 (1.0- 5.0)	2.25±0.28 (1. 0- 6.0)	9.41±8.22 (1.0- 182.0)	0.147	P>0.05
Sulphate (mg/L)	0.46± 0.10 [b] (0.0- 1.0)	0.46±0.10[b] (0.0- 1.0)	0.67± 0.10 [a] (0.0- 1.0)	0.67±0.10 [a] (0.0- 1.0)	0.32±0.10[c] (0.00- 1.0)	0.190	P<0.05
Iron (mg/L)	0.63± 0.12[b] (0.0- 2.0)	0.54±0.10[b] (0.0- 1.0)	0.88± 0.11[a] (0.0- 2.0)	0.96±0.11[a] (0.0- 2.0)	0.64±0.10[b] (0.0- 1.0)	0.051	P<0.05
Manganese (mg/L)	0.04± 0.01 [b] (0.01- 0.12)	0.05± 0.01 [b] (0.01- 0.10)	0.09± 0.01 [a] (0.04- 0.33)	0.09± 0.01 [a] (0.02- 0.20)	0.04± 0.01 [b] (0.00- 0.10)	0.000	P<0.001
Zinc (mg/L)	0.17± 0.02[a] (0.00- 0.48)	0.194± 0.02[b] (0.04- 0.48)	0.17± 0.08[a] (0.09- 0.65)	0.17± 0.08[a] (0.1- 0.90)	0.15± 0.02[c] (0.00- 0.31)	0.000	P<0.001
Copper (mg/L)	0.03± 0.01[b] (0.00- 0.08)	0.03± 0.00 [b] (0.01- 0.06)	0.05± 0.01[a] (0.02- 0.14)	0.06± 0.01 [a] (0.01- 0.23)	0.02± 0.00[c] (0.00- 0.06)	0.002	P<0.01
Chromium (mg/L)	0.02± 01 (0.00- 0.07)	0.02± 0.00 (0.0- 0.06)	0.03± 0.03 (0.00- 0.05)	0.03± 0.00 (0.00- 0.06)	0.02± 0.02 (0.00- 0.04)	0.018	P<0.05
Cadmium (mg/L)	0.02± 0.01[b] (00.0- 0.08)	0.02± 0.00[b] (0.00- 0.07)	0.03± 0.00[a] (0.00- 0.06)	0.03± 0.00[a] (0.00- 0.06)	0.01± 0.00[b] (0.00- 0.03)	0.058	P<0.05
Nickel (mg/L)	0.01± 0.00 (0.00- 0.02)	0.01± 0.0 (0.00- 0.03)	0.01± 0.00 (0.0- 0.0)	0.01± 0.00 (0.00- 0.04)	0.01± 0.00 (0.00- 0.01)	0.118	P>0.05
Lead (mg/L)	0.02± 0.01 (0.00- 0.03)	0.03± 0.01 (0.00 - 0.08)	0.03± 0.00 (0.00- 0.06)	0.03± 0.00 (0.00- 0.07)	0.02± 0.00 (0.00 - 0.05)	0.125	P>0.05
Vanadium (mg/L)	0.01± 0.00 (0.0- 0.03)	0.01± 0.00 (0.00- 0.02)	0.01± 0.00 (0.00- 0.08)	0.01± 0.00 (0.00- 0.03)	0.01± 0.01 (0.00- 0.09)	0.257	P>0.05
Total Hydrocarbon (mg/L)	0.14± 0.08 (0.0- 1.0)	0.17±0.08 (0.0-1.0)	0.08± 0.06 (0.0- 1.0)	0.0± 0.0 (0.0- 0.0)	0.01± 0.01 (0.0- 2.0)	0.117	P>0.05

Note: significantly different, * P> 0.05 = no significant difference, P< 0.05.

factor correlations of > 0.75, 0.74- 0.50 and 0.49- 0.30 are considered as strong, moderate and weak factor loading respectively (Liu et al., 2003).

RESULTS

Thirty-four physico-chemical parameters were analysed and used to obtain the water quality index of Ethiope River (Table 1). The various parameters were collected across the five designated stations. The stations were Umuaja (Station 1), Umutu (Station 2), Obiaruku (Station 3), Abraka (Station 4) and Eku (Station 5). The results showed varied values of physico-chemical parameters analysed across the stations. WHO standards were used to compare the WQI values of the sampled stations (Table 2). Station 3 recorded the highest mean WQI while the lowest value was obtained in station 5 (Table 3). Monthly variability of WQI showed highest value in May 2016 at station 1 and in December 2017 at station 4 (Table 4). Principal component Analysis (PCA) showed the controlling variables in data series (physico-chemical parameters), which played significant roles in the variation across the sampled stations (Table 5).

