World Journal of Advanced Engineering Technology and Sciences
eISSN: 2582-8266
Cross Ref DOI: 10.30574/wjaets
Journal homepage: https://wjaets.com/

(Research Article)

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Parametric Characterization of the Calabar River, Southern Nigeria

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World Journal of Advanced Engineering Technology and Sciences, 2025, 14(02), 080-094

Publication history: Received on 07 December 2024; revised on 22 January 2025; accepted on 25 January 2025

Article DOI: https://doi.org/10.30574/wjaets.2025.14.2.0009

Abstract

This study investigated the physicochemical and biological parameters in water from the Calabar River. A comparison of the water quality parameters to the Nigeria Standard for Drinking Water Quality (NSDWQ) was carried out. Samples were collected from ten (10) designated sampling points, spaced at five hundred (500) metres interval. The parameters analyzed included temperature, pH, TDS, DO, THC, TCC, Ammonium, Phosphate, Nitrate, BOD, COD, TCC and THC. The comparison of the results with the NSDWQ revealed that the permissible limits for the parameters varied for different locations. The results of conductivity analysis revealed that most of the samples had low ion concentrations. The Total Coliform level was found to be quite higher than the acceptable limit for all the points sampled. For the sampling points under review, only samples from two locations met the reference pH level of 6.5 – 8.5. T.D.S levels fluctuated across the sampling points, with a peak in sampling point 5, suggesting variability in the concentration of dissolved substances. A nexus of legislation and the implementation of a stricter pollution control measures, particularly around industrial sites and agricultural runoff, to minimize the introduction of contaminants into water bodies will go a long way in curbing the menace of water quality degradation

Keywords: Physicochemical; Bacteriological; Sampling; analysis; Concentration; Urbanization; Anthropogenic

1. Introduction

The background of this study underscores the escalating global apprehension regarding the degradation of water quality, a critical environmental issue with profound implications for human health, ecological integrity, and sustainable development. Urbanization, industrialization, and intensive agricultural practices have collectively intensified the discharge of various pollutants into water bodies, exacerbating the degradation of water quality on a global scale. Gupta and Srivastava (2020) emphasized that these anthropogenic activities have significantly altered natural hydrological processes and contributed to the contamination of surface water and groundwater sources. Rapid urbanization, characterized by the expansion of cities and the concentration of population centres, has amplified the demand for freshwater resources and increased the discharge of untreated wastewater into water bodies (Shrestha & Kazama, 2007). This influx of pollutants, including nutrients, heavy metals, and organic compounds, has compromised the integrity of aquatic ecosystems and impaired water quality (Shrestha & Kazama, 2007).

Furthermore, industrial activities such as manufacturing, mining, and energy production, have been identified as major sources of water pollution, releasing a diverse array of chemical contaminants into aquatic environments (Savci, 2012). In addition to urbanization and industrialization, agricultural practices have emerged as significant contributors to water quality degradation, particularly through the excessive use of fertilizers and pesticides (Zhang et al., 2015). Studies have shown that runoff from agricultural lands carries excess nutrients such as nitrogen and phosphorus into water bodies, thereby fuelling eutrophication and algal bloom (Zhang et al., 2015). Moreover, pesticides applied to crops can leach into groundwater or be washed into surface waters, posing risks to aquatic organisms and human health

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(Gupta & Srivastava, 2020). The cumulative impact of these anthropogenic pressures has led to a widespread decline in water quality, posing serious threats to human populations reliant on freshwater resources for drinking, sanitation, and livelihoods (Savci, 2012).

Furthermore, deteriorating water quality jeopardizes the health and resilience of aquatic ecosystems, disrupting ecological processes and diminishing biodiversity (Shrestha & Kazama, 2007). Consequently, urgent action is required to address the root causes of water quality degradation and implement effective management strategies to safeguard water resources for present and future generations (Zhang et al., 2015).

Marine environments present distinct water quality dynamics, influenced by factors such as tidal dynamics, saltwater intrusion, and marine biodiversity, which warrant separate consideration and specialized methodologies (Xiao and Shinyil, 2019).

The background of this study highlights the multifaceted nature of water quality degradation, driven by urbanization, industrialization, and agricultural intensification. By recognizing the interconnectedness of human activities and environmental health, this study aims to contribute to the development of proactive solutions for preserving and enhancing water quality in a rapidly changing world.

Despite numerous initiatives aimed at improving water quality management, existing methods continue to face significant limitations, which undermine their effectiveness in guiding decision-making and policy formulation (Ameen et al., 2021).

One of the primary challenges confronting current water quality assessment practices is the lack of standardization, consistency, and comprehensiveness across different methodologies and approaches (Duan et al., 2019). Variations in sampling protocols, parameter selection, and data analysis techniques contribute to inconsistencies in results, making it difficult to compare water quality assessments across different regions and time periods (Duan et al., 2019).

The dynamic nature of environmental systems, driven by rapid changes in land use, climate patterns, and population dynamics, poses additional complexities for water quality management (Sharma et al., 2016). Urbanization and industrialization lead to alterations in land cover and increased pollutant loads discharged into water bodies, while climate change exacerbates hydrological extremes and alters the distribution and behaviour of contaminants (Sharma et al., 2016). The cumulative impact of these challenges underscores the urgent need for a reliable and comprehensive tool to assess water quality effectively.

The objectives of this study were a critical assessment of the physicochemical and bacteriological parameters of the Calabar River which are indicative of water quality status and ecosystem health. These parameters included the pH, Dissolved Oxygen (DO), Biochemical Oxygen Demand (BOD), nutrients (e.g., nitrogen and phosphorus), temperature, faecal coliforms. The parameters were analysed using standard acceptable international approaches. They were subsequently subjected to simple Microsoft Excel analysis to obtain interpretative plots that were employed in the characterization of the water.

2. Importance of Assessing Water Quality

Assessing water quality holds paramount importance due to its multifaceted implications for human health, ecological integrity, and socio-economic well-being. Several studies underscore the critical role of water quality assessment in safeguarding public health and environmental sustainability, providing empirical evidence and theoretical frameworks to support this assertion. Water quality assessment plays a pivotal role in protecting public health by identifying and mitigating risks associated with waterborne diseases and contaminants. According to Li., (2020), poor water quality is a significant contributor to waterborne illnesses, with microbial pathogens, chemical pollutants, and toxic substances posing considerable health risks to exposed populations. The timely detection and management of water quality issues are essential for preventing outbreaks of waterborne diseases and ensuring the safety of drinking water supplies (Li et al., 2020). Poor water quality can impair the ability of ecosystems to provide essential services, such as water purification, nutrient cycling, and habitat provisioning, leading to cascading impacts on biodiversity and ecosystem functioning (Carpenter, 2018) and (Dudgeon, 2006).

2.1. : Methods of Water Quality Assessment:

Water quality assessment methods encompass a diverse array of techniques and approaches tailored to capture the complexity of water quality dynamics across different environments and stressor contexts. These methods draw upon a combination of traditional laboratory-based analyses, field measurements, remote sensing technologies, and advanced sensor platforms to monitor physical, chemical, and biological parameters indicative of water quality status (Kumar, 2020).

