Quality Assessment of Surface Waters and Sediments of Anya-Ogologo River

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Abstract: This study evaluated physical and chemical properties and calculated the Water Quality Index of the Anya Ogologo River in Rivers State, Nigeria. Four stations along the river were identified for this study based on accessibility and activities taking place on the river bank. Water and sediment sample collection were conducted once a week every month spanning a period of four months (February – May). In-situ measurements of surface water were taken for the following parameters: pH, salinity, electric conductivity, total dissolved solids, dissolved oxygen and temperature. Surface water was collected from each station to the laboratory and analysed for phosphate, nitrate sulphate, biochemical oxygen demand, and metals (lead, cadmium, manganese and copper). The parameters studied showed variations across stations. Sediment samples indicated the presence of manganese and copper metals. The WQI values observed were as follows; station 1: 55.07%, station 2: 43.58%, station 3: 56.29% and station 4: 67.10%. This indicates that generally the river is unsuitable for drinking, swimming, irrigation particularly.

1. Introduction

A River is a naturally occurring resource that plays an important role in the biosphere because of their abundant uses. The Earth's surface is covered 70% by water, but only 3% of it is freshwater, distributed in aquifers, polar ice caps, rivers, lakes and other reserves such as clouds and steam; 97% is saltwater. They are used by humans for transportation, fishing, hydropower and domestic, industrial agricultural water supplies [1]. The preservation of a healthy aquatic ecosystem depends mainly on the physicochemical properties and biological diversity [2]. Water is important for natural ecosystems and human development. It is important for various activities such as drinking, cooking, industry, agriculture, and recreation. In the human body, it is also used to transport, dissolve organic matter and add nutrients while carrying waste materials, regulates body temperature and reduces dehydration [3]. The importance of rivers cannot be overemphasized, and for this reason, they should be monitored to assess their "health" or "status".

River water quality can be affected by the activities on the watershed, geology of the watershed, riparian zone vegetation and interaction between dry and wet interphase which contributes to nutrient input in the river [4-6]. The increase in human population has been identified as a stressor to the natural environment, this is because, to accommodate the increasing human population, changes in the natural environment is will occur. Conversion of undeveloped expanses of land into urban areas can lead to changes in the natural topography which can change the spatial and temporal dynamics the environmental. New constructions such as buildings and bridges can alter the natural precipitation infiltration percolation and runoff, this can change natural boundaries and drainages in the catchment area [7].

Water quality index is one of the most effective tools to communicate information on the quality of water. It is an important parameter for the assessment and management of

surface water. It provides up-to-date information about the concentration of various solutes in a place and time. The quality parameters provide a yardstick for assessing the nature of water for designated use and to improve the existing condition [8]. Water Quality Index (WQI) can be useful for decision-makers in assessment and classification rivers [9]. In regions with limited surface water resource, it can play an essential role in assigning use for waters, understanding the level of pollution in water and creating management tools to mitigate pollution where necessary. The quality of water is directly related to the physical and chemical parameters of the water. It is also important to note that these parameters can vary from season and location (i.e. temporally and spatially) [10, 11]. Hence the importance to study these parameters in a wholistic matter i.e. WQI.

In a study carried out in Dende and Bengo Rivers in Angola, they aimed to evaluate the water quality (physicochemical and microbiological parameters) of three Angolan rivers (Kwanza, Bengo and Dande) in locations where water is used as drinking water or abstracted for human consumption. Their results indicated that in dry season the water was suitable for the purpose while in wet season the water was unsuitable for that purpose (high levels of faecal coliforms were detected) [12]. In another study, observations were carried out in the surface waters of Saraydüzü Dam Lake within Sinop provincial borders for 1 year to determine water quality. The basic 28 variables used to determine water quality were measured monthly at six stations. Taking into account the World Health Organization's drinking water standards, the water quality index (WQI) and Turkey's Ministry of Forestry and Water Affairs Surface Water Quality Regulations (SWQR) were used in determining the water quality. Water quality parameters did not exceed the recommended limit values in all months and at all stations. According to these values, the Saraydüzü Dam Lake water belongs to the 'very good' class in terms of drinking water quality [13]. Between March and December 2002, a study assessed the quality and pollution status of source surface waters in Zaria, Nigeria by monitoring the nature, cause and extent of pollution in Samaru stream, Kubanni River and Kubanni dam [14]. Their results showed that the main pollution sources to the river were municipal wastewater, stormwater runoffs, the ABU sewage treatment plant, abattoir effluents and irrigation farms treated with chemical fertilisers.

