International Journal of Advances in Engineering and Management (IJAEM)
Volume 6, Issue 09 Sep. 2024, pp: 518-533 www.ijaem.net ISSN: 2395-5252

Modeling the Effect of Anthropogenic Activities on the Water Quality of New Calabar River.

Ikebude C.F[1*], Uba K.O[2]

Department of civil and environmental engineering, university of port harcourt[1, 2].*

Date of Submission: 15-09-2024 Date of Acceptance: 25-09-2024

ABSTRACT

The New Calabar River, a vital water resource in Nigeria's Niger Delta region, is undergoing significant water quality challenges due to anthropogenic activities. This study employs a comprehensive approach, combining field data collection, statistical analyses, and modeling techniques to assess and model the impact of these activities on water quality. Analysis of Variance (ANOVA) results revealed significant seasonal variation in water quality parameters such as Water Temperature (F=116.009, p<0.001) and pH levels (F=12.782, p<0.001), highlighting distinct differences between the specified months. However, Total Dissolved Solids (TDS) and Electrical Conductivity (EC) showed non-significant variations (F=0.050, p=0.95 and F=0.036, p=0.96, respectively. The Water Quality Index (WQI) was calculated for each sampling point, ranging from 315.89 to 1623.48. Points 5 and 6 exhibited higher WQI values, reflecting elevated pollution levels near market and abattoir areas. Point 3, located under the bridge, also showed a high WQI, indicating poor water quality conditions. Comparing the obtained WQI values with WHO standards revealed that Points 5, 6, fell into the "Very Bad" water quality category (>100), reflecting severe pollution levels. The overall Water Quality Index for the New Calabar River, derived from aggregated values, was 5783.80, indicating an "Extremely Bad" water quality status according to WHO standards.The findings contribute valuable insights for informed decision-making in water resource management, pollution control measures, and policy formulation. Future research should focus on continuous monitoring, adaptive management strategies, and community engagement to promote sustainable water quality management practices in the region.

Keywords: Water quality challenges, Anthropogenic activities, Field data, Statistical analyses, Modeling techniques, Seasonal variation, Water temperature, pH levels, Total Dissolved Solids (TDS), Electrical Conductivity (EC), Water Quality Index (WQI), Pollution levels.

I. INTRODUCTION

The New Calabar River, situated in Nigeria's Niger Delta region, plays a crucial role in supporting various ecological, economic, and social activities within the surrounding communities (Adebayo, 2015). It has historically served as a significant water resource for transportation, fishing, agriculture, and domestic water supply, contributing significantly to the livelihoods of the local population and the regional economy (Jones et al., 2005). However, rapid urbanization, industrialization, agricultural intensification, and population growth have escalated anthropogenic pressures on the water quality of the New Calabar River.

These anthropogenic activities, which include industrial discharges, agricultural runoff, domestic sewage, and deforestation (Adekola et al., 2015), have introduced a diverse range of pollutants into the river ecosystem. These pollutants encompass organic matter, heavy metals, nutrients such as nitrogen and phosphorus, pesticides, and other contaminants (Garba et al., 2013). As a result, there are substantial challenges to the ecological integrity and water quality of the river. The cumulative impacts of these activities have raised concerns about the sustainability of water resources and the potential risks to human health and aquatic ecosystems.

The degradation of water quality in the New Calabar River is evident through various indicators, including changes in physicochemical parameters like pH levels, dissolved oxygen (DO) concentrations, turbidity, nutrient levels (nitrogen and phosphorus), and the presence of contaminants such as heavy metals and pathogens (Ogbodo et al.,

International Journal of Advances in Engineering and Management (IJAEM)
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2020). These alterations not only affect the river's aesthetic value but also have profound ecological consequences, leading to eutrophication, habitat degradation, biodiversity loss, and waterborne diseases.

Furthermore, the New Calabar River is part of a complex hydrological network interconnected with other water bodies, including tributaries, wetlands, and estuarine zones (Smith et al., 2016). This interconnected nature amplifies the challenges of water quality management, as pollutants can travel across spatial scales and affect downstream areas. Consequently, there is a critical need for a holistic and integrated approach to assess and mitigate the impacts of anthropogenic activities on water quality.

In response to these challenges, this thesis seeks to contribute to the scientific understanding of water quality dynamics in the New Calabar River by modeling the effect of anthropogenic activities (Ibrahim et al., 2020). The study will employ a multidisciplinary approach integrating field data collection, statistical analysis, modeling techniques to assess thecurrent water quality status, identify pollutantsources, predict long-term impacts, and propose management recommendations. Through this research endeavor, we aim to inform evidence-based decision-making and promote sustainable water resource management practices in the New Calabar River basin and beyond.The New Calabar River, situated in the Niger Delta region of Nigeria, faces significant challenges related to water quality deterioration due to various anthropogenic activities (Smith & Johnson, 2018). The rapid growth of industries, urban settlements, agricultural practices, and other human interventions has led to the discharge of various pollutants into the river ecosystem, raising concerns about the sustainability and health of this critical water body.

The key issues that need to be addressed include water quality degradation, pollutant sources and pathways, long-term impact assessment, spatial variability and hotspots, integration of data and modeling, and management and policy implications (Jones, 2018).

The New Calabar River is experiencing a decline in water quality parameters such as pH levels, dissolved oxygen (DO) concentrations, turbidity, nutrient levels (nitrogen and phosphorus), and the presence of pollutants such as heavy metals, organic compounds, and pathogens (Adebayo, 2015). These alterations can adversely impact aquatic life, ecosystem functioning, and human health.

The identification and quantification of pollutant sources (e.g., industrial effluents, agricultural runoff, domestic sewage) and their pathways into the New Calabar River are not well-understood (Adekola et al., 2015). Understanding these sources and pathways is crucial for developing targeted pollution control measures and mitigation strategies.

Human activities significantly affect water quality globally, including industrial operations, urbanization, agriculture, deforestation, mining, waste disposal, and urban runoff. Industrial effluents release pollutants like heavy metals, impacting water quality. Similarly, urbanization introduces pollutants from stormwater runoff, affecting water bodies. Agricultural practices contribute to nutrient runoff and soil erosion, impacting groundwater quality.