Table 2. Grades of surface water using water quality index.

Standard WQI levels	Description
<50	Excellent
0 - 100	Suitable for drinking
101 -200	Poor for drinking
201- 300	Very poor for drinking
>301	Unsuitable for drinking

Source: WHO (2011).

Table 3. Water quality index mean values obtained from the five studied stations from Ethiope River revealed poor water for drinking.

Stations	WQI mean values for Stations
1	129.41
2	137.03
3	173.61
4	147.86
5	112.70

Table 4. Mean monthly water quality index across the five studied stations.

		Station 1	Station 2	Station 3	Station 4	Station 5	Bench-mark
2016	Jan	19.25	23.69	20.77	37.71	29.11	100
	Feb	236.00	23.69	20.77	37.71	29.11	100
	Mar	55.21	189.74	103.90	53.45	313.08	100
	Apr	226.70	100.82	162.54	76.60	63.57	100
	May	531.83	444.50	390.22	215.63	363.37	100
	Jun	510.20	440.78	396.35	208.49	339.70	100
	Jul	147.68	313.78	377.19	162.47	92.20	100
	Aug	71.90	226.66	101.11	81.68	147.32	100
	Sep	229.41	89.28	146.17	329.45	65.03	100
	Oct	151.70	131.31	258.44	115.76	68.10	100
	Nov	70.83	48.08	85.58	53.53	38.28	100
	Dec	28.94	106.44	135.09	85.00	10.81	100
2017	Jan	55.06	124.27	81.72	9.67	74.10	100
	Feb	148.04	129.58	262.37	117.19	67.47	100
	Mar	78.37	250.13	218.61	159.29	117.90	100
	Apr	32.81	71.04	141.55	131.45	92.83	100
	May	18.08	96.70	202.63	182.41	101.97	100
	Jun	18.98	67.06	88.72	119.68	32.20	100
	Jul	8.26	72.97	129.53	195.94	70.48	100
	Aug	12.28	54.37	80.46	117.29	33.71	100
	Sep	75.52	113.91	211.81	259.35	97.69	100
	Oct	86.00	32.12	124.38	154.82	40.26	100
	Nov	160.03	81.24	194.50	293.64	120.03	100
	Dec	132.77	56.56	232.21	350.44	87.02	100
	Mean	129.41	137.03	173.61	147.86	112.70	

Table 5. Eigenvectors and eigenvalues of the various components.