Table 1 Location, latitude, longitude and sampling points from the Calabar River Location

Location	**Sample Points**	**Longitude(E)**	**Latitude (N)**
The Calabar River, Calabar, Nigeria.	Point 1	8.314557	4.97264
	Point 2	8°18’52.4”	4°58’28.695”
		8.312938	4.97114
		8°18’46.4”	4°58’16.117”
	Point 3	8.311379	4.96978
		8°18’40.96”	4°58’11.23”
	Point 4	8.3095549	4.9678906
		8°18’34.39”	4°58’4.4”
	Point 5	8.307457	4.96623
		8°18’26.74”	4°57’58.2”
	Point 6	8.306211	4.96507846
		8°18’22.34”	4°57’54.11”
	Point 7	8.30429	4.962889
		8°18’15.19”	4°57’46”
	Point 8	8.30227	4.961107
		8°18’8.12”	4°57’46”
	Point 9	8.3006944	4.9586447
	Point 10	8°18’2.45”	4°57’3099”

In this study, all samples were selected to cover a wide range of variables and key point which represent the water quality of the river. Water samples from ten sites located along a five-kilometre (5km) stretch of the Calabar River were collected at five hundred (500) metre interval. The collection points are shown in the table above. Water samples were collected for physicochemical analysis in high density polyethylene bottles prewashed with detergent and were rinse at the river site at each point before collection of samples from ten different points at the Calabar River in July, 2024. The water sample was collected in 200ml sterilized borosilicate glass bottles for physicochemical and bacteriological analyses. All analyses were done following the standard method of APHA (2005) and guide manual. Various physicochemical parameters such as pH, EC, Temp and DO were measured *in situ* using the Combined DO- meter (Hach HQ1130 series). Each container was clearly marked and labelled.

3. Materials and Methods

3.1. Sample Preservation

Each of the samples was carefully preserved in an ice-packed cooler to maintain a steady state temperature. These samples were subsequently stored at 4^0C for as short a time as possible before analysis to minimize physicochemical changes.

3.2. Sample Preparation

The physicochemical water quality was measured in terms of the potential hydrogen (pH), electrical conductivity (EC), total dissolved solids (TDS), Turbidity (T), Dissolved Oxygen (DO) Calcium (Ca), Potassium (K), Nitrite (NO_2), Total Suspended Solids (TSS), Temperature (T), Alkalinity (AL), Biological Oxygen Demand (BOD), Chemical Oxygen Demand

(COD) and Ammonium. All analyses were conducted according to American Public Health Association Standard Methods (APHA, 2005; APHA, 1999).

3.3. Bacteriological Analysis

Ten samples were collected from the Calabar River along coordinates 1 to 10. The 10 samples were all sub-surface water samples. Epiploic sub-surface water samples were collected into sterile sampling polyethylene bottles rinsed with the river prior to collection. All samples were transported in ice-packed coolers to laboratories for analysis.

The set of samples earmarked for microbiological analysis were analysed within 12h of collection at the Environmental Microbiology and Biotechnology laboratory of the University of Calabar. 10 ml of sample was measured into flask containing some amount of diluent. Each sample was diluted by 10-fold dilution in series.

Three different dilutions were plated in triplicates by the pour plate technique of Harrigan and McCance (1990) onto freshly prepared Tryptic soy agar for enumeration of total aerobic cultivable bacteria and on freshly prepared Eosin methylene blue (EMB) agar for total coliform enumeration. Plates were incubated at 30^{o}C for 24hrs. Discrete colonies were enumerated by means of a colony counter.

4. Results and Discussions

The Nigeria Standard for Drinking Water Quality (NSDWQ, 2017) was the reference standard employed in this research. For all the tables and plots, it should be noted that plot point 1(one), is the reference concentration while points 2 to 11 are the concentrations for the 10 points sampled.

Table 2 Conductivity Concentration for all Sampled Points

CONDUCTIVITY	0.1	0.09	0.7	0.1	0.11	0.12	0.11	0.1	0.1	0.11	400

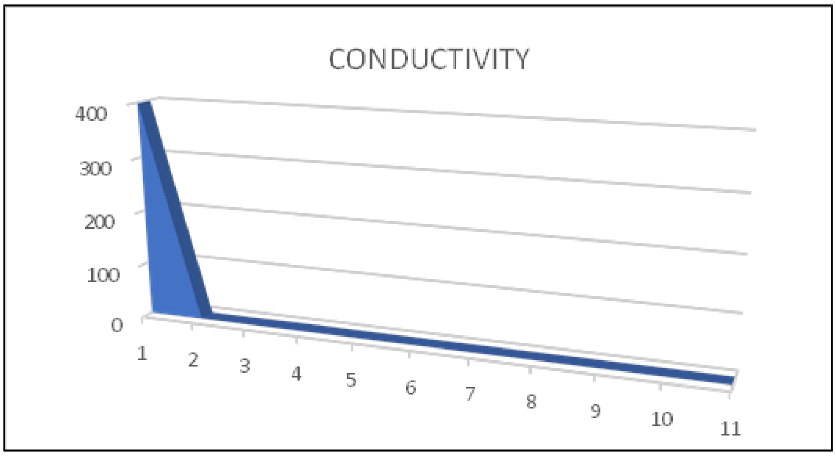

Figure 1 Plot of Conductivity for all Locations

Conductivity in water is of paramount importance as it can be an indicator for level of pollution, salinity as well as the type of aquatic life that can subsist in a given aquatic milieu. Conductivity indicates in primary perspective, the concentration of dissolved salts in a given water sample. Figure 1 shows the display of the conductivity for the locations sampled. Sample point 3 showed a significantly higher conductivity than the others (0.7mg/l). All other sampled points showed much lower conductivity, approximately in the range of 0.09 to 0.12. The higher value for sample point 3 suggests that this point has unique properties that dramatically increased its conductivity compared to the others. This could be due to the material composition, temperature conditions, or the presence of impurities that facilitated charge transport, etc. In all, the concentration values were found to be grossly lower than the reference standard of 400mg/l