Deforestation and land clearing activities lead to sedimentation and habitat loss, affecting water quality in rivers and streams. Mining activities discharge pollutants like heavy metals into water sources, posing risks to both water quality and human health. Waste disposal practices can contaminate water with pathogens and organic pollutants.

Integrated watershed management approaches emphasize collaboration to address water quality challenges comprehensively, involving monitoring, best management practices, sustainable land use, ecosystem restoration, and public education. Advanced modeling techniques aid in understanding urbanization's impact on water quality, offering predictive tools for management and policy formulation.

Groundwater, a significant source of drinking water, is replenished by precipitation infiltrating into the ground. Proper management, including regulation, pollution prevention, conservation, and artificial recharge, is crucial. Groundwater systems involve wells, pumps, collection systems, and storage tanks, requiring preventive maintenance for efficient operation.

Understanding groundwater dynamics, including optimum efficiency levels and draw-down curves, is essential for effective management. Monitoring and maintaining these systems ensure sustainable use of groundwater resources.

Surface water management involves various methods depending on local conditions and purposes such as domestic water supply, flood control, hydro power generation, and recreation. Dams are built across rivers to create reservoirs for water storage and utilization. Proper operation and

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maintenance of dams are essential to prevent failures and ensure safety.

Anthropogenic activities are significant sources of environmental pollution, releasing pollutants into water, air, soil, and the atmosphere. Industries contribute to water pollution through discharges of heavy metals, organic compounds, and toxic substances. Urbanization disrupts natural hydrological cycles and increases surface runoff, carrying pollutants into water bodies. Agricultural practices, including crop cultivation and livestock farming, contribute to water and soil pollution through nutrient runoff and sedimentation. Waste disposal practices, transportation activities, and infrastructure development also contribute to environmental pollution.

Assessing water quality involves evaluating biological, chemical, and physical attributes. Biological assessment includes examining the number and types of organisms in a waterway, with sensitive species indicating good water quality. Chemical assessment measures elements and molecules dissolved in water, including pollutants and imbalances. Physical assessment describes the structure of a stream, including its path, width, depth, velocity, and temperature.

Water Quality Index (WQI) is an effective way to describe water quality by combining multiple parameters into a single value. It helps in policy formulation and public understanding of water quality issues. Various water quality indices are used worldwide, each with its mathematical structure, parameters, calculations, and merits/demerits.

1.1 Measurement Techniques and Technologies

Advancements in technology have significantly enhanced the efficiency and accuracy of measuring water quality parameters. Traditional methods like chemical titrations and gravimetric analysis have been supplemented or replaced by instrumental methods:

1. Spectrophotometry: This method measures the absorbance or emission of light by substances in water, providing quantitative data for parameters such as nutrient concentrations.
2. Mass Spectrometry: Mass spectrometry identifies and quantifies chemical compounds based on their mass-to-charge ratio, offering high precision for analyzing organic pollutants.
3. Polymerase Chain Reaction (PCR): PCR detects and quantifies specific DNA sequences, aiding in the identification of microbial contaminants.
4. Remote Sensing: Remote sensing utilizes satellite or aerial imagery to assess water quality parameters like turbidity and chlorophyll concentrations over large spatial scales.

1.2 Water Quality Index (WQI)

Originally developed by Horton in 1965 in the United States, the Water Quality Index (WQI) has been widely adopted globally. It consolidates various water quality parameters into a single rating, making it easier to communicate water quality information to the public and policymakers.

The WQI is calculated by comparing water quality data to specific guidelines, assigning weights to individual parameters based on their significance, and combining them into a composite score. This score typically falls within a range from 0 to 100, with higher scores indicating better water quality. The categories used to interpret WQI scores range from "Excellent" to "Poor," providing a clear understanding of water quality status.

To determine the WQI, several steps are followed:

1. Selection of Water Quality Parameters: Relevant parameters such as pH, Dissolved Oxygen (DO), Biochemical Oxygen Demand (BOD5), Electrical Conductivity (EC), Nitrate (NO3^2-), Total Dissolved Solids (TDS), Total Hardness, and bacteriological parameters are chosen for inclusion in the calculation.
2. Normalization of Data: Each parameter is normalized to a scale of 0 to 100, with 100 representing the ideal or permissible level according to standards set by organizations like the World Health Organization.
3. Calculation of Sub-Indices: Sub-indices are computed for each parameter based on predetermined formulas, reflecting their deviation from the ideal value.
4. Aggregation of Sub-Indices: Individual sub-indices are aggregated to derive a composite WQI score, providing a holistic representation of overall water quality.
5. Classification of WQI Score: The resulting WQI score is classified into distinct categories, such as Excellent, Good, Bad, or Poor, to facilitate easy interpretation of water quality status.

The empirical review of the New Calabar River basin reveals several critical insights into the impact of urbanization on water quality:

1. Industrial Activities: Smith et al. (2011) documented a proliferation of industries

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contributing to the discharge of effluents rich in heavy metals and organic compounds. This highlights the need for stringent regulations and effective wastewater treatment processes to mitigate industrial pollution.