The Anya Ogologo River is exceptionally important to the inhabitants of Mgbuosimini community, but due to the numerous human activities in the area such as dredging, drainage constructions, waste disposal, and burning, building construction, and agriculture, this river is also susceptible to the pollution that comes about due to the above-mentioned activities. This study aims to 1) determine levels of some physiochemical parameters in surface water and sediment of Anya-Ogologo River, 2) determine levels of heavy metals (lead, copper, cadmium and manganese) in surface water and sediment, 3) determine the level of the microbial activities by assessing THB, TCB and FCB in surface water of the Rive, 4) compare levels of measured parameters with Standard Permissible Limits and 5) calculate the Water Quality Index for each sample station along the river.

2. Materials and Methods

2.1. Description of the Study Area

The study was carried out on a headwater stream of the Anya-Ogologo River in Mgbuosimini Community of Port Harcourt, Rivers State Nigeria. The community covers a land area of about $4.2km^2$ and the length of our study path on the river stretches to about 1.14km, with an average elevation of 4m and an average slope of 0.8%. The local people use the river for fishing, washing and other municipal activities. The river headwater runs behind the community into which urban drainage empties, there is also evidence of dumping of waste products from homes. The Anya-Ogologo River plays host to a fish market which is important to the community and fish farming and marketing are part of the culture of the people.
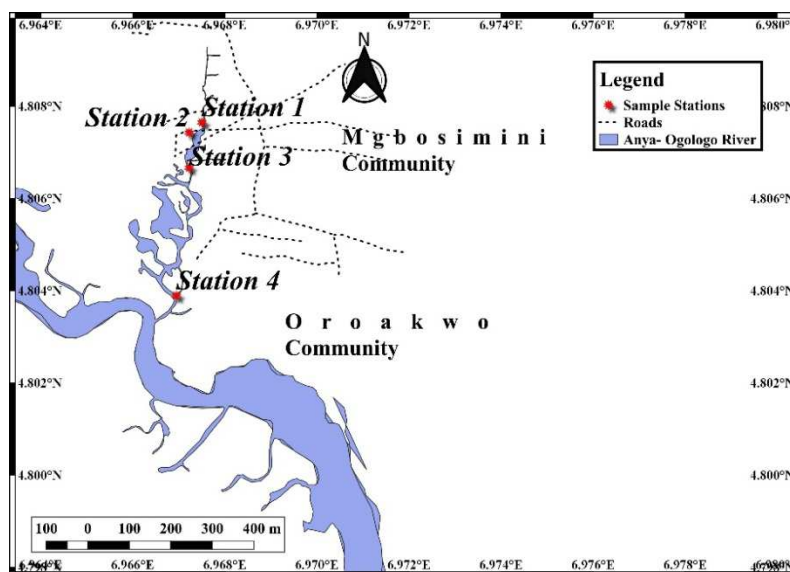

Figure 1. *Study area map.*

The sampling stations were selected using a Geographic Positioning System (GPS) tool, and 4 sampling stations were initially identified. the choices of sample points were based on accessibility to the study river. Water and sediment samples were collected from each station once every week for four months from February to the end of May 2018. Five samples were collected at each sample station and mixed together to make a composite sample, Station 1: 4°48'27.6"N 6°58'03.0"E, Station 2: 4°48'26.8"N 6°58'02.0"E, Station 3: 4°48'24.0"N 6°58'02.0"E, Station 4: 4°48'14.0"N 6°58'01.0"E (Figure 1).