Table 3 TDS Concentration for all Sampled Points

TDS	500	450	510	480	630	480	460	520	450	480	560

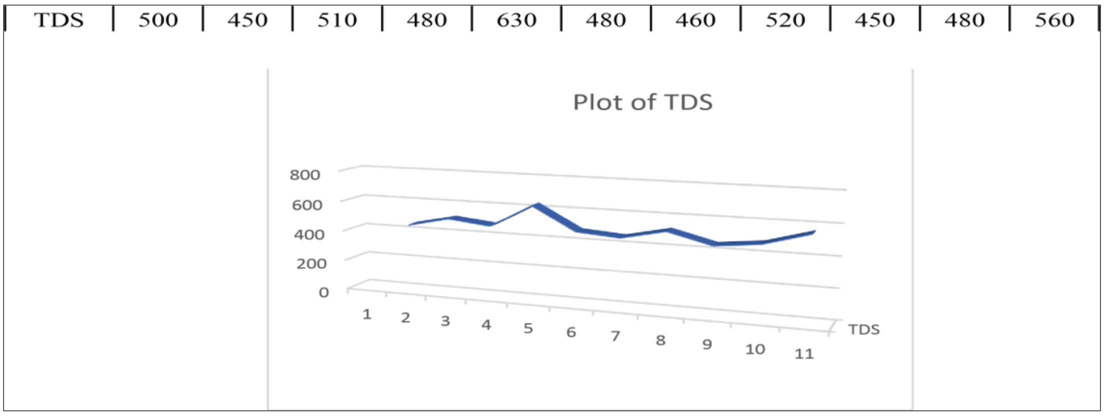

Figure 2 Plot of Total Dissolved Solids (TDS) for all Locations

Figure 2 shows the TDS for all the sampled points. Levels were observed to fluctuate between approximately 450 and 630, with a peak around sample point 4 where TDS reached its highest value (630), followed by a decline and stabilization above 400 ppm from sample point 5. The varying TDS levels across the samples suggest changes in the concentration of dissolved substances. These fluctuations might be due to different factors such as ingressed water sources, or contamination levels in the sample. The sharp peak at sample 4 indicates a significant increase in dissolved solids, which could be due to a specific factor like a higher concentration of salts or minerals at that sampling point. High TDS levels can indicate high concentrations of minerals, salts, and organic materials, which may affect water quality for drinking, agriculture, or industrial use.

Table 4 DO Concentration for all Sampled Points

DO	4	37	36.9	36.8	37.4	36.7	38.4	35.2	36.3	29.3	30

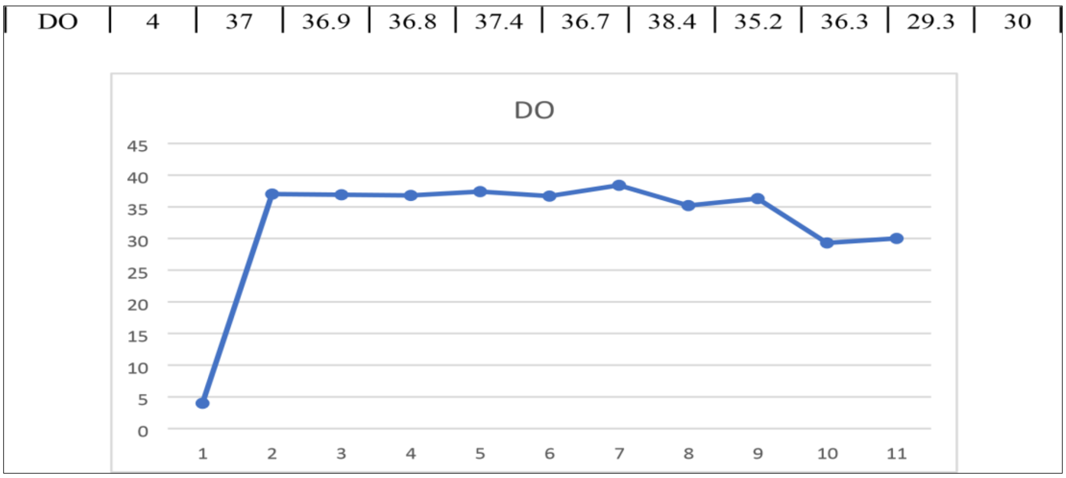

Figure 3 Plot of Dissolved Oxygen (DO) for all Locations

Dissolved Oxygen is known to be a key essential for aquatic life and an essential determinant of water quality. Higher dissolved oxygen levels generally indicate better water quality, which is essential for supporting aquatic life. Figure 3 shows the DO level for all the sampled locations in the study area. The consistent levels suggest the water might be well-oxygenated at the start. A decline in DO levels toward the end could signal the introduction of pollutants or a change in environmental conditions (temperature increase, increased microbial activity, or organic matter). Dissolved oxygen level is crucial for understanding the ecosystem's health. In all however, the DO concentration for all sampled points were observed to be higher than the referenced concentration of 4mg/l.

Table 5 Temperature Concentration for all Sampled Points

Temp	27	27.7	27.7	27.6	27.6	27.7	27.5	2709	27.6	28.6	28.8

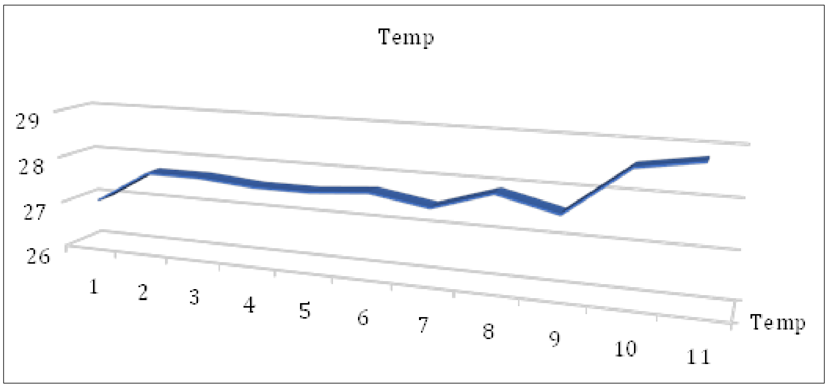

Figure 4 Plot of Temperature for all Locations

Figure 4 shows the plot of temperature for all sampled points along the designated stretch on the Calabar River. The plot shows a trend of temperature readings over a series of points. The overall temperature values ranged between 27.5°C and 28.9°C. The sharp rise in temperature after point 9 could indicate a change in external environmental conditions, such as increased solar radiation, thermal pollution, or local climate effects. Traditionally, temperature and dissolved oxygen are inversely related—higher temperatures typically result in lower DO levels because warm water holds less oxygen. This could explain the declining DO values observed in the earlier plot from point 8 onward. Temperature is a critical factor in aquatic ecosystems, influencing metabolic rates of organisms and overall water chemistry. The rise in temperature toward the end might stress aquatic life if optimal level is exceeded. Temperature at all sampled points were observed to be higher than the referenced temperature of 27^0C