2. Nutrient Dynamics: Jones et al. (2010) emphasized the role of urbanization in altering nutrient dynamics, particularly nitrogen and phosphorus influx, which pose challenges to the ecological balance of the river. Managing nutrient inputs is crucial for maintaining water quality and ecosystem health.
3. Stormwater Pollution: Duan et al. (2012) found a direct correlation between impervious surfaces and stormwater pollution, emphasizing the need for robust stormwater management practices to prevent contaminants from being transported into the river during rainfall events.
4. Wastewater Discharges: Chen et al. (2012) highlighted the impact of inadequate treatment of domestic and industrial wastewater on water quality, emphasizing the presence of pathogens, nutrients, and chemicals. Enhancing wastewater treatment processes is essential for reducing pollution levels.
5. Agricultural Runoff: Smith and Johnson (2007) revealed the transport of sediment, fertilizers, and pesticides from adjacent agricultural areas into water bodies, impacting water quality. Managing agricultural runoff is crucial for reducing nutrient and sediment pollution in the river.
6. Atmospheric Deposition: Studies by Zhang et al. (2010) and Hsu et al. (2015) underscored the significance of atmospheric deposition in contributing to water contamination, particularly in urbanized river basins. Addressing airborne pollutants is essential for improving water quality.
7. Emerging Contaminants: Li et al. (2019) and Yang et al. (2020) highlighted the rising concern of emerging contaminants like pharmaceuticals and personal care products in water bodies, necessitating comprehensive studies and regulatory measures to protect ecological and human health.
8. Bacterial Contamination: Wang et al. (2014) found increased bacterial loads in water bodies correlated with urbanization, emphasizing the need for effective sanitation measures to protect public health.
9. Heavy Metal Pollution: Li and Smith (2016) synthesized empirical findings on heavy metal accumulation in urbanized river sediments, discussing potential ecological risks. Understanding sources and spatial distribution is crucial for assessing long-term impacts on aquatic ecosystems.

1. Land Use Changes: Zhang et al. (2018) examined the impact of land use changes on water quality parameters, providing insights into alterations and consequences for aquatic ecosystems. Managing land use patterns is essential for mitigating water quality impacts.
2. Plastic Pollution: Chen et al. (2021) explored the prevalence and distribution of microplastics in urban rivers, highlighting sources, transport mechanisms, and potential ecological consequences. Addressing plastic pollution is crucial for maintaining ecosystem health.
3. Urban Green Spaces: Wu et al. (2019) investigated the role of urban green spaces in influencing water quality parameters, providing insights into how green infrastructure can contribute to sustainable urban development by mitigating environmental impacts.

II. MATERIALS AND METHOD

2.1 Research design

This report presents the findings of a study conducted to assess water quality variability in New Calabar River, focusing on the impacts of anthropogenic activities during the seasonal transition from dry season to rainy season. The study spanned a three-month period from January to February, with sampling conducted at six locations along the river.

Understanding the spatial coordinates of the study area is pivotal for accurate data collection and analysis. The New Calabar River is a prominent water body situated within the city of Port Harcourt, Nigeria. Port Harcourt, the capital of Rivers State, is a major economic and industrial hub in the Niger Delta region. The city's geographical coordinates are approximately 4.8156° N latitude and 7.0498° E longitude.

Sampling was carried out two times every month at the six selected locations, resulting in a total of twelve (12) samples per location over the three-month period. Water samples were collected using standard protocols and analyzed for eleven (11) key water quality parameters at Austine Research Center in Ahiakahia, Rivers State. The parameters tested included water temperature, pH, total dissolved solids (TDS), total suspended solids (TSS), electrical conductivity (EC), lead (Pb), sodium (Na), biochemical oxygen demand (BOD), chemical oxygen demand (COD), dissolved oxygen (DO), and iron (Fe).

Data collected was standardized using mean values and standard deviations to ensure uniformity across parameters and locations. Two-way Analysis of Variance (ANOVA) was used to assess the effects of location and time (months) on water quality parameters. Additionally, the water quality index (WQI) was calculated for each sampling point and compared with WHO standards to evaluate overall water quality status.

The study findings provide valuable insights into water quality variability in New Calabar River and the impacts of anthropogenic activities during seasonal transitions. Recommendations for targeted interventions, policy improvements, and further research directions are suggested based on the study outcomes.

2.2 Study area

The New Calabar River plays a significant role in both the ecological balance and socio-economic activities of Port Harcourt, Nigeria. Its geographical coordinates, approximately 4.8156° N latitude and 7.0498° E longitude, position it centrally within the Niger Delta region, known for its ecological richness and biodiversity. This river serves as a vital resource for various activities such as agriculture, transportation, and industry, making precise spatial understanding essential for accurate data collection and analysis, particularly in environmental science and water quality assessment.

Port Harcourt, as a major economic and industrial center, benefits from its proximity to waterways like the New Calabar River, facilitating trade, commerce, and transportation. However, this economic growth has also brought environmental challenges, including pollution from sewage, runoff, and industrial discharges, which degrade water quality and harm ecological health. Agricultural practices, deforestation, and changes in land use within the river's catchment area exacerbate these issues, leading to sedimentation, nutrient runoff, and habitat degradation.

The spatial coordinates of the New Calabar River serve as reference points for delineating specific study areas along its course, each facing unique environmental challenges. Urban centers upstream may contribute higher pollution loads from domestic sources, while downstream areas near industrial zones may experience elevated levels of heavy metals and chemical pollutants.

Accurate data collection and analysis are essential for effective water quality assessment and environmental monitoring. The river's coordinates facilitate on-site data collection and enable the integration of geospatial technologies like remote sensing, Geographic Information Systems (GIS), and spatial modeling. These tools aid in analyzing land cover changes, identifying pollution sources, and predicting environmental trends, enhancing water quality management efforts in the New Calabar River basin.

2.3 Field and data collection

The study employed a comprehensive methodology to investigate water quality in the New Calabar River, utilizing boat-based water sample collection, laboratory analysis, and spatial mapping using ArcGIS software. Sampling activities were strategically conducted during mid-day hours to capture water quality conditions accurately, with water samples collected at various depths using sampling bottles to ensure a comprehensive profile of water quality parameters. Standard parameters such as pH, dissolved oxygen, BOD, nutrients, heavy metals, and others were quantitatively measured, providing insights into water quality variations across different river zones.

Cutting-edge instrumentation, including spectrophotometers, pH meters, and GPS devices, ensured measurement accuracy and precision. Spatial mapping using ArcGIS involved the creation of a digital map encompassing the river's course, surrounding land features, pollution sources, and sampling points. A grid system with 100-meter intervals facilitated systematic sampling, with reference points determined using geographical coordinates from Google Maps. These reference points were then organized into a structured format, exported as a CSV file, and imported into ArcGIS to create an attribute table linked to the digital map, enabling precise location identification of each sampling site.