Parameter	Principal Components										
	PC 1	**PC 2**	**PC 3**	**PC 4**	**PC 5**	**PC 6**	**PC 7**	**PC 8**	**PC 9**	**PC 10**	**PC 11**
Air temperature (°C)	0.01	0.00	-0.02	0.01	-0.02	0.13	0.05	0.07	-0.06	0.01	-0.19
Water Temperature (°C)	0.02	0.00	-0.01	-0.02	0.00	0.07	-0.03	0.06	0.04	0.05	-0.17
Flow rate (ms^{-1})	-0.03	-0.22	**0.84**	0.25	0.14	-0.02	0.11	0.23	-0.09	-0.06	-0.06
Depth(m)	-0.09	0.02	0.02	0.09	0.19	-0.16	**0.30**	**-0.40**	**0.66**	**0.35**	-0.01
Hydrogen ion concentration	-0.07	0.22	**-0.33**	-0.06	0.13	-0.24	0.07	0.23	-0.12	-0.27	-0.27
Conductivity(μSm^{-1})	**0.49**	-0.28	-0.05	-0.09	-0.21	**-0.39**	-0.14	0.05	0.10	0.04	0.07
Salinity (g/L)	-0.04	0.08	0.00	0.02	0.17	-0.07	0.11	0.08	0.01	-0.03	0.03
Colour(pt.co)	0.19	**0.46**	0.22	-0.08	**-0.41**	-0.02	0.05	-0.17	-0.12	0.12	0.11
Turbidity(NTU)	0.15	**0.51**	0.21	0.00	-0.26	-0.21	0.16	-0.17	-0.05	-0.15	0.08
Total suspended solid(mg/L)	0.15	**0.45**	0.07	-0.08	0.09	0.25	-0.14	**0.51**	**0.38**	0.17	**-0.31**
Total dissolved solids(mg/L)	**0.37**	-0.11	-0.03	-0.02	0.13	**-0.49**	0.12	0.26	0.07	-0.05	-0.03
Dissolved oxygen(mg/L)	0.03	-0.05	-0.01	0.01	-0.03	-0.01	-0.11	-0.14	0.01	-0.09	-0.07
Biochemical oxygen(mg/L)	0.03	0.15	0.03	0.01	**0.36**	0.04	-0.29	-0.28	-0.13	-0.18	0.15
Chemical oxygen demand(mg/L)	0.24	0.16	0.15	0.02	**0.38**	-0.07	**-0.56**	-0.21	0.16	-0.20	0.00
Bicarbonates(mg/L)	**0.42**	-0.12	0.05	-0.19	0.16	0.18	0.10	-0.25	-0.29	**0.34**	**-0.51**
Sodium(mg/L)	0.13	0.03	-0.04	0.02	0.08	0.05	0.16	-0.05	-0.11	0.03	0.04
Potassium(mg/L)	0.00	0.05	-0.01	0.03	0.11	0.04	0.13	0.01	-0.02	0.00	0.07
Calcium(mg/L)	0.21	0.03	-0.05	0.04	0.13	0.11	0.25	-0.04	-0.18	-0.08	0.12
Magnesium(mg/L)	0.01	0.19	-0.04	0.09	**0.43**	-0.08	**0.41**	0.05	-0.15	-0.07	0.09
Chloride(mg/L)	**0.39**	-0.15	-0.04	-0.05	-0.09	**0.53**	0.22	0.02	**0.33**	**-0.49**	0.18
Phosphrous(mg/L)	0.16	0.02	-0.10	0.11	0.11	0.09	0.01	0.10	0.04	0.29	**0.35**
Ammionium Nitrogen(mg/L)	-0.01	0.06	-0.01	0.03	0.11	-0.01	0.06	0.04	0.03	-0.01	0.07
Nitrate(mg/L)	0.16	0.04	-0.20	**0.92**	-0.16	0.04	-0.09	-0.01	-0.03	0.02	-0.16
Sulphate(mg/L)	0.11	0.01	-0.05	0.03	0.08	-0.07	0.09	0.07	-0.03	-0.03	0.14
Iron(mg/L)	0.12	0.06	-0.07	0.04	0.10	0.17	-0.04	-0.05	-0.19	0.26	0.13
Manganese(mg/L)	0.01	0.01	0.00	0.01	0.03	0.04	0.00	-0.01	-0.01	0.01	0.02
Zinc(mg/L)	0.06	0.03	-0.03	0.02	0.07	0.08	-0.04	-0.02	-0.12	0.11	0.03
Copper(mg/L)	0.01	0.01	-0.01	0.01	0.01	0.02	-0.01	0.00	0.00	0.03	0.03
Chromium(mg/L)	0.01	0.00	0.00	0.00	0.01	0.00	-0.01	0.01	-0.01	0.02	0.02
Cadmium(mg/L)	0.01	0.00	0.00	0.00	0.01	0.00	-0.01	0.02	0.00	0.02	0.02
Nickel(mg/L)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01
Lead(mg/L)	0.01	0.00	0.00	0.00	0.01	0.00	-0.02	0.02	-0.01	0.02	0.02
Vanadium(mg/L)	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.01	0.00	0.00	0.00
Total Hydrocarbon(mg/L)	0.04	0.02	-0.02	-0.04	0.04	0.04	-0.18	**0.33**	-0.08	**0.34**	**0.45**
Eigenvalue	0.24	0.10	0.08	0.05	0.04	0.02	0.02	0.02	0.01	0.01	0.01
% variance	38.20	16.43	12.61	7.68	5.59	3.44	2.94	2.81	2.11	1.68	1.17

varimax factor correlation coefficient of >0.75, 0.74 - 0.50 and 0.49-0.30 are considered as strong, moderate and weak factor loading respectively (Liu et al., 2003).