Table 6 pH Concentration for all Sampled Points

pH	6.5-805	5.82	5.82	5.79	5.73	6	6.8	6.9	5.8	5.9	5.8

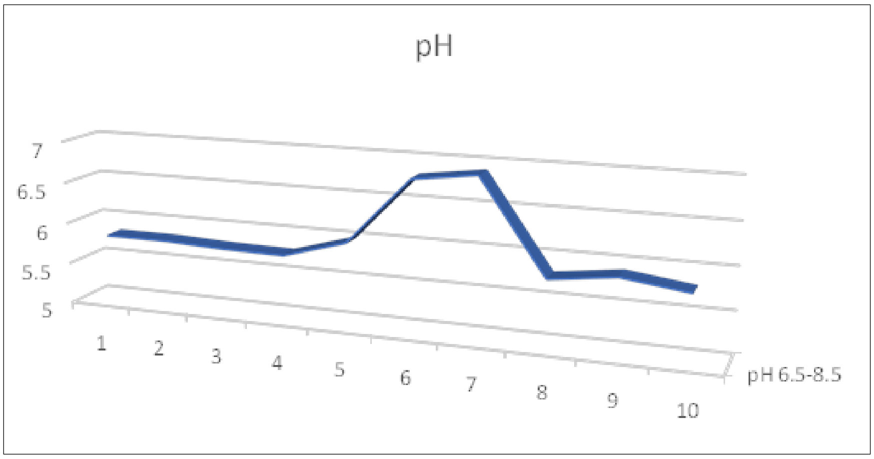

Figure 5 Plot of pH for all Locations

pH in water can influence a lot of aquatic events. For example, higher water pH makes the water bitter to taste, while lower pH encourages corrosion and dissolving of metals which, in essence, is injurious to aquatic life. Figure 5 shows the plot of pH for all the sampled points.

The minor rise and fall between samples 6 and 9 could indicate varying factors affecting pH, such as different solutes, reactions, or environmental conditions. The pH levels between points 6 and 7 were the only ones close to neutrality. All other points were found to be acidic, which is typically acceptable for many biological or environmental systems. It was equally observed that only sampled points 6 and 7 met the acceptable pH standard range of 6.5-8.5. Understanding pH trends is important in fields such as environmental monitoring, agriculture, and chemistry, where pH affects chemical reactions and biological activities.

Table 7 Ammonium Concentration for all Sampled Points

Ammonium	1.5	0.171	0.168	0.188	0.124	0.344	0.817	0.803	0.671	0.158	0.776

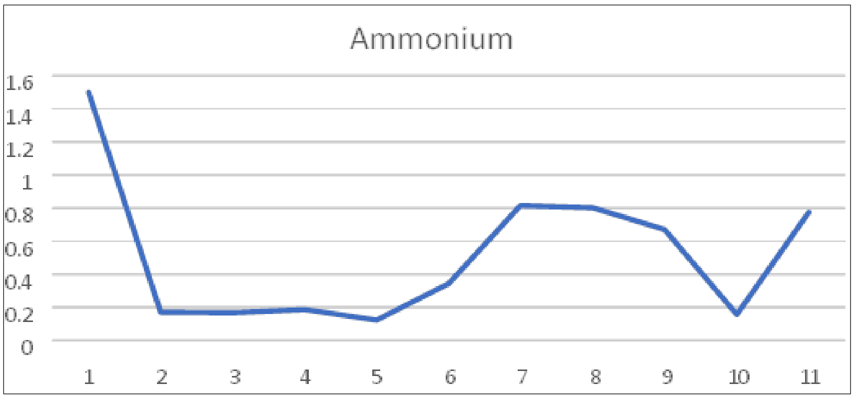

Figure 6 Plot of Ammonium for all Locations

The plot of Ammonium for all the sampled points is as displayed in figure 6. The observed peaks at points 6 and 10, could indicate external factors or processes leading to an increase in ammonium levels. The sharp decline at point 9 suggests either the removal of, or rapid depletion of ammonium, possibly due to chemical reactions, environmental factors, or biological processes. The rebound observed at point 10 could signify another event or shift in conditions that increase ammonium concentration.

Table 8 COD Concentration for all Sampled Points

COD	120	0.506	0.555	0.52	1.01	0.39	0.248	3.52	1.695	0.88	0.515

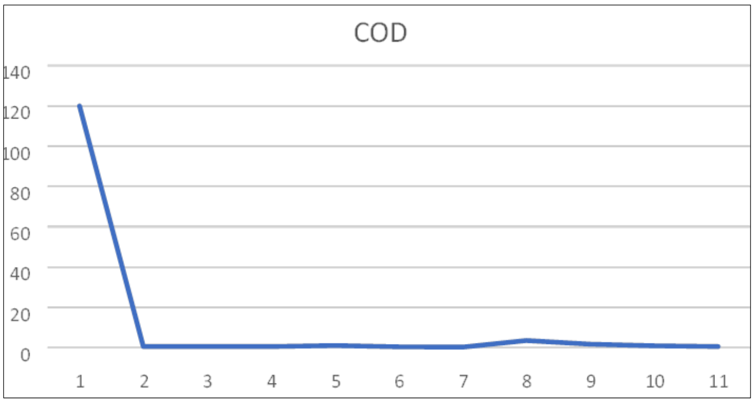

Figure 7 Plot of COD for all Locations

Chemical Oxygen Demand is a water quality parameter that measures the quantity of oxygen essential to break down organic pollutants in water. Putrefaction of organic matter in water consumes oxygen, and can lead to drastic reduction, or outright depletion of oxygen in a given aquatic system. This might lead to anaerobic conditions which are detrimental to aquatic ecology. Figure 7 shows the plot of COD for all the points sampled. Initially, there was an observed relative stability as the COD concentration remained low and stable between points 1 and 6. There was a dramatic increase at point 7, where the value moved up to 3.52, indicating a significant rise in organic pollutants or oxidizable substances. The rapid decline after point 8, clearly suggests a reduction in the organic load, possibly due to degradation, treatment, or dilution.

Table 9 Calcium Concentration for all Sampled Points

Calcium	10	0.662	0.565	0.434	0.553	0.603	0.522	0.608	0.551	0.653	0.554

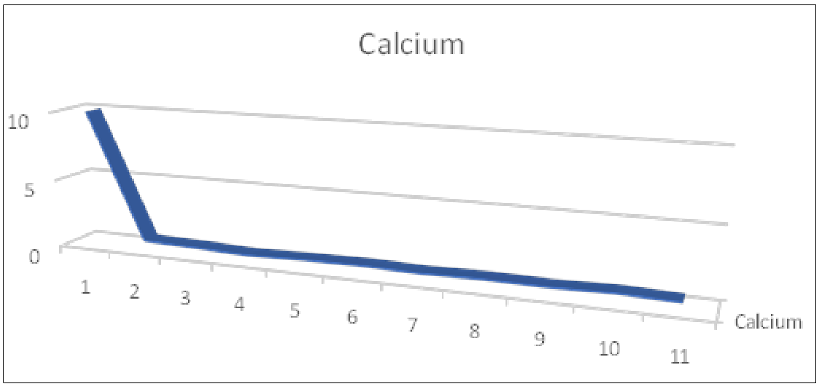

Figure 8 Plot of Calcium for all locations

Figure 8 shows the plot of calcium concentration for all points sampled. It is a known fact that calcium is a major contributor to the hardness of water apart from causing corrosion and scaling. In aquatic environment, calcium affects aquatic faunas by directly influencing metal toxicity. For the points sampled, there was no significant increase or decrease after the initial rise to 0.66 at point one, showing that calcium levels have largely stabilized. It was observed that from point 2, the calcium levels fluctuated but remained within a relatively narrow range (0.43 to 0.65), suggesting some stability with minor variations over time These minimal fluctuations might reflect changes in environmental conditions or processes influencing calcium content, such as water hardness or chemical reactions.