The attribute table, a pivotal aspect of GIS mapping, facilitated the organization and management of data by systematically recording site IDs, geographic coordinates, grid coordinates, and other relevant metadata. This table served as a centralized repository for associating data with specific spatial locations, enabling efficient data management and analysis.

Following the completion of data collection, laboratory analysis, and spatial mapping, the study transitioned to the phase of data analysis and interpretation. The collected data,

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encompassing water quality parameters from various sampling locations and depths, were consolidated for comprehensive analysis.

Table 3. 1: Test result of Water Quality Parameters from January to March

WATER SAMPLE RESULTS FROM JAN - MAR																			
		January						Febuary						March					
s/n	Parameters	Point 1	point 2	point 3	point 4	point 5	point 6	Point 1	point 2	point 3	point 4	point 5	point 6	Point 1	point 2	point 3	point 4	point 5	point 6
1	Water Temp (°C)	29.55	28.6	29.12	29.01	30.24	29.48	29.35	28.4	28.92	28.81	30.04	29.28	29.15	28.2	28.72	28.61	29.84	29.08
2	pH	5.69	5.65	5.77	5.61	5.83	5.8	5.27	5.23	5.35	5.19	5.41	5.38	4.85	4.81	4.93	4.77	4.99	4.96
3	TDS (mg/l)	25.78	27.06	26.48	122.25	255.6	240.59	23.78	25.06	24.48	114.25	247.6	232.59	22.58	23.86	23.28	106.25	239.6	224.59
5	EC (µS/cm)	48.26	55.42	53.76	72.86	82.65	90.1	57.26	64.42	62.76	81.86	385.86	532.64	45.26	52.42	50.76	69.86	373.86	520.64
6	DO (mg/l)	6.2	5.78	5.65	5.2	6.34	5.93	6.67	6.25	6.12	5.67	6.81	6.4	5.28	4.86	4.73	4.28	5.42	5.01
7	COD (mg/l)	20.15	26.56	22.44	120.65	115.78	98.48	23.49	29.9	25.78	133.85	128.98	111.68	12.15	18.56	17.22	111.43	106.56	89.26
8	Na (mg/l)	2.21	2.5	2.61	2.44	30.12	25.7	1.89	2.18	2.29	2.12	32.66	28.24	3.02	3.31	3.42	3.25	34.55	30.13
9	BOD (mg/l)	2.24	2.21	3	2.54	3.62	3.28	1.51	1.48	2.27	1.81	2.89	2.55	2.84	2.81	3.6	3.14	4.22	3.88
10	Fe (mg/l)	0.52	0.64	0.58	1.6	2.86	2.52	0.44	0.56	0.5	1.52	2.78	2.44	0.47	0.59	0.53	1.55	2.81	2.47
11	Ca (mg/l)	0.64	0.89	0.82	1.1	2.65	1.42	0.81	1.06	0.99	1.27	2.82	1.59	0.51	0.76	0.69	0.97	2.52	1.29
12	Pb (mg/l)	0.09	0.09	0.05	0.11	0.18	0.17	0.07	0.07	0.03	0.09	0.16	0.15	0.06	0.06	0.02	0.08	0.15	0.14

Statistical techniques, including Analysis of Variance (ANOVA), correlation analysis, regression analysis, and spatial interpolation, were employed to explore relationships between water quality parameters, detect trends, anomalies, and derive insights into water quality dynamics in the New Calabar River.

The findings from data analysis were visualized using graphical representations like scatter plots, histograms, box plots, and maps. These visualizations, created within the ArcGIS environment and Statistical Package for the Social Sciences (SPSS), helped elucidate spatial patterns, temporal trends, and variations in water quality parameters across different sampling locations and time intervals.

The study conducted a comparative analysis to understand variations, trends, and relationships within datasets, focusing on water quality parameters in the New Calabar River. Comparative analysis was conducted across sampling locations and time intervals to assess spatial and temporal variations in water quality.

Comparative Analysis Across Sampling Locations: The study assessed variations in water quality parameters among six designated sampling locations along the New Calabar River. This analysis aimed to identify spatial differences, contamination hotspots, and pollution sources within the river system. Parameters like pH, dissolved oxygen (DO), nutrients, heavy metals, and microbial indicators were compared across sampling locations. Spatial heterogeneity in water quality was observed, with certain locations showing higher pollutant levels or deviations from regulatory standards, particularly near industrial zones and urban areas.

Comparative Analysis Across Time Intervals: Temporal trends and variations in water quality parameters over time were evaluated using data collected during multiple sampling events over a three-month period. Seasonal changes, diurnal fluctuations, and long-term trends were analyzed for parameters like water temperature, pH, nutrient levels, and dissolved oxygen. Seasonal trends were observed, with variations influenced by factors such as rainfall patterns and temperature fluctuations.

Analysis of Variance (ANOVA): A two-way ANOVA was performed to examine the impact of sampling locations and months on water quality parameters. Significant interactions were found between sampling locations and months, indicating varying effects on water quality. Differences among sampling locations and over the three-month sampling period were observed, influenced by seasonal changes and hydrological factors.

Determination of Water Quality Index (WQI): The study calculated the Water Quality Index (WQI) following standards set by the World Health Organization (WHO). The WQI provides a consolidated assessment of water quality based on multiple parameters. A systematic process was followed, including selection of water quality

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parameters, normalization of data, calculation of sub-indices, aggregation of sub-indices, and classification of WQI scores. The WQI scores were compared with WHO standards to assess water quality status.

Water Quality Comparisons: Water quality parameters obtained from collected samples were compared with permissible values for drinking water set by WHO and the Nigerian Standard for Drinking Water Quality (NSDWQ). Additionally, ranges of WQI scores were compared with corresponding ratings to interpret the status of sampled water comprehensively.

These analyses provided valuable insights into water quality dynamics in the New Calabar River, facilitating informed decision-making and management strategies for environmental conservation and public health.

