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Assessment of Water Quality Along River Ethiope, Delta State

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Abstract

The environment, economic growth, and human health all depend on the quantity and quality of water supplies. Given this, the significance of water quality monitoring cannot be overstated.This study was aimed at assessing the water quality of River Ethiope. To achieve this, surface water samples were collected from Ethiope River along its banks at the following towns; Umuaja (SWI), Ebedie (SW2), Abraka (SW3), Sapele (SW4) and Ughara (SW5) axis during the rainy seasons; June to October, 2023. A total of 25 samples were collected each month from sampling sites. Using a standard analytical approach, the physicochemical properties, biochemical properties, and microbiological contents were ascertained. To evaluate the data and findings, descriptive analysis, correlation analysis, analysis of variance, and the water quality index (WQI) were used. Total heterotrophic fungi (THF) and Total coliform bacteria (TCB) showed significant difference (p<0.05) among the stations while pH, temperature and dissolved oxygen showed no significant difference (p>0.05) among some of the stations. Correlation study between total dissolved solids (TDS) and electrical conductivity (EC) showed perfect correlation while chemical oxygen demand (COD) and biochemical oxygen demand (BOD), PO_4^{3-} and NO_3^-, Na and Mg, Cl and TDS, Ca and Na revealed significant positive relationship (p<0.01), Negative significant relationships existed between DO and TDS, Chloride and PO_4^{3-}, BOD and DO, COD and DO (p<0.01). The WQI calculated showed that water quality was excellent in station SWI (11.441) and SW2 (17.354), poor in stations SW3 (74.633) and SW5 (54.823), and very poor in station SW4 (78.777). Seasonal variance should be incorporated into future research.

Keywords: Water quality index, assessment, river Ethiope, water characteristics

INTRODUCTION

One of the planet's most important natural resources is water. Water is essential to all life, including human existence. Water resources and quality are critical to human health, economic development, and the environment [1]. Global freshwater use, including reservoirs, municipalities, industries and agriculture, has grown rapidly over the past 100 years. Natural water may contain dissolved substances and non-dissolved particulate matters which are necessary components of good quality water [2]. However, water quality deterioration has become a problem worldwide [3]. The increased level of pollutants which include heavy metals, VOCs, acid rain and pesticide have gained ample attention. Water pollution may result from rural run-off loads, atmospheric deposits, industrial waste water, seepages from municipal solid waste water disposal sites, seepages/leachates from land fill sites, domestic waste water/sewage and oil and gas

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production [4]. Human induced water pollution is enormous, such as dumping of refuse, defecating, washing of cloths and dredging [5]. Periodic monitoring of these threats can save public health as well as habitat degradation [6].

The main cause of water-borne illnesses is the consumption of harmful bacteria and other microbes. Drinking water of low quality increases the chance of developing numerous illnesses that can be fatal [7]. According to a 2012 study, 280,000 deaths globally were attributed to poor sanitation, and 502,000 deaths were attributed to diarrhea brought on by drinking water of low quality [8].

According to UNICEF and WHO estimates from 2013, 768 million people lack access to safe drinking water, which results in hundreds of thousands of illnesses and deaths among children annually. The majority of those without access to clean water are impoverished and reside in either urban or rural areas [9].

River Ethiope rises from Umuaja and flows through Ebedei, Abraka, Eku, Okpara, Jesse, Sapele, among others for over 96.6km into the Atlantic Ocean. The inhabitants of these settlements depend on the water from the river for domestic purposes, recreation, transportation, fishing, and industrial purposes. However, a good number of researchers have reported the impairments of River Ethiope as a result of geologic and anthropogenic activities. The water is susceptible to pollution and might not be fit for human consumption as a result of these operations [10]. Erhenhi, and Omoigberale, (2020) reported that the water quality index (WQI) values of River Ethiope were above the benchmark and clearly showed that they were unfit for drinking [11]. Omo-Irabor and Olobaniyi, (2007) reported physico-chemical quality of River Ethiope was compatible with WHO guideline for domestic use and water samples consisted high microbial population such as Total Coliform Bacteria (TCB) and Escherichia coli (E. coli) [12]. Hence regular and sustained monitoring is imperative to mitigate ecological and health hazards. Due to growing urbanization, industrialization, and human activity near water bodies, water quality can be evaluated using its physico-chemical and biological properties [13]. The most crucial phases in determining the quality of water are the classification, modeling, and interpretation of monitoring data.