2.2. Sample Collection and Analysis

In-situ measurements were taken for DO, turbidity, TDS, salinity, temperature, conductivity and pH with a meter. The BOD_5 was calculated by deducting the DO after five days of incubation from the DO measurement on a collection of samples at the same point in mg/L and multiplying by the volume of sample incubated [15]. Reagents used for the analysis of nitrate were; nitrate-free water, stock nitrate solution, intermediate nitrate solution and hydrochloric acid solution [16]. The Stannous Chloride Method was used for phosphate ion measurement [17]. The metals (Pb, Cd, Cu and Mn) were analysed using Atomic Absorption Spectrophotometer [18]. Membrane Filtration Method was used to determine Total Coliform Bacteria and Faecal Coliform Bacteria [19]. Was used to determine Total Heterotrophic Bacteria [20].

2.3. Data Analysis

Statistical analysis of variance (ANOVA) was used to compare the variation in spatial and temporal data for water and sediment using Sigma Plot package (Version 14.0) [21].

Water quality index (WQI) is defined as a technique of rating that provides the composite influence of individual water quality parameter on the overall quality of water [22]. The quality rating scale for each parameter q_i was calculated by using this expression:

$$q_i = \left(\frac{c_i}{s_i}\right) \text{X } 100 \qquad (1)$$

Where C_i is the parameter concentration and S_i respective standard.

Unit weight (W_i) was calculated by a value inversely proportional to the recommended standard (S_i) of the corresponding parameter (Table 1):

$$W_i = \frac{1}{s_i} \qquad (2)$$

The WQI was then calculated as follows:

$$\text{Overall WQI} = \sum q_i W_i / \sum W_i \qquad (3)$$

Table 1. Relative weights (W_i) of the parameters and used for WQI determination.

Parameter	Unit	Water Quality Standard	Unit Weight (Wi)
Electric Conductivity	μs/cm	1000	0.001
pH		6.5-8.5	0.13
Dissolved Oxygen	mg/l	5	0.2
Total Dissolved Oxygen	mg/l	500	0.002
Biological Oxygen Demand	mg/l	5	0.2
Nitrate	mg/l	45	0.022
Sulphate	mg/l	150	0.007

Water Quality Standard [23]

Table 2. WQI range, status and possible usage of the water sample.

WQI	Water quality status (WQS)	Possible usage
0-25	Excellent	Drinking, Irrigation and Industrial
26-50	Poor	Drinking, Irrigation and Industrial
51-75	Very Poor	Drinking, Irrigation and Industrial
Above 100	Unsuitable for drinking and fish culture	Proper treatment required before use

[24]

3. Results and Discussion

3.1. Physical and Chemical Parameters

pH varied in mean values of 6.52±0.45 as maximum 6.29±0.15 as a minimum for station 3 and station 2 respectively (Figure 2A & 3A). After the statistical variance was calculated, it showed no significant difference from station 1 to station 4 in water and sediment *(p>0.05)*. The variation in pH could be as a result of climate change, infiltration of CO_2 into the river and its removal through photosynthesis pH values during different season of the year were also attributed to factors like removal of CO_2 by photosynthesis through bicarbonate degradation, dilution of waste with freshwater, reduction of temperature, and decomposition of organic matter [25]. This is supported by a previous study carried out by [26]. The analysis results gave values of salinity ranging from 0.22±0.04 ppt at station 1 to 2.75±0.88 ppt at station 4 (Figure 2B & 3B). EC values ranged from 438±86.49 μs/cm (lowest) in station 1 to 4793.5±1394.324 μs/cm in station 4 (highest) (Figure 2C & 3C). High values of EC show that a large number of ionic