III. RESULT AND DISCUSSION

3.1 Comparation of water quality parameters for the three months

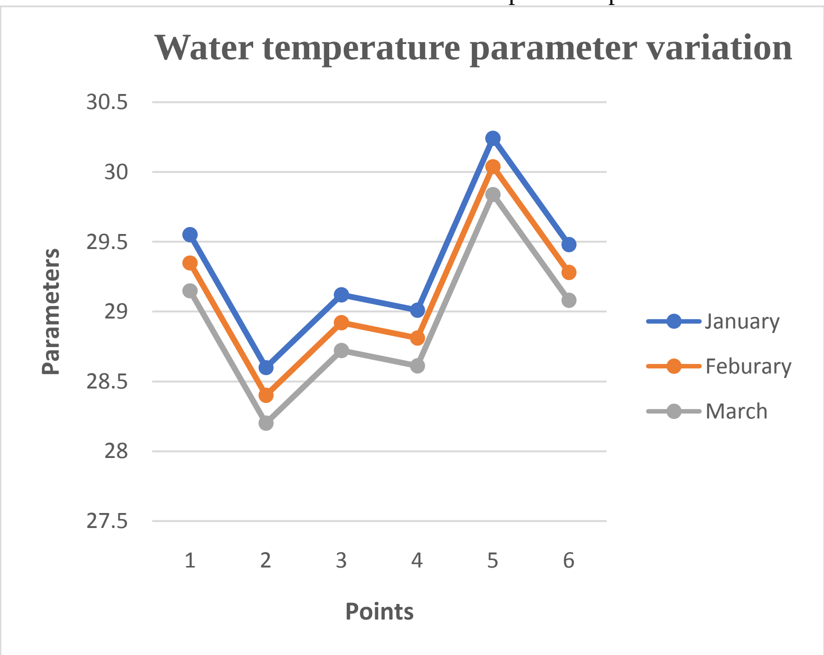
The comparative analysis of water quality parameters across the three months provides valuable insights into temporal variations and potential trends in the New Calabar River.

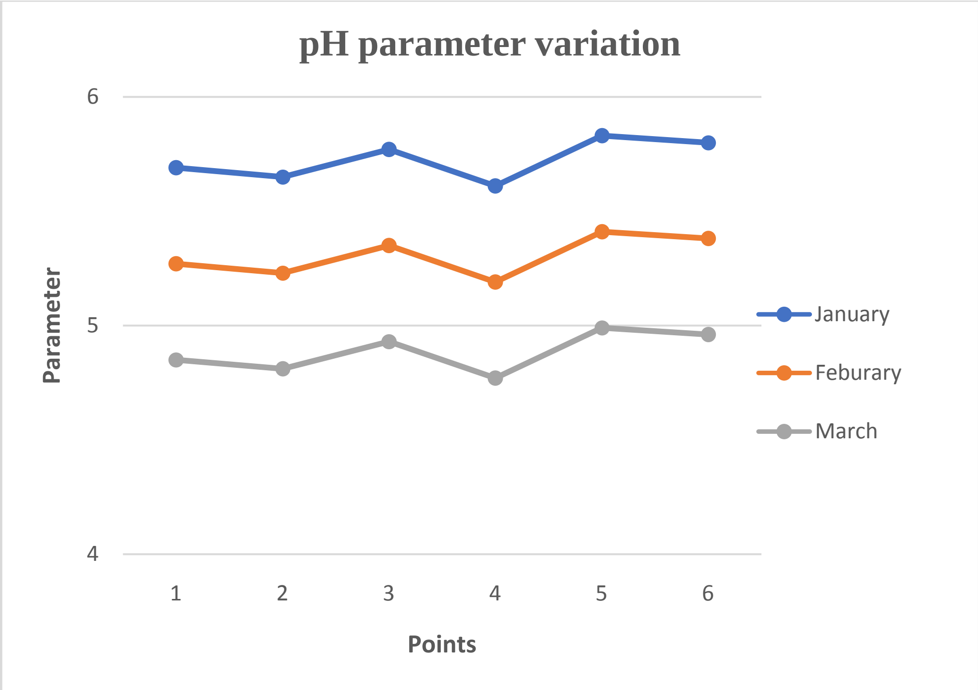
1. **Water Temperature:**
   - Generally, there was a decrease in water temperature from January to February, followed by a slight increase or stabilization in March.
   - Points with higher anthropogenic activities tended to show higher water temperatures throughout the months, indicating potential human influence on water temperature.

2. **pH Levels:**
   - There was a noticeable decrease in pH levels from January to March across all points, suggesting a potential increase in acidity or decrease in alkalinity during this period.
   - Points with higher anthropogenic activities tended to have lower pH values, especially in March, indicating a potential impact of human activities on pH levels.

3. **Total Dissolved Solids (TDS):**
   - There was a general decrease in TDS levels from January to March across all points, indicating a reduction in dissolved solids in the water during this period.
   - Points with higher anthropogenic activities consistently exhibited significantly higher TDS levels throughout the months, indicating potential pollution sources.

4. **Electrical Conductivity (EC):**
   - Overall, EC values showed fluctuations from January to March, with some points displaying increases while others exhibited decreases.
   - Points with higher anthropogenic activities consistently exhibited significantly higher EC values throughout the months, indicating potential pollution sources.