For many years, hydrochemistry has made good use of multivariate statistical techniques, such as factor analysis. Hidden information can be extracted from the data set using multivariate statistical techniques [14]. The aim of this study was to assess water quality along River Ethiope using correlation analysis and water quality index (WQI).

MATERIALS AND METHODS

Study Area

The River Ethiope is located on the West African coast in southern Nigeria, in the Niger Delta basin. It covers a distance of 96.6km and flows into the Atlantic Ocean. The river is located between lactitudes 50551N and 50451N, and longitudes 50601E and 60101E at the equatorial region. River Ethiope is a body of running crystal clear water which originated from Umuaja in Ukwuani Local Government Area, Delta State.

Four local government councils—Ukwuani, Ethiope East, Okpe, and Sapele—share the river. The nearby villages' residents depend on the river for inter-village transit, sand mining, fishing, washing, and domestic water supply. Five designated stations were surveyed along the Ethiope River watercourse. They are Umuaja (SWI), Ebedie (SW2), Abraka (SW3), Sapele (SW4) and Ughara (SW5)

Samples Collection and Preservation

Samples were collected from Ethiope River upstream along its banks at the following towns; Umuaja, Ebedie, Abraka, Sapele and Ughara axis during the rainy seasons; June, August and October as shown in Figure 1. A total of 60 water samples were collected, made up of 20 samples in each month, comprising five sampling sites.

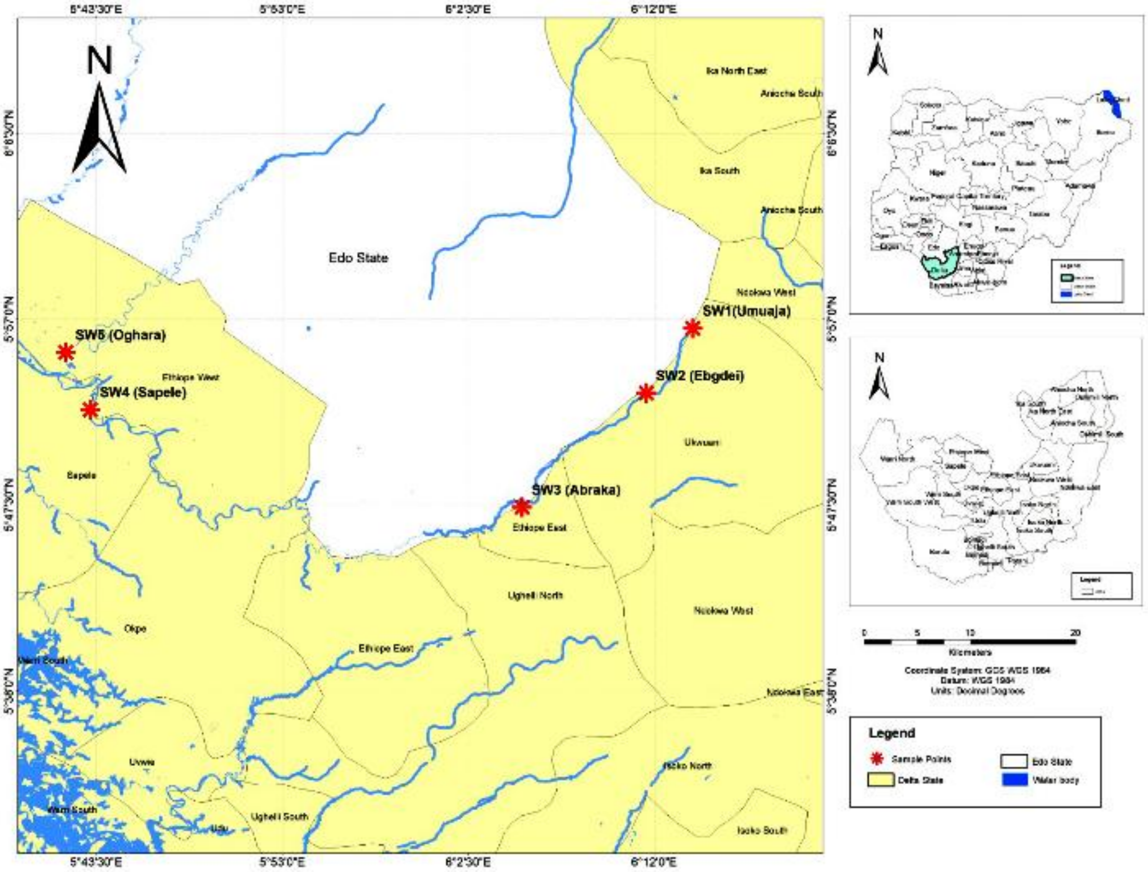

Figure 1. Diagram of the study area.