substances are present in water [27]. Station 3 and station 4 having noticeably high values for electric conductivity mainly because of the dumpsite burning at station 3 and brackish water at station 4.
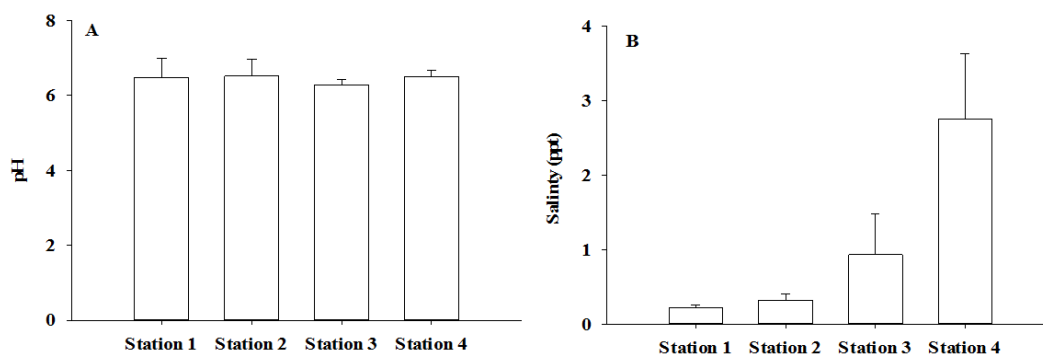
The amount of dissolved oxygen in a pristine freshwater usually range from 7.56 mg/l at 30°C to 14.62 mg/l at 0°C [28]. Research has shown that the quantity of oxygen in a river is directly proportional to the water quality index of a river [29]. Impurities such as dissolved minerals reduce the quantity of oxygen that dissolves in water. Dissolved oxygen enters the water by diffusion from the atmosphere. When water is mixed with air as it falls over rocks and waterfalls, the level of DO is greatly increased. The result of the analysis showed DO values that ranged from 0.75±0.9 mg/l in station 2 to 2.55±1.1 mg/l in station 4 (Figure 2D), the high values recorded can be attributed to the fast-flowing nature of the river at station 4. Mean values of biochemical oxygen demand in the river showed a statistically significant difference (p<0.001) from station 1 to station 4. BOD is a measure of microbial activities that consume dissolved oxygen in the water. Water temperature in all stations was measured during the sample collection. The river temperature varied from 30.30±0.83°C in station 1 to 31.73±1.02°C in station 2, (upstream) and from 31.18±1.08°C in station 3 to 30.90±1.09°C in station 4 (downstream) (Figure 2E). ANOVA analysis between stations showed no significant difference in values (*p>0.05).