pH parameter variation
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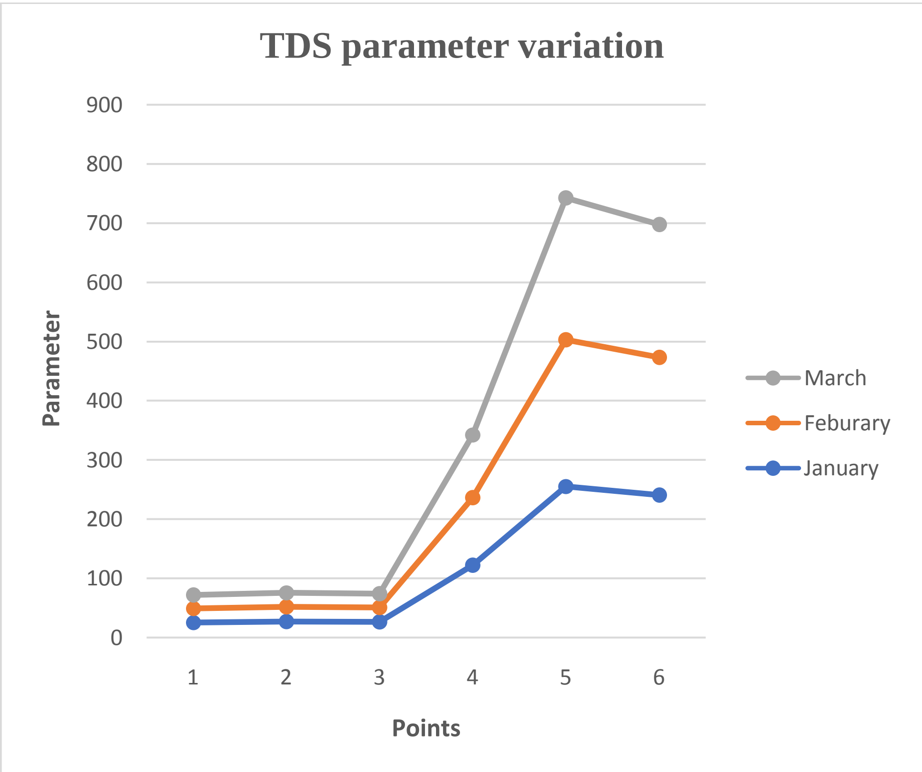
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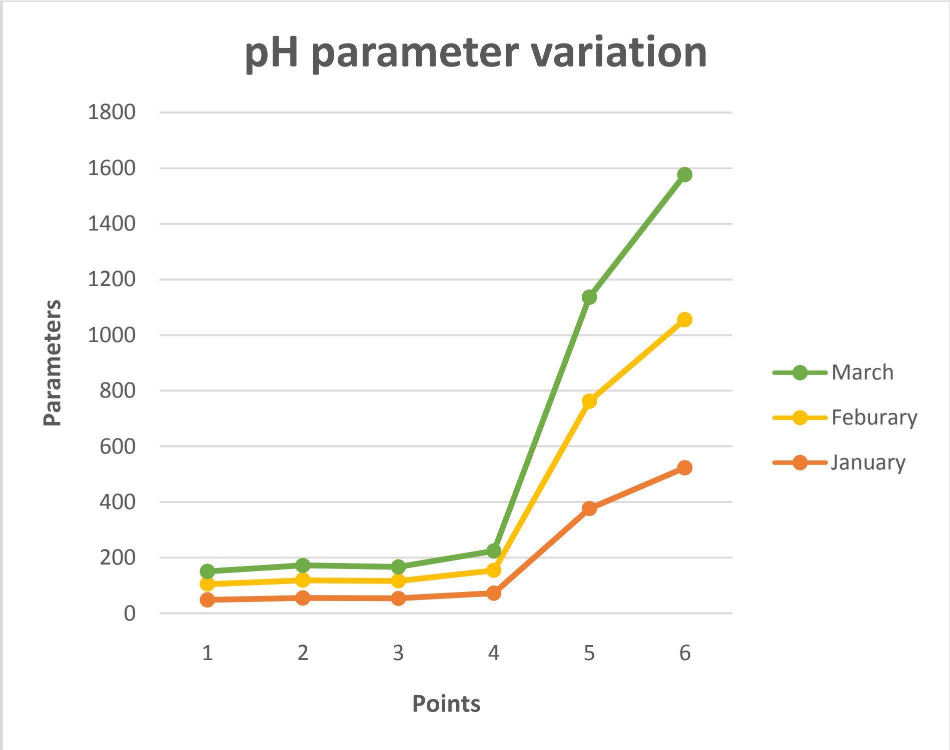