DISCUSSION

The physico-chemical parameters values obtained in this work may have been affected by the prevailing anthropogenic activities at the various designated five stations. The physico-chemical properties of an aquatic ecosystem can be contaminated with human-induced activities and waste disposal around the catchment along its course. It is pertinent to determine these factors in order to proffer mitigation measured aimed at ensuring excellent water (< 50) suitable for drinking. The marked variation and significant differences in the physico-chemical parameters of the water body indicated different environmental conditions.

Surface water temperature did not show any conspicuous disparity, which is classical of tropical inland freshwater and rivers. The mean temperature values obtained in this study ranged from 24.50 to 26.82°C (Table 1). These findings were similar to the values (24.95 to 25.56°C) reported by Arimoro et al. (2015) in Ogba River. Erhenhi and Francis (2018) obtained a range of

26.1 to 28.3°C in Ethiope River. The similar temperature may be due to riparian vegetation of the dense canopy cover of different tree species. River bed or siltation influences the flow rate of a river, hence reflects the nutrient status of the studied stations and in turn affects the water quality. The values obtained in this study ranged from 0.28 to 1.83 m/s. Similar values were also reported by Arimoro (2009) (0.16 to 0.38 m/s) in upper reaches of Warri River and Udebuana et al. (2015) who obtained a value ranging from 1.66 to 2.61 m/s in Okhuo River.

The mean depth obtained in this study ranged from 0.67 to 1.21 m (Table 1). Ikomi and Arimoro (2014) recorded a value ranging from 0.16 to 0.32 m in Ethiope River. The values obtained in this study could be attributed to the position and topography of the sampled stations. Electrical conductivity can be defined as the ability of any substance to carry or transport electrical current. Electrical conductivity is usually dependent on the concentration of ions in water or the quantity of the total dissolved salt (Shrinivasa et al., 2000). The mean electrical conductivity values obtained in this study ranged from 88.45 to 126.0 usm^{-1}.The conductivity values obtained in this study were lower than those reported by Kaizer and Osakwe (2010) and Ogbuagu et al. (2011). This may be attributed to less dissolved substances.

pH concentration of an aquatic ecosystem can be changed by biological activities as a result of small change which can be a threat to the aquatic fauna. The values obtained in this study ranged from 5.41 to 5.64. Similar findings on pH values ranged from 5.2 to 5.4 on Ethiope River as earlier reported by Erhenhi and Francis (2018). Low hydrogen ion concentration indicated weak buffering capacity in relation to the volume of the water and decomposing organic matter.

Salinity is mostly controlled by rainfall pattern and is one of the most ecological factors in the tropics. The salinity levels obtained in this study ranged from 0.0 to 0.13 g/L. This is similar to that obtained in the freshwater ecosystem reported by Egborge (1994) in Lagos harbour Badadary creek system. The results had a similar trend with works done by Davies (2009) and Arimoro et al. (2011) in different water bodies.

Colour variation is an indicator of intense human disturbance in a water body. The aesthetic objective limit is fifteen true colour units (TCU). The values obtained in this study ranged from 3.50 to 5.80 TCU (Table 1). Station 4 obtained the highest colour value; this could be attributed to increased waste disposal and organic matter decomposition. Turbidity measures the optical ability of sediments suspended to inhibit the penetration of light. The turbidity profiles for this study ranged from 2.45 to 3.58 NTU (Table 1). The values obtained were below the maximum limit of 5 NTU set by WHO (2005). Contrary to the values recorded in this study, Omo-Irabor and Olobaniyi (2007) obtained a value ranging from 1.16 to 8.12 NTU in Ethiope River. More so, scaling the principal component analysis for water (Table 5) in which a turbidity value of 0.506 NTU was obtained revealed a moderate loading factor across the studied stations. The low values obtained in this study may be due to an increase in induced-human activities.

Total suspended solids are particles that are larger than two microns and are found in water column; they can also be referred to as the sum total of suspended particles. The values obtained in this range from 0.4 to 9.13 mg/L (Table 1). The low value recorded in this study is suggestive of the physical, geological and biological process at the position and time of sampling. Ofonmbuk et al. (2014) also reported low mean values ranging from 1.78 to 3.37 mg/L in Ediene River, whereas Edokpayi and Osimen (2001) obtained much higher total suspended solid ranging from 3406.78 to 3954.07 mg/l in Ibeikuma River. Total dissolved solid value < 100mg/l are suitable and good enough for drinking and agricultural purposes while total dissolved solid value >500 mg/L is not desirable for drinking and remains a threat to aquatic fauna. Total dissolved solid values obtained in this study ranged from 43.77 to 62.0 mg/L, which are rather high compared to the low values of total dissolved solids (9.8 to 17.0 mg/L) recorded in Ethiope River by Iloba (2017). The rise in total dissolved solids may have been influenced by waste disposal and dredging of sand in the river.