* Primary sources for higher TDS in the river water might be due to the discharge of domestic waste, discharge of sewage and other human activities like washing clothes with detergent, parking vehicles near the river. The river flow rate and volume also play a part in the level of total dissolved solids that are present at the station on the river. Murhekar, (2011) also reported similar TDS values (221 to 3534 mg/l) for river water (Figure 2F). Statistical analysis of variance gave results showing no statistically significant difference (*p>0.05)* across the river.
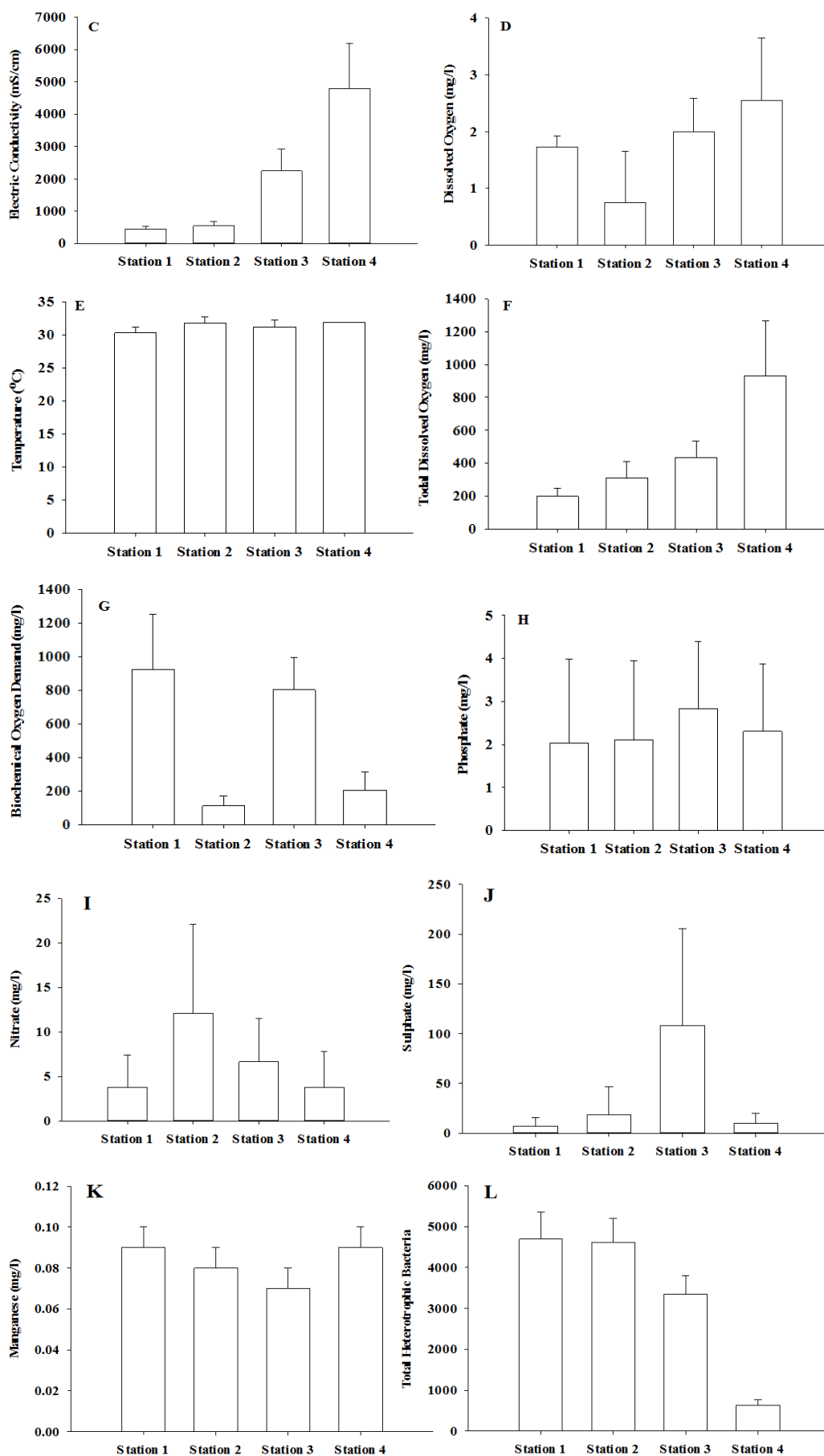
Phosphorus is essential for the growth of aquatic plants in a stream. However, at certain concentrations, phosphate encourages the growth of eutrophication in rivers [5]. Research has shown that phosphate increase in a fluvial system can be attributed to discharge from both urban, such as wastewater and sewage effluent and agricultural sources from phosphorus-enriched soil [5]. Mean values of phosphate were higher in station 3 cross the river (Figure 2H). Nitrate occurs naturally in aquatic systems; aquatic organisms add to the concentration of nitrate in a river by excreting waste high in ammonia which is then converted to nitrate and further to nitrite by certain microbial species. Nitrate, similar to phosphate, in excess can lead to a eutrophic condition in a river. Eutrophication can also lead to a reduction in the quantity of dissolved oxygen is present in the river, in turn reducing the rate of conversion of ammonia to nitrite and to nitrate, leaving a high concentration of nitrite and ammonia, which are more toxic in the river [31]. The reduction in the quantity of dissolved oxygen in the river can lead to an inhabitable condition for aquatic lives. Mean values of nitrate were highest in station 2 (12.10±9.99 mg/l) and lowest in station 1 (3.78±4.04 mg/l) (Figure 2I). The concentration of nitrate in this study river was similar, those slightly higher, to those in River Ona and River Alaro which ranged between 3.00-8.55 [32].