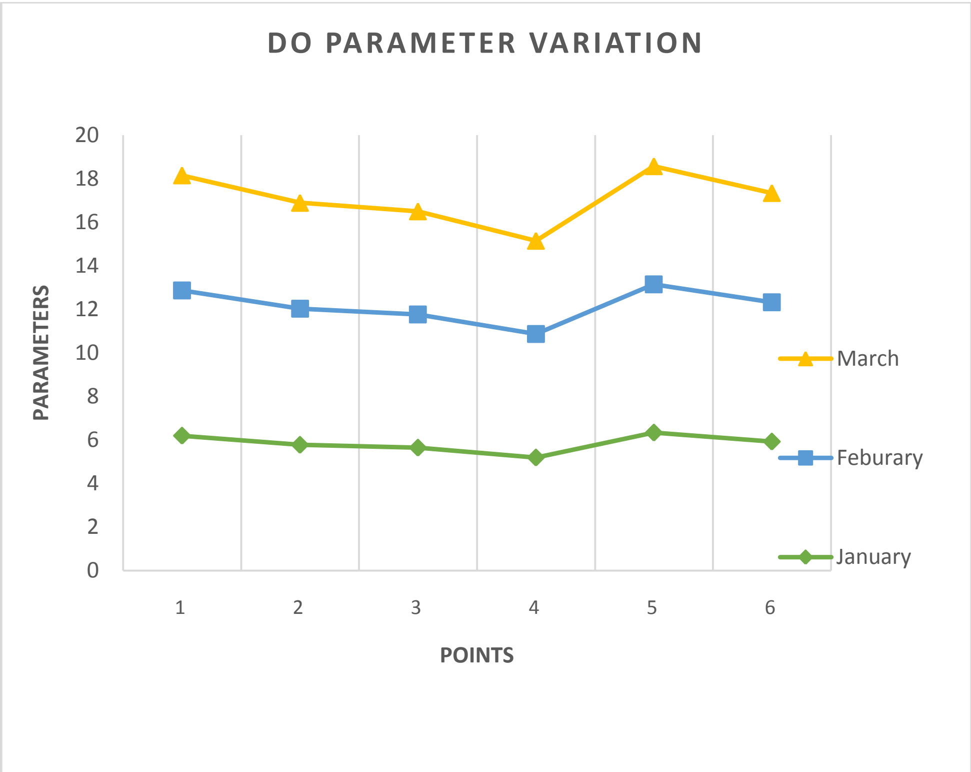

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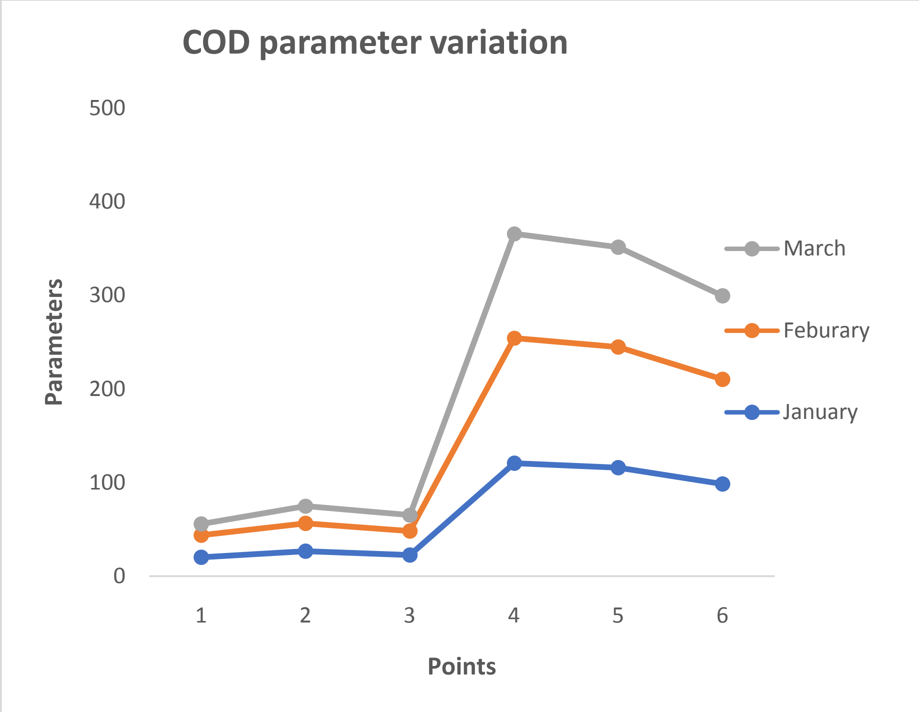