Table 10 Alkalinity Concentration for all Sampled Points

Alkalinity	20	0.267	0.385	0.348	0.267	0.26	0.274	0.269	0.27	0.266	0.351

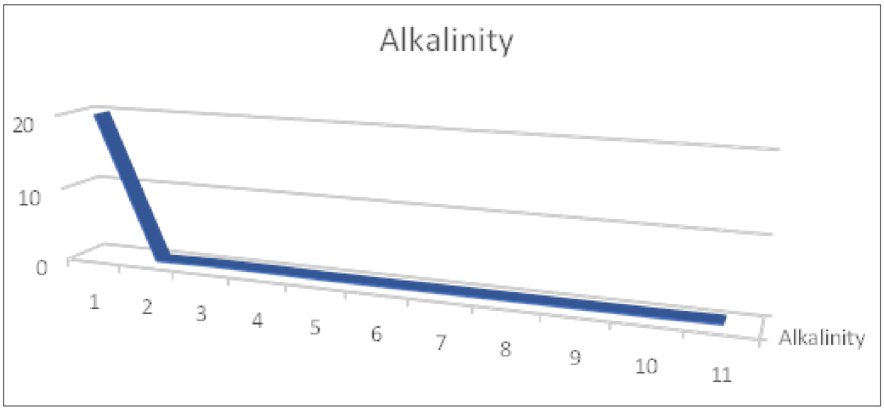

Figure 9 Plot of Alkalinity for all Locations

The figure 9 above displays the plot of alkalinity of the 10 points sampled along the 5km stretch of the Calabar River. The plot clearly shows changes in alkalinity over time. Alkalinity generally is a direct measure of a water sample's ability to resist changes in the pH. High alkalinity normally results in scale forming on filters and chemical precipitate which often times result in pipe clogging. For the strip sampled, there was little or no serious changes in the concentration apart from sampling points 2, 3 and 10 where the values went up above 0.3, indicating fluctuations and stabilization of alkalinity levels.

Table 11 Potassium Concentration for all Sampled Points

Potassium	10	0.401	0.351	0.65	0.669	0.64	0.554	0.598	0.186	0.473	0.224

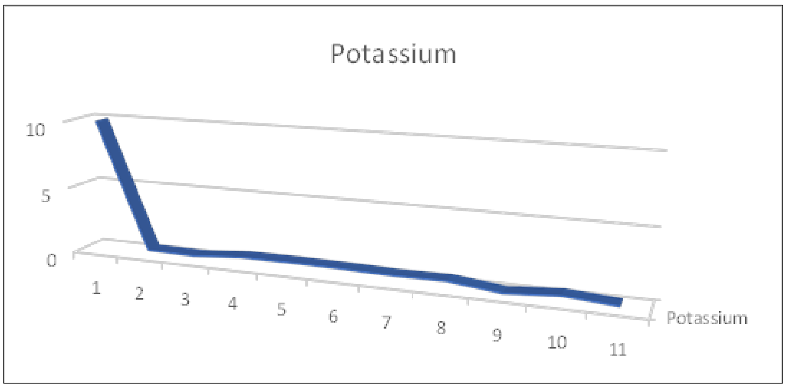

Figure 10 Plot of Potassium for all Locations

Figure 10 shows the plot of potassium concentration for the points sampled. High levels of potassium in water may result in nutrient imbalances that can, in the long run, harm aquatic ecosystem and biodiversity by exacerbating river eutrophication. The plot shows variations in potassium levels over time. It initially rises sharply, peaks between points 4 and 6, and then starts to decline, reaching a significant dip at point 9 before partially recovering. This indicates fluctuating in potassium concentrations, with a notable drop followed by some instability.

Table 12 Nitrate Concentration for all Sampled Points

Nitrate	10	0.279	0.378	0.382	0.363	0.299	0.278	0.301	0.303	0.289	0.276

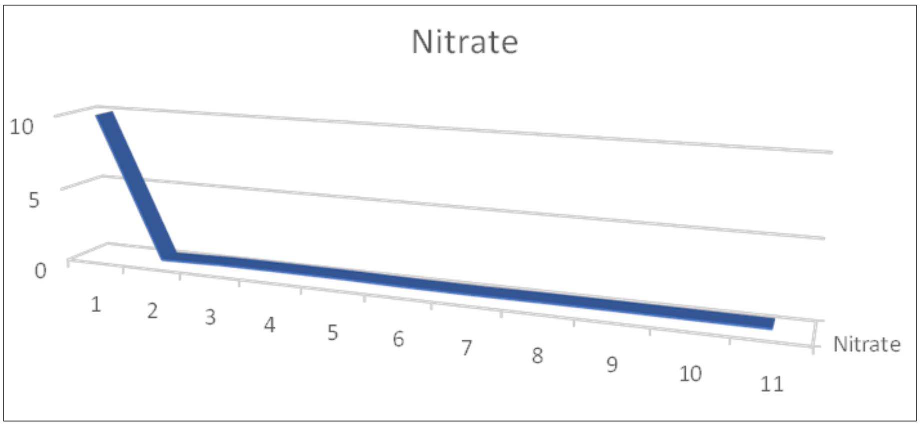

Figure 11 Plot of Nitrate for all Locations

Figure 11 shows a plot of the nitrate concentration for all the points sampled along the river. The diagram illustrates changes in nitrate levels across different locations. High concentration of nitrate in water can lead to algal blooms which blocks light for underwater floras and deplete oxygen in the water. There is equally a potential tendency for deformities in aquatic faunas when nitrate levels rise above the tolerable limits. For the points sampled, there was an initial rapid increase, peaking around points 3 to 4, followed by a gradual decline and stabilization. This indicates an initial spike in nitrate concentrations, which eventually levels out. Nitrate level was observed to be relatively low, probably indicating lack of anthropogenic activities along the stretch of the river sampled.