Metals studied in this research include: Manganese (Mn), Cadmium (Cd), Copper (Cu) and Lead (Pb). Although Cd and Pb were not detected in either water or sediment in the study river, Mn and Cu were detected in the river. The concentrations of the detected metals were higher in the sediment than in the water (Figure 3D & 3E). Metal concentrations in the surface water were lower than those measured in a tropical manmade lake Southwestern Nigeria [33]. Similarly, the metal concentrations were also lower than those measured in River Balogun which had metal concentrations higher than WHO standards [34].

Faecal coliform bacteria are a collection of relatively harmless microorganisms that live in large number in the intestines of the warm and cold-blooded animals [35]. Escherichia coli (commonly called E. Coli), is the most common species of this group os bacteria. Their presence in surface water indicates the presence of faecal waste entering the water from human beings and other warm-blooded animals [35]. There were high microbial activities observed in this river. Results showed variations of bacterial activities from station 1 to station 4 (Figure 2L, 2M &2N). This decline of microbial population and activity from up to downstream could be as a result of the increase in salinity from station 1 to station 4 [36]. The microbial count in the study river is higher than those measured in Zamfara state [14]. In the assessment of the quality of water from hand-dug wells in ghana, Total coliform and Escherichia coli were below the minimum detection limit (MDL) of 20 MPN per 100 ml in all the samples which were lower than those in the present study [37].
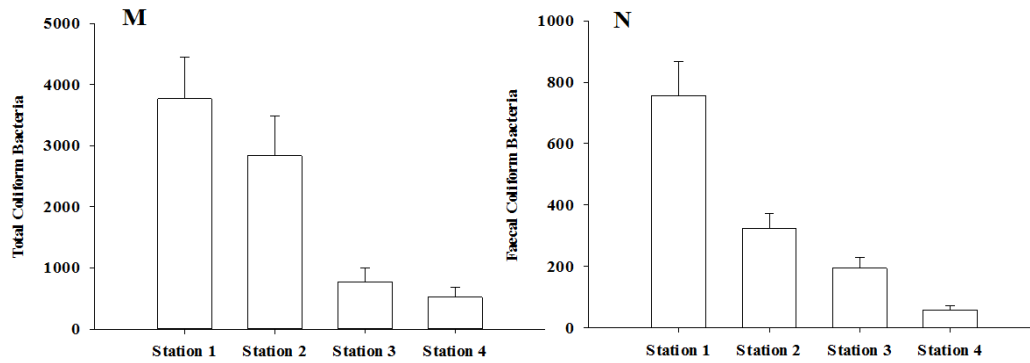
Figure 2. Spatial distribution of surface water parameters of Anya-Ogologo River. A-pH, B-Salinity, C-Electric Conductivity, D-Dissolved Oxygen, E-Temperature, F-Total Dissolved Oxygen, G-Biochemical Oxygen Demand, H-Phosphate, I-Nitrate, J-Sulphate, K-Manganese, L-Total Heterotrophic Bacteria, M-Total Coliform Bacteria, N-Feacal Coliform Bacteria.
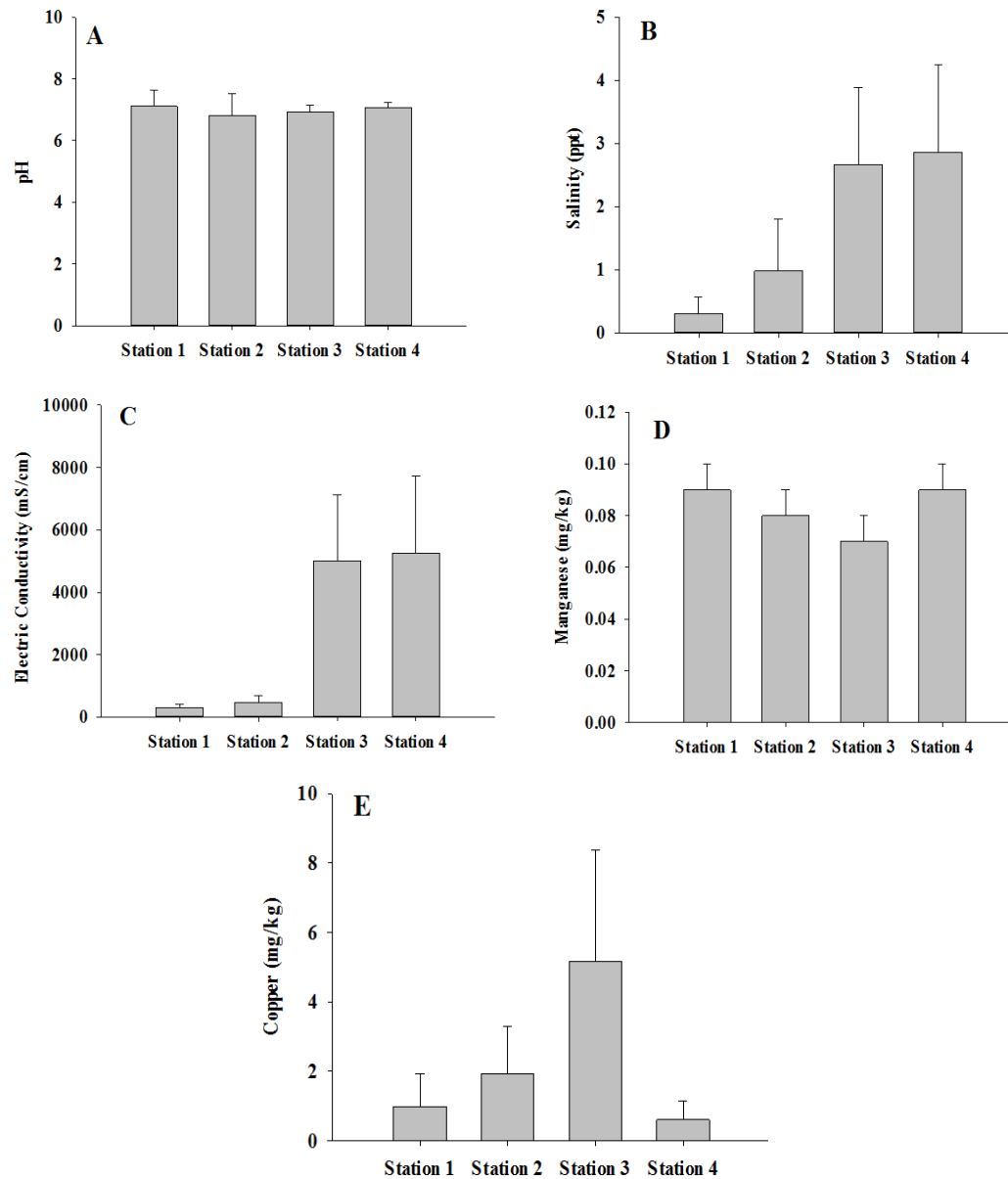