The grab sampling technique was employed for the collection of all the water samples at about 1m below the surface. Water samples were collected into Amber bottles (for BOD), glass bottles (for COD) and sterilized plastic containers for bacteriological parameters. Every sample that was gathered was brought to the lab in an ice chest, and COD was maintained using HSO_4.

With the use of Hanna HI9829 multi-parameters, in-situ measurements of the unstable parameters—such as pH, temperature, conductivity, total dissolved solids, and dissolved oxygen—were conducted in the field to preserve correct data of the surface water samples. Prior to usage, the meter was calibrated using buffer standards (purchased from Hanna) with pH values of 4, 7, and 10, as well as 1413µ∫/cm potassium chloride solutions and a zero oxygen solution. Following meter calibration, the probe was submerged in the sample, and once stability was achieved, the reading was obtained. To avoid cross-contamination from later samples, the probe was cleaned with deionized water after each sample was measured.

Laboratory Methods

The samples after collection were taken to Endpoint Laboratories and Equipment Limited, a government certified laboratory located in Port Harcourt for the various analyses of the surface water samples. Guidelines and standard procedures from the Federal Ministry of Environment, including APHA, ASTM, EPA, and API standard methodologies, served as a guide for the sample analysis. The following are the description of the standard methods for the various analyses carried out on the surface water samples.

Water Quality Index (WQI)

The water quality index weighted arithmetic technique was applied. This method is superior to other methods in that it involves a single fundamental mathematical equation for many quality parameters and can assess the quality of both surface water and groundwater [15]. Numerous Physico-chemical variables are employed for both the analysis of information for each station and their potential value to human use.

This method involves multiplying various water quality measurements by a weighting factor. Then, they are aggregated using the simple arithmetic mean. The suggested standard (Si) for each parameter is inversely proportional to the weight (Wi) for those parameters. Table 1 Wi values are calculated from the following formula

$$W_i \times \frac{1}{sn} \quad (1)$$

$$W_i = \frac{k}{sn} \quad (2)$$

$$k = \frac{1}{\sum_{i=1}^{n}\left(\frac{1}{sn}\right)} \quad (3)$$

Where
Wi = relative weight (weightage)
sn = reference standard

$$qi = \frac{V_n - X_o}{S_n - X_o} \times 100 \quad (4)$$

Where
qi = the relative value of quality ranging for each parameter in water bodies;
Vn = is the measured value for each parameter;
Xo= the measured value for each parameter in pure water;
Sn = the allowable standard value for each parameter.

For all parameters, the ideal value (Xo) = O, while for pH and DO parameters the (Xo) is equal to 7 and 14.6 respectively. The main formula to calculate water quality index (WQI) is as follows [16].

$$WQI = \frac{\sum_{i=1}^{n} Wi \times qi}{\sum_{i=1}^{n} Wi} \quad (5)$$

Multivariate Statistical Methods

The computer statistical package for social science (SPSS) 15.0 for Windows software was used to perform a one-way Analysis of Variance (ANOVA) on the collected data in order to identify any significant differences ($p<0.05$). Correlation matrix studies were conducted in order to determine the degree of relationship among the water quality measures. The statistical package for social science (SPSS) was used to calculate the correlation matrix of 16 variables.

RESULT AND DISCUSSION

The results from Table 2 showed that the pH of SW1 (7.16) was within the limit of WHO 6.5 -8.5, while SW2 (6.1), SW3 (6.26), SW4 (5.98) and SW5 (6.14) are all below the limit of 6.5-8.5 indicating that they are slightly acidic.

Table 1. Water quality index (WQI) values and classes.

WQI Value	Water Quality Class
<25	Excellent
26-50	Good
51-75	Poor

76-100	Very Poor
>100	Unfit for Drinking

Table 2. The Significance of variation of the physicochemical parameters of water samples.