Table 13 Phosphate Concentration for all Sampled Points

Phosphate	100	0.335	0.165	0.145	0.244	0.161	0.248	0.247	0.262	0.265	0.177

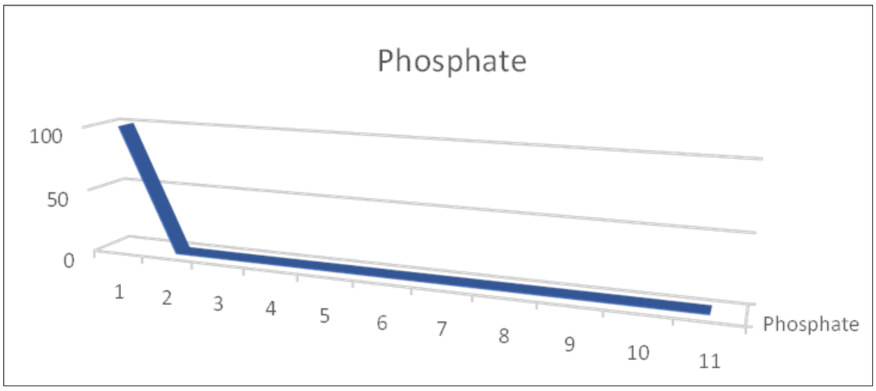

Figure 12 Plot of Phosphate for all Locations

Figure 12 shows the plot of phosphate concentration for all the points sampled. A consistent phosphate concentration across most locations after the initial rise was observed. The initial variation might point to different environmental or human activities affecting phosphate concentrations, such as agricultural runoff, industrial wastes discharges, or natural processes like erosion or mineral deposits cum weathering. Elevated phosphate levels can lead to environmental issues like eutrophication, which can negatively impact aquatic ecosystems by promoting excessive algae growth resulting in the bloom scenario. Understanding these trends can help in managing water quality and protecting the ecosystems.

Table 14 BOD Concentration for all Sampled Points

BOD	40	0.467	0.316	0.502	0.346	0.596	0.346	0.566	0.501	0.524	0.473

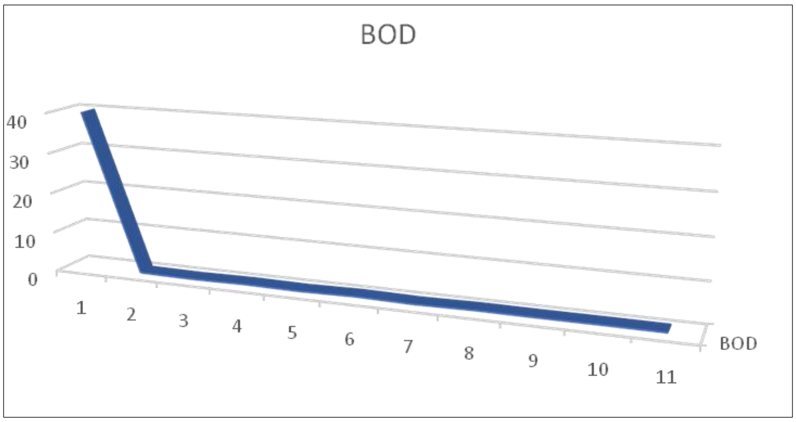

Figure 13 Plot of BOD for all Locations

Figure 13 shows the plot of BOD for all the points sampled. BOD is an important indicator of water quality, reflecting the amount of dissolved oxygen needed by microorganisms to break down organic matter in the water. For the points sampled, it was observed that the BOD concentration sharply increased at location 2, indicating higher organic pollution in that area. This could be due to factors such as wastewater discharges, agricultural runoff, or other pollution sources.

However, after the rise at location 3, BOD levels fluctuated between 0.3 and 0.6 across the remaining locations. This suggests varying degrees of organic load and oxygen demand in different areas. High BOD levels at locations 6 and 8, indicate regions with more potential pollution loads, which may lead to lower oxygen levels in the water, potentially stressing aquatic life. High BOD values, especially those above 0.5, may suggest significant organic pollution, which can cause deoxygenation of water bodies and harm aquatic ecosystems. Lower BOD levels represent better water quality, with fewer organic pollutants requiring oxygen for decomposition.

Table 15 Turbidity Concentration for all Sampled Points

Turbidity	5	0.214	0.223	0.195	0.235	0.231	0.243	0.204	0.199	0.198	0.208

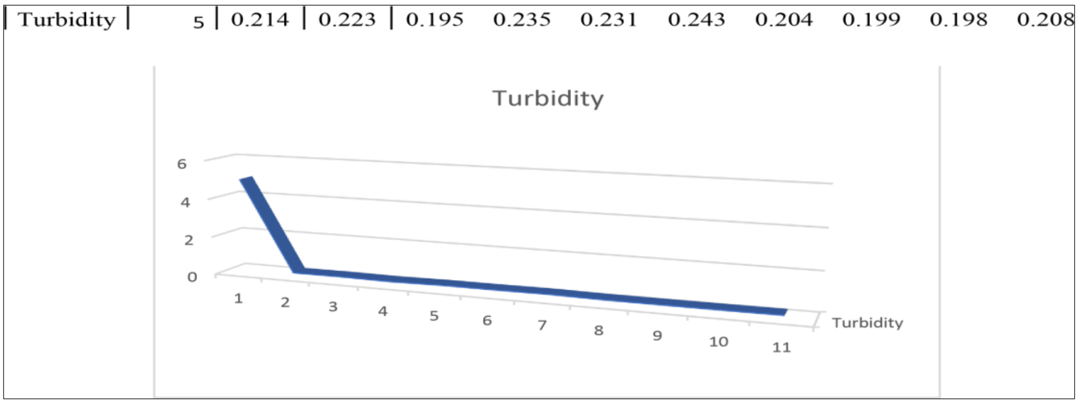

Figure 14 Plot of Turbidity for all Locations

Figure 14 shows the plot of turbidity for all points sampled. Turbidity measures the cloudiness or haziness in water, which can indicate the presence of suspended particles such as sediments, particulates, microorganisms, or pollutants. There was a rapid rise in turbidity between locations 1 and 2, suggesting an influx of suspended particles. This could be due to soil erosion, construction runoff, or other factors leading to water contamination. From location 2 to location 7, the turbidity remained relatively stable around 0.2–0.25, indicating consistently high particle levels in the water. This steady pattern suggests persistent conditions affecting water clarity, such as nearby land use activities. After location 7, there was a slight decrease in turbidity, followed by a stable trend from locations 8 to 10. This suggests a potential reduction in the sources of turbidity or natural settling of particles downstream. High turbidity can negatively affect aquatic ecosystems by reducing light penetration, which hampers photosynthesis in aquatic floras and algae. It can also affect fish and other aquatic faunas by clogging gills and reducing water quality.