Figure 3. Spatial distribution of sediment parameters of Anya-Ogologo River. A-pH, B-Salinity, C-Electric Conductivity, D-Manganese, E-Copper.

In Station 1, the WQI was 51.01, which has a water quality status of "very poor" for drinking, irrigation and industrial use. Station 2 had WQI of 41.87 with water quality status of "poor". Station 3 and station 4 had water quality status of "very poor" (Tables 2 & 3).

3.2. Water Quality Assessment

As stated earlier, WQI is designed to combine multiple parameters in a river in order to give a holistic view of the river and quantify the level of cleanliness of pollution. In the present study, EC, pH, TDS, DO, Sulphate and Nitrate were used to assess the WQI. WQI ranged from 41.87 - 62.40 (Table 3). The WQI very poor, however, it can be used for irrigation and industry. Despite the high WQI measured in this study river, they were lower than those measured in River Ravi at Madhopur (India) [38]. WQI from the different sampling stations in the Niger Delta were found to be varied from 34.80 to 36.26 for pipe-borne water, 38.52 to 48.67 for borehole water and 55.05 to 84.94 for stream water [39]. This present study calls within the range for stream water.

Table 3. Water quality index for Anya-Ogologo River.

Parameter	Observed Values C_i	Standard Value S_i	Unit Weight W_i	Quality Rating q_i	$q_i w_i$
Station 1					
Electrical Conductivity	438	1000	0.001	43.8	0.0044
pH	6.49	7.5	0.13	86.5	11.245
Total Dissolved Solids	199.5	500	0.002	39.9	0.0798
Dissolved Oxygen	1.73	5	0.2	34.6	6.92
Nitrate	3.8	45	0.022	8.4	0.1848
Sulphate	7.05	150	0.007	4.7	0.0329
WQI	51.01				
Station 2					
Electrical Conductivity	546	1000	0.001	54.6	0.0546
pH	6.52	7.5	0.13	86.93	11.301
Total Dissolved Solids	312.25	500	0.002	62.45	0.1249
Dissolved Oxygen	0.75	5	0.2	15	3
Nitrate	12.1	45	0.022	26.89	0.5916
Sulphate	18.48	150	0.007	12.32	0.0863
WQI	41.87				
Station 3					
Electrical Conductivity	2242.5	1000	0.001	224.25	0.2243
pH	6.29	7.5	0.13	83.87	10.903
Total Dissolved Solids	433	500	0.002	86.6	0.1732
Dissolved Oxygen	2	5	0.2	40	8
Nitrate	6.67	45	0.022	14.8	0.3256
Sulphate	108.48	150	0.007	72.32	0.5062
WQI	55.61				
Station 4					
Electrical Conductivity	4793.5	1000	0.001	479.35	0.4794
pH	6.51	7.5	0.13	86.8	11.284
Total Dissolved Solids	931.5	500	0.002	186.3	0.3726
Dissolved Oxygen	2.55	5	0.2	51	10.2
Nitrate	3.78	45	0.022	8.4	0.1848
Sulphate	10.35	150	0.007	6.9	0.0483
WQI	62.4				

4. Conclusion

This study assessed the physicochemical parameters and water quality index of the Anya Ogologo river and identified factors that cause changes in different stations on the river and in different seasons. Results show that physical and chemical properties varied spatially and temporally. Although rains are seen to wash off pollutants into the aquatic system, in this study, the coming of the rains diluted the concentrations of the pollutants.

Physical and chemical parameters varied spatially and temporally from station 1 to station 4. Cadmium and lead were below detectable limits in water and sediment, however, manganese was detected in water, while both manganese and copper were identified in the sediment. This confirms that sediment is the sink of contaminants in the aquatic system. However, the microbiology analysis identified very high concentrations of Faecal Coliform Bacteria and Total Coliform Bacteria. Results of WQI scores also show that the general health of the river is unsafe for drinking, irrigation and recreational activities and may potentially pose a threat to aquatic life. Therefore, for this surface water to suitable for use, there is a need for treatment. The concentrations of the pollutants identified in the study can be attributed to the human activities taken place in the catchment area.

Acknowledgements

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