Parameters	SW1	SW2	SW3	SW4	SW5	WHO 2011 LIMIT
pH	7.16±0.04[a]	6.11±0.36[b]	6.26±0.13[b]	5.98±0.11[b]	6.14±0.04[b]	6.5-8.5
Temperature (Oc)	27.17±0.68[a]	27.33±0.54[a]	28.19±0.44[a]	28.21±0.37[a]	28.93±0.91[b]	25
EC (uS/cm)	27.67±3.51[a]	58.67±16.04[b]	95.33±24.95[c]	137.67±15.70[d]	90.67±12.06[c]	1000
TDS (mg/l)	14.00±2.00[a]	29.33±8.02[b]	48.33±11.72[c]	69.00±7.94[d]	45.33±6.03[c]	600
DO (mg/l)	6.36±0.24[a]	5.44±0.32[b]	4.86±0.56[c]	4.29±0.18[c]	4..54±0.28[c]	5
turbidity (NTU)	1.46±0.31[a]	3.53±1.11[b]	11.45±4.87[c]	14.06±5.04[c]	14.20±4.10[d]	5
Alkalinity (mg/l)	2.77±0.39[a]	2.38±0.54[a]	3.33±1.21[b]	2.14±0.70[a]	2.51±0.53[a]	
BODs (mg/l)	1.81±0.11[a]	2.52±0.27[b]	6.24±1.24[c]	8.29±2.01[d]	5.80±1.82[c]	3
COD (mg/l)	7.02±1.60[a]	10.07±1.40[b]	42.15±5.16[c]	51.70±4.32[d]	34.52±5.70[e]	30

Tips: Values are represented as mean±SD. Values in the same row with the same letter are not statistically different from each other at a significance level of p>0.05

The results were greater than the values between 5.2 and 5.4 reported by Erhenhi and Francis [17]. Low acidic pH, according to Slomezynka and Slomezynski, is a sign that waste is going through an acid-producing phase, which could result in the presence or synthesis of acidic compounds like carboxylic acids [18]. The presence of basic salts and other inorganic contaminants in the surface water may be the cause of SW1's somewhat alkaline nature [19]. In station SW1, the pH is noticeably higher. Temperature SW1 (27.17oC), SW2 (27.33oC), SW3 (28.19oC), SW4 (28.21oC) and SW5 (28.93oC) are all above the limit, this may be as a result of the depth and fewer vegetation cover.

With the exception of station SW5, which has a greater temperature, there was no discernible variation in temperature throughout the stations. The results of this study's surface water temperature matched those of Olele in the Ethiope River, who recorded a comparable range of 27.90C to 29.200C, and Arimoro in the Warri River, who recorded a range of 26.30C to 30.30C [20, 21]. Total Dissolved Solids (TDS) ranges from 14-69mg/l. This shows that TDS are below the limit of WHO (600mg/l) for all the stations. TDS showed significant difference across the stations except stations SW3 and SW5.

Electrical Conductivity SW1 (27.67), SW2 (58.67), SW3 (95.33), SW4 (137.67) and SW5 (90.67) are all below the limit. These corresponds to values reported by Erhenhi [11]. It indicates low level of dissolved solids. EC showed significant difference across the stations except stations SW3 and SW5. EC is significantly higher in station SW4.

Dissolved Oxygen (DO) for Station SW1 (6.36mg/l) and SW2 (5.44mg/l) are above the limit (5) while station SW3, SW4 and SW5 are below the limit. Low DO may be as a result of increased organic pollutants and farm activities around the area [22]. DO showed significant difference in station SW1 and SW2 with values (6.34±0.24) and (5.44±0.32) respectively.

Turbidity for Station SW3 (11.45 NTU), SW4 (14.06 NTU) and SW5 (14.20 NTU) are above the limit value (5). The cloudiness maybe as a result of anthropogenic activities such as dredging, washing, urban runoff etc. [12]. Turbidity is significantly higher in station SW3, SW4 and SW5. BODs and COD were significantly higher in station SW3 and SW5 with the highest values recorded in station SW4.