Oxygen enters an aquatic ecosystem through diffusion of air and photosynthesis in aquatic plants where oxygen is given out as a by-product. Oxygen depends on temperature, depth, flow rate, salinity and pressure of the water body. The values obtained in this study ranged from 5.50 to 5.67 mg/l (Table 1). Some authors who had assessed Ethiope River earlier reported varying ranges for dissolved oxygen. Omo-Irabor and Olobaniyi (2007) recorded a range of 4.40 to 7.60 mg/L; while Ikomi and Arimoro (2014) obtained a range of 4.9 to 5.9 mg/L. Others included Iloba (2017), who obtained a range from 2.1 to 3.1 mg/L and Erhenhi and Francis (2018) who recorded a range of 5.5 to 6.2 mg/L in the riffles and 4.0 to 4.6 mg/L in the pools. These changes in the dissolved oxygen concentrations may be attributed to the dynamics of respiration and photosynthesis (Akintola, 2011).

The amount of oxygen essential for an organism to breakdown or utilize the organic present in a water body over a while at a specific temperature is regarded as Biochemical Oxygen Demand. This factor is vital for determining the safety and cleanliness of any water. Similarly, Ogbuagu et al. (2011) stated that biochemical oxygen demand value of uncontaminated water body state value is < 2 mg/L. While contaminated water body may have values up to 8 mg/L or more, and biochemical oxygen demand is responsible for odour and taste of water. The values obtained in this study range from 2.05 to 2.76 mg/L (Table 1). This range of values is in conformity with that reported by Ikomi and Arimoro (2014) who obtained a range value of 1.4 to 2.7 mg/L, and Erhenhi and Francis (2018) who recorded 1.0 to 1.3 mg/L (riffles) and 2.0 to 2.2 mg/L (pools). The low biochemical oxygen demand values imply the ability of a river to decontaminate itself if biochemical oxygen demand is below 4 mg/L (Radajevic and Bashkin, 1999).

The mean chemical oxygen demand values recorded in this study was comparatively low, ranging from 10.14 to 16.17 mg/L. On the contrary, Ayobahan et al. (2014) recorded a higher mean range from 19.14 to 115.65 mg/L in Benin River. The observed changes could be attributed to contamination, especially by organic matter.

Bicarbonates also refer to the property of water which prevents lather formation with soap and increases the boiling points of the water. It depends on the amount of calcium and magnesium salt. Based on bicarbonate, water is classified into three categories: soft water ranges from 0 to 75 mg/L, moderately hard water ranges from 76 to 150 mg/L and hard water ranges from 1.51 to 300 mg/L (Soni et al., 2013). The mean bicarbonates values obtained in this study ranged from 18.41 to 33.58 mg/L, which categorizes Ethiope River as soft water. Omo-Irabor and Olobaniyi (2007) reported similar values ranging from 25.50 to 45.0 mg/L in Ethiope River.

Sodium and Potassium (Na^+ and K^+) metals are known as alkali metal and belong to group 1 of the periodic table with one valence electron. The values obtained for this study ranged from 0.86 to 1.13 mg/l for sodium; and 0.0 to 0.04 mg/L for potassium (Table 1). Omo-Irabor and Olobaniyi (2007) obtained higher values for sodium, ranging from 3.91 to 27.05 mg/L while that of potassium ranged from 3.91 to 8.73 mg/L in Ethiope River. The low values obtained in this study could be due to the geochemical impact of soil mineral via runoff.

The mean values for the alkaline earth metals ranged from 1.41 to 2.63 mg/L (calcium) and from 0.36 to 1.17 mg/L (magnesium). Omo-Irabor and Olobaniyi (2007) reported high values for calcium (3.21 to 9.60 mg/L) and magnesium (1.46 to 5.84 mg/L). These changes in alkaline metals concentration could be attributed to the intensity of water flow, weather condition (precipitation and evaporation) and type of plant cover (Kurita, 2015).