Table 16 THC Concentration for all Sampled Points

THC	250	182	120.33	75	228.33	174.33	222.67	155.67	93.33	123.33	81.67

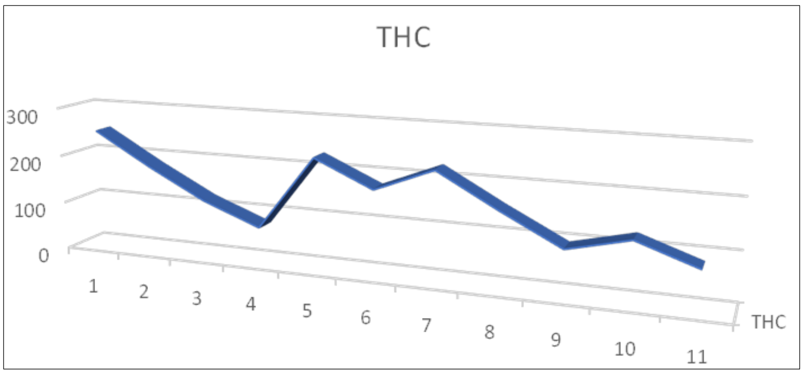

Figure 15 Plot of THC for all Locations

Figure 15 shows the plot of the Total Heterotrophic Count (THC) for the points sampled. The plot shows significant variability in THC levels across the locations. For example, location 1 starts with a low value but quickly spikes at location 2 and continues to fluctuate dramatically between locations 3 and 6. The graph peaks at location 5, indicating the highest THC levels, while there are notable drops at locations 4 and 9. This suggests varying environmental or operational factors influencing the THC levels at different sites. After reaching the peak at location 5, there was a general declining trend from location 6 to location 9, followed by a minimal rise at location 10, indicating a potential decrease in THC concentration in those areas. The locations with high THC levels (e.g., 2, 5, and 7) may need further investigation to understand what environmental factors are contributing to these spikes. Similarly, the low levels at other locations could suggest successful mitigation efforts or inherently lower emissions. The exact significance would depend on the context, such as whether these locations are industrial sites, urban areas, or natural environments. The pattern might indicate the need for targeted interventions where the spikes occur.

Table 17 TCC Concentration for all Sampled Points

TCC	0	119	184	224.57	207.33	223	95.33	130.67	175.33	156.67	143

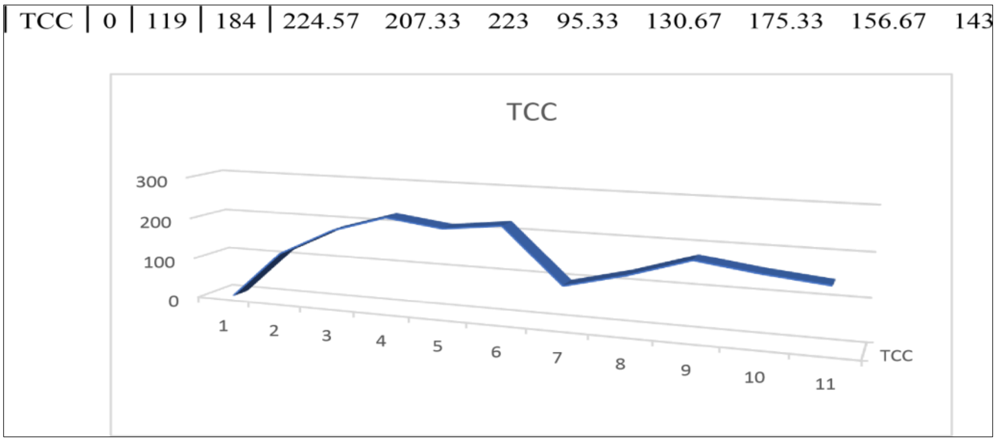

Figure 16 Plot of TCC for all Locations

Figure 16 shows the plot of Total Coliform Counts (TCC), for all the sampled points. From location 1 to location 6, there was a steady rise with a peak around location 6, similar to the THC plot, although the fluctuations were less dramatic. A significant drop was observed at location 7, marking a low point in TCC levels, followed by a rapid increase again at locations 8 and 9, Locations 3 to 6 show a relatively high concentration of TCC, peaking between locations 4 and 6. Locations 7 and 8 show contrasting behaviour, with the sharp drop and subsequent rise indicating potential site-specific variations. Like the THC plot, locations 4 and 6 gave a common peak, suggesting that human activities such as open defecation, foster the thriving of feacal bacteria. Additionally, both hydrocarbons and carbon content are high in this region. Locations with high TCC levels (around 2 to 6 and 9) could indicate high emission zones or areas with greater organic content, while the low values at location 7 suggest either reduced emissions or more effective control measures in place

5. Conclusion

This study assessed the water quality of several samples through the analysis of physiochemical parameters, including pH, conductivity, Total Dissolved Solids (TDS), and Dissolved Oxygen (DO). These parameters are critical in determining water suitability for various uses, such as drinking, agriculture, and industrial purposes. The results were used to characterize the water. The conductivity analysis revealed that most of the samples had low ion concentrations TDS levels fluctuated across the samples. The pH levels remained stable between 6 and 7 for most samples.

The study concluded that the water quality in the analysed samples generally does not meet optimal standards for safe consumption based on the results from the individual parameters. These results highlight the need for water treatment and continuous monitoring, especially in areas showing anomalies.

Recommendations

Based on the findings, the following recommendations are submitted:

- There is need to analyze the entire stretch of the river to document the concentration levels of the basic water quality parameters.
- Development of a Water Quality Index (WQI) for the river is strongly recommended
- The Total Coliform level was found to be quite higher than the acceptable limit for all the points sampled. There is need therefore for legislation against open river defecation.
- For pH for all the points sampled, only two met the reference level of 6.5 – 8.5. Human activities that acidify the aquatic ecosystem should be legislated against. Such practice like chemical fishing with explosives, should be strongly discouraged.
- Direct discharge of wastes water that has not met the specified effluent standards into the river should be vehemently discouraged.
- Education and enlightenment of the local communities on the importance of protecting water sources from pollutants and encourage practices that support water conservation and safety is of utmost importance.
- There is need for the implementation of a stricter pollution control measures to minimize the introduction of contaminants into water bodies.
- As said earlier, there will be need to conduct a more comprehensive research to investigate the long-term impact of contaminants, expand sample sizes, and explore seasonal variations in water quality.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

Statement of ethical approval

This article meets with the ethical required standard

Funding

This research was funded with the generous support of the Tetfund Institution Based Research (IBR) Grant.

References

[1] Afolabi, T. A., Amoo, I. A., & Nwachukwu, E. O. (2014). Water Quality Assessment of Ogun

River, Southwestern Nigeria. American Journal of Water Resources, 2(5), 121-126.

[2] Agwu, C. O. C., & Emenike, C. P. (2015). Assessment of Surface Water Quality in Owerrinta Abia State, Nigeria. American Journal of Environmental Protection, 3(6), 206-213.

[3] Ajah, K. O., Chima, G. N., & Agbo, K. C. (2015). Physicochemical and Bacteriological Analysis of River Alaro in Ibadan, Oyo State, Nigeria. Journal of Environmental Science, Toxicology and Food Technology, 9(5), 9-15.

[4] Akpor, O. B., & Ohioma, E. I. (2014). Impact Assessment of Abattoir Effluent on the Physicochemical and Microbiological Quality of Water of Orogodo River in Delta State, Nigeria. Environmental Systems Research, 3(1), 1-10.

[5] Allan, J. D. (2004). Landscapes and riverscapes: the influence of land use on stream ecosystems. Annual Review of Ecology, Evolution, and Systematics, 35, 257-284.

[6] Antunes, P., Santos, R., & Monteiro, H. (2006). Hydrological and water quality models: use in river management. Water Science and Technology, 53(1), 231-241.

[7] Asagwara, C. E., & Nwoko, C. I. A. (2017). Assessment of Pollution Indices and Water Quality of Orogodo River, Agbor, Nigeria. Journal of Environmental Science, Toxicology and Food Technology, 11(2), 17-25.