In Table 3, the nutrient parameters (nitrates, sulphate and phosphate) are all below their standard values. This could be the cause of the absence of an algal bloom in certain areas. The values (0.59-1.87mg/l) of nitrate from the study were below the WHO limit. The low levels of nutrients in the soil may be the cause of the low nitrate readings [23]. Biochemical Oxygen Demand (BOD)for Station SW3 (6.24mg/l), SW4 (8.29 mg/l) and SW5 (5.80 mg/l) are above the standard limit of (3). The values obtained showed that BOD in station SW1 and SW2 were within the WHO limit, while stations SW3, SW4 and SW5 with mean values of 6.24 mg/l, 8.29mg/l and 5.80 mg/l respectively were above the limit. High biological activity brought on by a large microbial population may be the cause of the observed variation in the BOD value [24].

Total alkalinity results (2.14-3.33mg/l) agreed with the findings of Iloba in river Ethiope, which is comparable to the suitable alkalinity range of 2.0-300mg/l [25]. Alkalinity is significantly higher in station SW3. The result showed that SW1 (7.02) and SW2 (10.07) were below the WHO limit, while SW3, SW4 and SW5 values were above the limit.

The high COD values obtained in stations SW3, SW4 and SW5 may be an indication of high chemically oxidizable organic pollutants [26]. The low concentration of chemically oxidizable organic pollutants in SW1 and SW2 may be the cause of the decreased COD values.

The high values of THF and THD obtained across the stations could be a result of direct sewage discharge into the river. The high values of TCB recorded in SW3, SW4 and SW5 may be attributed to microbial degradation of waste materials.

In Table 3, the nutrient parameters showed slight difference across the stations. In Table 4, Microbial parameters (THB, THF and TCB) showed significant differences across the stations (P>0.05). In Table 5, a perfect correlation existed between TDS and EC. Positive significant relationship existed between COD and BOD, PO_3 and NO_3, Na and Mg, Cl and TDS, Ca and Na (P<0.01). Negative significant relationships existed between DO and TDS, Cl and DO, BOD and DO, COD and DO(P<0.01).

Surface Water Quality Index

In Table 6, the water quality index of the River Ethioperevealed that the water quality of the study area was excellent in stationsSW1 (11.441) and SW2 (17.354), poor in stations SW3 (74.632) and SW5 (54.823), and very poor in station SW4 (78.777). Erhenhi, reported values (129.41, 137.03, 173.61, 147.86 and 112.70) higher than these values 11.441, 17.354, 74.632, 54.823 and 78.777 [11].

Table 3. The significance of variation of Nutrient Levels in water samples.

Parameters	SW1	SW2	SW3	SW4	SW5
Nitrate (mg/L)	0.59±0.08^a	0.59±0.27^a	1.87±1.78^b	1.36±0.99^b	0.99±0.85^c
Sulphate (mg/L)	1.35±0.33^a	1.70±0.23^a	3.45±1.80^b	4.12±0.97^c	3.44±0.68^b
Phosphate (mg/L)	ND	ND	0.22±0.06^a	0.12±0.09^b	0.06±0.06^c
chloride (mg/L)	2.24±0.31^a	3.28±0.63^b	6.15±1.04^c	7.11±0.42^d	5.05±0.57^e
Ammonia (mg/L)	ND	ND	ND	ND	ND
Magnesium (mg/L)	0.23±0.04^a	0.26±0.07^a	0.65±0.25^b	0.81±0.61^c	0.56±0.29^d
Sodium (mg/L)	0.72±0.17^a	0.90±0.07^b	2.86±0.45^c	2.89±1.56^c	1.24±0.37^d
Calcium (mg/L)	0.24±0.22^a	0.53±0.13^b	3.67±1.01^c	3.08±1.75^d	1.48±0.64^e

Tips: Values are represented as mean±SD. Values in the same row with the same letter are not statistically different from each other at a significance level of p>0.05

Table 4. Microbial count level in water samples.

Microbial Counts	SW1	SW2	SW3	SW4	SW5
THB (cfu/mL)	486.67±617.85^a	7666.78±957.90^b	144500.00±138332.00^c	91333.0±39526.00^d	15333.00±11240.00^e
THF (cfu/mL)	14.33±3.52^a	273.33±155.35^b	2066.70±1803.70^c	3833.3±2516.60^d	296.7±156.90^b
TCB (cfu/100mL)	2.43±0.65^a	5.17±1.04^b	14.87±4.42^c	20.50±2.00^d	11.97±3.66^e

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Tips: Values are represented as mean±SD. Values in the same row with the same letter are not statistically different from each other at a significance level of p>0.05

Table 5. Correlational analysis of water samples.