Chloride– is an inorganic compound resulting from the combination of chlorine gas with metals (sodium and magnesium); hence essential for living organisms. The chloride concentration in this study ranged from 27.68 to 48.04 mg/L. Comparatively, previous studies on the Ethiope River reported by Omo-Irabor and Olobaniyi (2007) obtained a value ranging from 17.55 to 35.10 mg/L and Iloba (2017) recorded a range from 2.2 to 4.9 mg/L. The high value recorded in this study, notably at station 4, is an indication of sewage waste.

Phosphorus is an essential nutrient for algal productivity of a water body. The values obtained in this study ranged from 0.08 to 1.17 mg/L (Table 1). These values are similar to previous studies on Ethiope River for phosphate levels reported by several authors; Ikomi and Arimoro (2014); Iloba (2017) and Erhenhi and Francis (2018). On the contrary, Omo-Irabor and Olobaniyi (2007) reported high range of phosphous values in their study in Ethiope River, Nigeria. The high mean values of phosphous obtained in this study were above the Nigeria standards for drinking water quality, 0.1 mg/l; source of phosphorus could be as a result of surface runoff from inorganic fertilizers from the surrounding farmland.

Nitrate is a form of nitrogen and a vital nutrient for growth, reproduction and survival for aquatic fauna. High nitrate levels greater than 1 (>1 mg/L) are not suitable for aquatic life (Carnargo et al., 2005). The values of nitrate obtained in this study ranged from 1.42 to 9.41 mg/L (Table 1). The values obtained were rather high as compared to previous studies carried out in Ethiope River by Omo-Irabor and Olobaniyi (2007) who recorded a value ranging from 0.19 to 0.55 mg/l; Iloba (2017) obtained a range from 0.08 to 0.18 mg/L, Erhenhi and Francis (2018) obtained 0.14 to 0.16 mg/L for riffles and 0.20 to 0.23 mg/L for pools. The high nitrate value at station 5 for this study could be attributed to the autochthonous materials obtained from PRESCO oil mill and decay plant parts. Ammonium nitrogen is one of the forms of nitrogen in water. The values obtained in this study ranged from 0.0 to 0.0 4 mg/L (Table 1). Arimoro (2009) reported high values of ammonium nitrogen ranging from 14.25 to 43.58 mg/L in Adofi River, Niger Delta area of Nigeria. The low values of ammonium nitrogen reported in this study might come from runoffs in leachable forms such as nitrate, nitrite and organic forms of nitrogen such as urea and amino acids.

Sulphate occurs naturally in water and essential in primary productivity nutrients. The values obtained in this study ranged from 0.32 to 0.67 mg/L. Similar studies reported by Iloba (2017) had a range from 2.1 to 3.7 mg/L in Ethiope River and Ayobahan et al. (2014) obtained a range from 0.93 to 2.59 mg/l in the surface water in Benin River. The low mean sulphate values obtained in this study might be from gypsum and other common minerals.

The mean concentration of iron ranged from 0.54 to 0.96 mg/L. The concentration of iron observed in this study was higher than the permissible values of 0.03 mg/L set by WHO (2012). The concentration of Iron obtained in this study was greater than those reported by similar studies (Hong et al., 2014). High levels of iron could be attributed to rusting steel or scapes in contact with water and natural biochemical and geochemical process in the aquifers around the catchment. The mean concentration of Manganese in water sample ranged from 0.04 to 0.09 mg/L (Table 1) in the studied stations. These values were similar to those reported by Kaizer and Osakwe (2010) in Ethiope River. The concentrations of manganese in the samples at stations 3 and 4 were higher than WHO (2012) standard values of 0.05 mg/L.

The mean concentration of Zinc ranged from 0.15 to 0.19 mg/L. The concentrations of Zinc obtained in this study are below the standard values of 5.0 mg/L set by WHO (2012).These values are similar to the values obtained by Hong et al. (2014) in Benue River. The mean concentration of copper in the water samples across the studied stations ranged from 0.02 to 0.06 mg/L. The concentrations of copper were below the standard value of 2 mg/L set by WHO (2012).Lower concentrations of copper have also been reported by Farombi et al. (2014).

The mean concentration of chromium in the water samples across the studied stations ranged from 0.02 to 0.03 mg /L (Table 1). Similar concentrations were reported by Kaizer and Osakwe (2010). The mean concentration of chromium in this study was below the WHO (2012) maximum value of 0.05 mg/L .The source of chromium in the river may be from discharge of municipal wastes into the river directly or indirectly and fuel spent.