[8] Brown, A. E., Chen, J., McAnally, W. H., & Jackson, T. J. (2005). Comparison of digital elevation models for hydrologic applications. Journal of Hydrology, 308(1-4), 123-138.

[9] Chude, L. A., Okoye, C. O. B., & Nwosu, J. N. (2015). Assessment of Surface and Groundwater Quality of Ojoto River, Idemili South L. G. A. Anambra State, Nigeria. Journal of Environmental Science.

[10] Egboka, B. C. E., Nnaji, C. C., Orah, C. N., & Nwoye, C. I. (2017). Evaluation of Water Quality and Pollution Sources of River Awba in South-Eastern Nigeria. Journal of Environmental Science, Toxicology and Food Technology, 11(4), 1-8.

[11] European Commission. (2018). Directive 2000/60/EC of the European Parliament and of the Council of 23 October 2000 establishing a framework for Community action in the field of water policy.

[12] Ezenwaji, H. M. G., Eze, C. L., & Omenogor, E. C. (2018). Evaluation of Heavy Metals Contamination of Water Samples from Selected Boreholes in Imo State, Nigeria. Journal of Environmental Science, Toxicology and Food Technology, 12(1), 33-38.

[13] Harris, G. P., Jenkins, G. P., & Williams, R. (2000). Zooplankton as indicators of water quality in the rivers, lakes and lagoons of South-west New South Wales. Freshwater Biology, 44(3), 455-474.

[14] Helsel, D. R., & Hirsch, R. M. (2002). Statistical methods in water resources. Techniques of Water-Resources Investigations, Book 4, chapter A3.

[15] Hickey, C. W., Clements, W. H., & Kaufmann, P. R. (2012). Development and evaluation of numerical nutrient criteria for rivers and streams in nutrient ecoregion VI: Western Mountains and Upper Colorado Basin. US Environmental Protection Agency, Office of Research and Development, National Center for Environmental Assessment.

[16] Hsieh, C. L. (2018). Streamflow forecasting using extreme learning machine: an application to El Niño-affected basins in the Pacific Northwest USA. Journal of Hydrology, 565, 844857.

[17] Igwe, J. C., & Okonkwo, J. O. (2016). Physicochemical Parameters and Heavy Metal Contents of Drinking Water from Boreholes in Owerri Metropolis, Imo State, Nigeria. Journal of Environmental Science, Toxicology and Food Technology, 10(2), 16-24.

[18] Igwe, O., Igwe, N., Adedokun, O. A., & Oyekunle, J. A. O. (2017). Assessment of Water

Quality Index and Heavy Metal Contamination in Surface Water of Ero Dam, Ifaki-

Ekiti, Southwestern Nigeria. Journal of Environmental Science, Toxicology and Food Technology, 11(3), 1-10.

[19] Kümmerer, K. (2009). Pharmaceuticals in the environment: sources, fate, effects and risks. Springer Science & Business Media.

[20] Merritt, R. W., Cummins, K. W., & Berg, M. B. (2008). An introduction to the aquatic insects of North America. Kendall Hunt.

[21] Michalak, A. M., Anderson, E. J., Beletsky, D., Boland, S., Bosch, N. S., Bridgeman, T. B., ... & Zagorski, M. A. (2013). Record-setting algal bloom in Lake Erie caused by agricultural and meteorological trends consistent with expected future conditions. Proceedings of the National Academy of Sciences, 110(16), 6448-6452.

[22] Ministry of the Environment and Climate Change (MOECC). (2018). Ontario Provincial Water Quality Objectives.

[23] Nriagu, J. O. (1996). A history of global metal pollution. Science, 272(5259), 223-224.

[24] Nwachukwu, E. O., Obilor, C. C., & Ejiofor, C. (2017). Water Quality Assessment of Orashi River in Ahoada, Rivers State, Nigeria. Journal of Environmental Science, Toxicology and Food Technology, 11(4), 42-47.

[25] Obi, C., & Okoye, C. O. B. (2015). Water Quality Assessment of Ezeogba Stream in Abakaliki, Ebonyi State, Nigeria. Journal of Environmental Science, Toxicology and Food Technology, 9(9), 17-24.

[26] Odoh, R., Okonkwo, J., & Arinze, E. (2018). Assessment of Physicochemical Parameters, Bacteriological Quality and Pollution Status of Ezu River, South-East, Nigeria. American Journal of Environmental Protection, 6(5), 121-129.

[27] Ogamba, E. N., Ochuba, O. G., & Okpala, N. C. (2013). Assessment of Surface Water Quality in an Industrial Area of Aba, Nigeria. Environmental Monitoring and Assessment, 185(8), 6331-6341.

[28] Okonkwo, J. O., & Onyeagala, A. C. (2016). Pollution Status and Water Quality Assessment of Nworie River, Southeastern Nigeria. Journal of Environment and Earth Science, 6(5), 54-63.

[29] Olobaniyi, S. B., Otubanjo, O. A., Adefisan, E. A., & Adeniji, A. O. (2013). Assessment of water quality index of Agboyi creek, Lagos, Nigeria. African Journal of Environmental Science and Technology, 7(12), 1107-1114.

[30] Onojake, C. M., & Ogah, M. U. (2016). Assessment of Water Quality of Aiyetoro Stream in Aiyetoro, Ogun State, Nigeria. Journal of Environmental Science, Toxicology and Food Technology, 10(5), 36-41.

[31] Reynolds, C. S. (2006). The ecology of phytoplankton. Cambridge University Press.

[32] Ribaudo, M. O., & Agapoff, J. (2001). Water quality incentives: Their effectiveness in reducing agricultural pollution. Agricultural Economic Report, (797).

[33] Shrestha, S., Kazama, F., & Nakamura, T. (2008). Use of analytic hierarchy process (AHP) for sustainable watershed management: A case study of the Kajaki Dam watershed, Afghanistan. Water Resources Management, 22(2), 125-143.

[34] Smith, V. H., Tilman, G. D., & Nekola, J. C. (1999). Eutrophication: impacts of excess nutrient inputs on freshwater, marine, and terrestrial ecosystems. Environmental Pollution, 100(1-3), 179-196.

[35] Stow, C. A., Reckhow, K. H., Qian, S. S., & Hope, D. Q. (2001). A Bayesian hierarchical model for the development of water quality criteria. Water Resources Research, 37(11), 27372744.

[36] U.S. Environmental Protection Agency (USEPA). (2015). National recommended water quality criteria: 2015.

[37] Ugochukwu, C. N., Chuku, E. C., & Odoh, R. (2018). Assessment of Water Quality and Heavy Metals in Ikenga River, Southeastern Nigeria. American Journal of Environmental Protection, 6(1), 15-22.

[38] Whelan, K., McDonnell, R. A., & Ferreira, R. S. (2009). The use of water quality guidelines in the management of environmental impacts associated with unconventional gas extraction in Queensland, Australia. Marine and Freshwater Research, 60(10), 10831092.