	pH	Temperature (Oc)	EC (us/cm)	TDS (mg/L)	DO (mg/L)	turbidity (NTU)	Alkalinity (mg/L)	NO_3(mg/L)	SO_4 (mg/L)	PO_4(mg/L)	Cl (mg/L)	BODs (mg/L)	COD (mg/L)	Mg (mg/L)	Sodium (mg/L)	Calcium (mg/L)
Ph	1															
Temperature (Oc)	-0.385	1														
EC (us/cm)	-.673**	.577*	1													
TDS (mg/L)	-.672**	.577*	1.000**	1												
DO (mg/L)	.829**	-.672**	-.883**	-.882**	1											
Turbidity (NTU)	-0.138	0.28	0.079	0.077	-0.263	1										
Alkalinity (mg/L)	0.286	0.07	-0.314	-0.301	0.325	-0.121	1									
NO_3 (mg/L)	-0.135	0.285	.560*	.556*	-0.375	-0.11	-0.252	1								
SO_4 (mg/L)	-0.501	.634*	.886**	.884**	-.783**	0.222	-0.327	.775**	1							
PO_3 (mg/L)	0.485	-0.304	0.482	0.483	0.133	-0.441	-0.306	.905**	0.688	1						
Cl(mg/L)	-.662**	0.505	.894**	.897**	-.861**	0.144	-0.128	0.401	.735**	0.2	1					
BODs (mg/L)	-.570*	0.496	.931**	.934**	-.811**	0.046	-0.288	.550*	.828**	0.543	.878**	1				
COD (mg/L)	-.590*	.555*	.930**	.933**	-.845**	0.074	-0.13	.534*	.837**	0.564	.951**	.958**	1			
Magnesium (mg/L)	-0.33	0.407	.783**	.782**	-.598*	0.02	-0.382	.782**	.847**	.763*	.595*	.856**	.746**	1		
Sodium (mg/L)	-0.4	0.342	.785**	.790**	-.633*	-0.033	-0.205	.664**	.776**	.807*	.745**	.833**	.809**	.859**	1	
Calcium (mg/L)	-0.433	0.438	.800**	.807**	-.677**	0.038	-0.156	.651**	.792**	.828*	.796**	.855**	.843**	.823**	.962**	1

*** Correlation is significant at the 0.01 level (2-tailed)*
** Correlation is significant at the 0.05 level (2-tailed).*

Table 6. The results and classification of WQI for all the locations.

Locations	∑QiWi	Class
SW1	11.44	Excellent
SW2	17.35	Excellent
SW3	74.63	Poor

SW4	78.78	Very Poor
SW5	54.82	Poor

Out of 17 indicators used in water quality index, turbidity, phosphate, BOD and total coliform bacteria parameters showed a higher influence on the surface water quality than any other physico-chemical and biological parameters. The WQI values of the water samples from stations SW3, SW4, and SW5 suggest increase in anthropogenic activities such as organic waste, runoff from agricultural fertilizers, discharge from sewage and human activities like dredging and washing of clothes.

CONCLUSION

The study's findings showed that some surface water parameters were greater in the downstream samples than in the upstream ones. The downstream surface water samples had somewhat acidic pH values, falling below the WHO's acceptable range of 6.5 to 8.5 for safe drinking water. High turbidity, BODs and COD values were observed in some water samples particularly in stations SW3, SW4 and SW5. The result obtained in this study revealed the presence of heavy load THB, TCB and THF in most water samples. There was a perfect link between EC and TDS. Positive significant relationship existed between some parameters while a negative significant relationship existed between DO and TDS, Cl and DO, BOD and DO, COD and DO.

Water quality index of the River Ethiope revealed that the water quality of the study area was excellent in stations SW1 (11.441) and SW2 (17.354), poor in stations SW3 (74.632) and SW5 (54.823), and very poor at station SW4 (78.777).

The outcome of this research work has shown that anthropogenic activities have impacted the surface water of some of the studied areas. This study therefore recommends that;

1. Further studies should include other irrigation quality indices to classify the acceptability of the water for irrigation such as Kelly's index (KI), Sodium Percentage (Na%) and Permeability index (PI).
2. Further studies should include seasonal variationurther studies should include more biological parameters (Bacillus spp, pseudomonas spp, streptococcus spp, etc.) in the assessment of the surface water.

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