The mean concentration of cadmium in the water samples in all studied stations ranged from 0.01 to 0.03 mg/L in the water samples in all studied stations. The mean concentration of cadmium obtained in the studied was greater than WHO (2012) standard value of 0.003 mg/l, an indication that the water from the river is contaminated. The mean concentration of nickel in the water samples was constant 0.01 mg/L across the studied stations. Lower concentration was also reported by Farombi et al. (2014).The mean concentration of nickel obtained in this studied was below the WHO (2012) standard of 0.02 mg/L. The presence of nickel from the river could be attributed to leaching from Ni – Cd battery from automobiles.

The mean concentration of lead in the water samples in all studied stations ranged from 0.02 to 0.03 mg/L (Table 1). Similar concentrations were reported by Kaizer and Osakwe (2010) and Wagboge and Ikhuabe (2015).The lead concentration in water was above the permissible limits of 0.01 mg/L set by WHO (2012). The high lead concentration could be run off from increased use of chemical fertilizers. The mean concentration of vanadium in the water samples was constant 0.01 mg/l across the studied stations. The concentration of vanadium obtained in this study is above the permissible values of 0.002 mg/l. The possible sources could be from wash off from paints and vanishes.

The concentration of THC ranged from 0.01 to 0.17 mg/L. The value of THC obtained in this research was below 10 mg/l set by WHO (2012).

Water quality index

Water Quality Index (WQI) is a very useful and efficient method which can provide a simple indicator of water quality that is understandable and useable by the public and its suitability for drinking purposes (Magesh et al., 2013).It is also a device for rating the influence of each physicochemical parameter on the overall water quality. The WQIs in this study using mean values of the five sampled stations are presented in Table 3 respectively. The WQI values of the water sample from the studied stations suggest increase in anthropogenic activities ranging from organic waste, run off from agricultural fertilizers, discharge from sewage and human induced activities. It is in conformity with the result obtained from PCA (Table 5) .However, the water quality across the studied stations (Table 3) is poor for drinking 101-200 compared with the standard grades of surface water quality using WQI (Table 2).

Principal component analysis

Principal component analysis was used to evaluate and identify physico-chemical parameters influencing the water quality and source of contamination .The results of the PCA based on the correlation matrix of physico-chemical parameters are presented in Table 5. The eigenvector classified the parameters into eleven components which accounted for 94.66% of the variance in the data set. The component PC1 represents 38.20% of variability. This indicates a moderate loading on electrical conductivity and weak loading factor on bicarbonates, total dissolved solids and chloride. PC2 with 16.43% variance denoted moderate loading factor on turbidity and a weak loading factor on total suspended solid and colour. PC3 with 12.61% displayed a strong positive loading on flow rate and a weak negative loading on Hydrogen ion concentration. PC4(7.68%) reflected a strong positive loading on nitrate, while PC5 5.59% of variance indicated weak loading on biochemical oxygen demand, chemical oxygen demand and magnesium and a weak negative loading factor on colour. Similarly, component PC6 (3.44% of variability) showed moderate loading factor on chloride and a weak negative loading factor on conductivity and total dissolved solids. PC7 represented 2.94% with a weak loading factor on magnesium and a negative moderate loading factor on chemical oxygen demand. PC8 (2.81% of variance) showed moderate loading factor on total suspended solids and a weak loading factor on total hydrocarbon. PC9 2.11% of variability revealed a moderate loading factor depth and a weak positive loading for total suspended solids and chloride. PC10 showed 1.68% of difference with a weak loading factor on depth, bicarbonates and total hydrocarbon; a weak negative loading chloride. PC11(1.17% of variability) reflected a negative moderate loading factor on bicarbonates, a weak loading factor on THC and phosphorus as well as a weak negative factor on total suspended solids. Considering the larger variability of PC1 and PC2 in comparison with other components revealed the impact of anthropogenic activities and inflow of other watersheds across the studied stations (Table 5).

Conclusion

The WQI values across the five studied stations above the benchmark > 100 clearly show they are unfit for consumption. The results from principal component analysis showed human-induced activities caused the water quality discrepancy in the studied stations of Ethiope River. It is wise to conclude that WQI and PCA are effective tools for understanding the relationship between water quality and human disturbances on water bodies. This research advocates for continuous monitoring of water quality by enforcing environmental laws and decision making processes towards mitigating the plethora of environmental challenges

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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