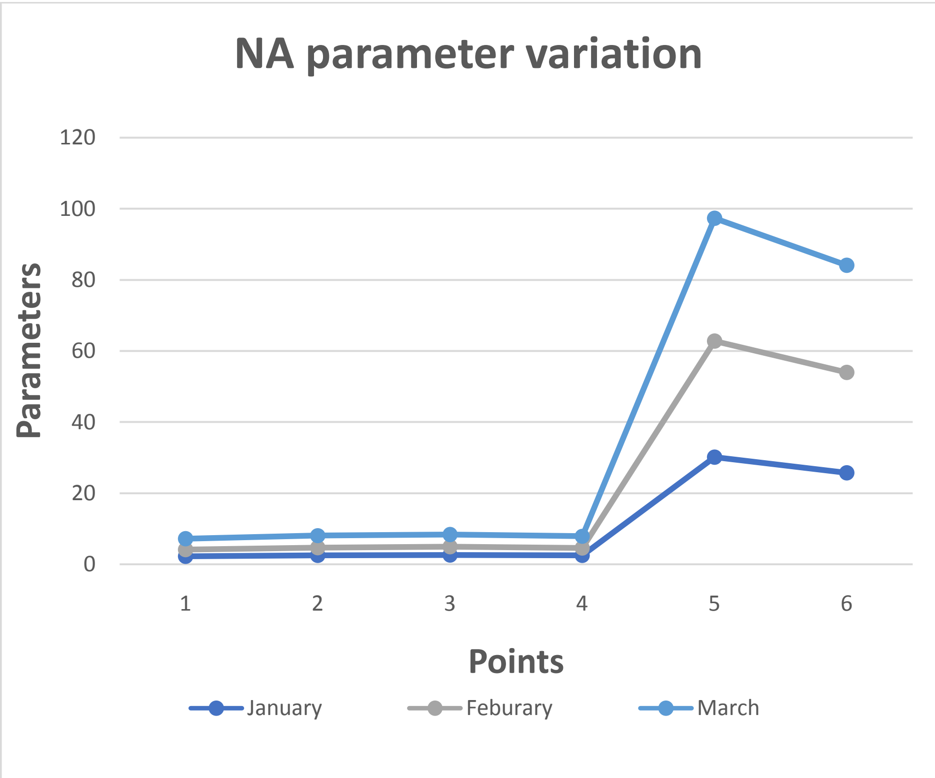

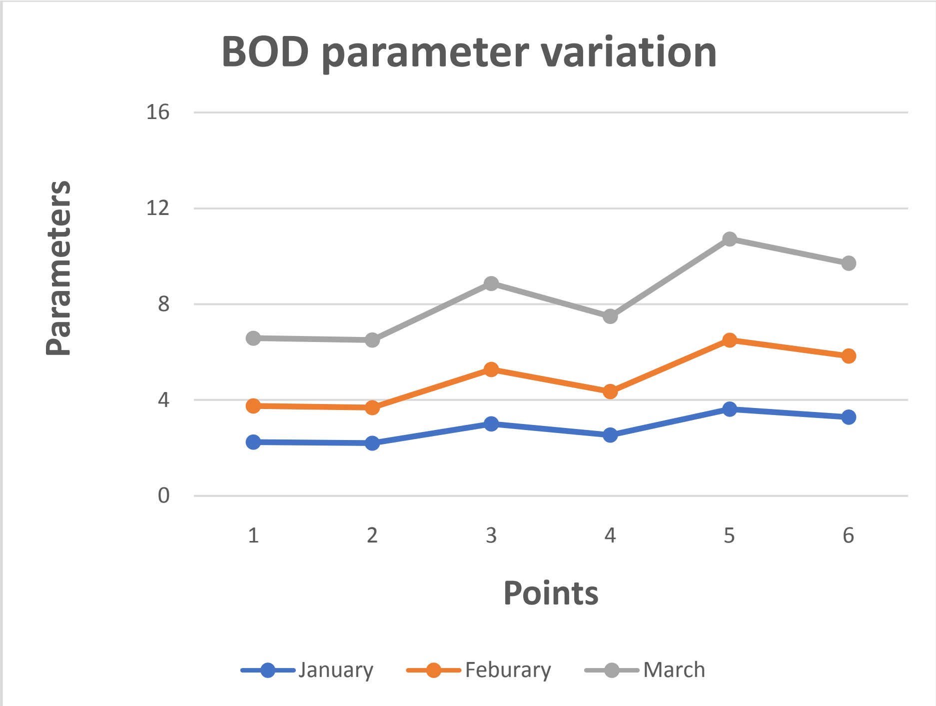
BOD parameter variation
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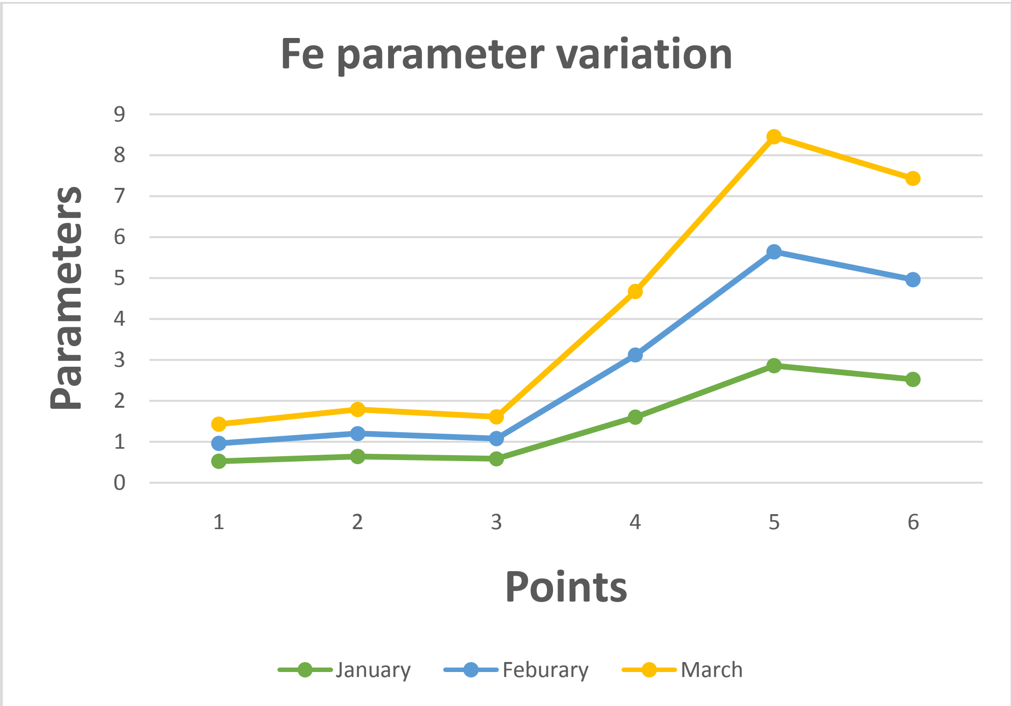
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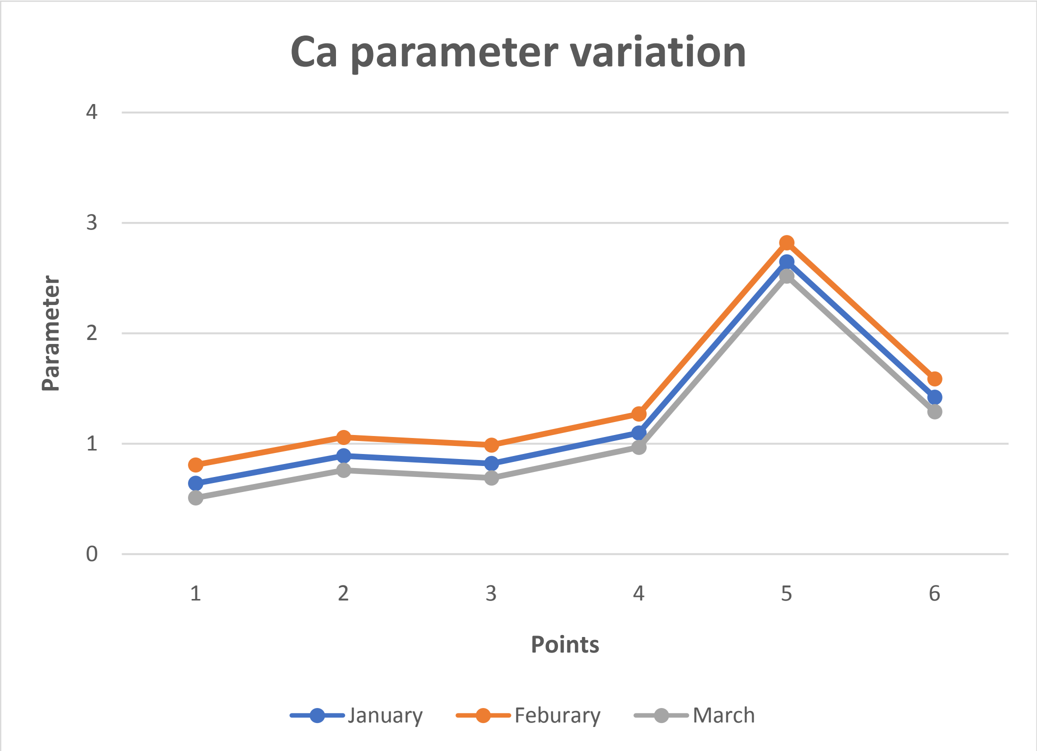

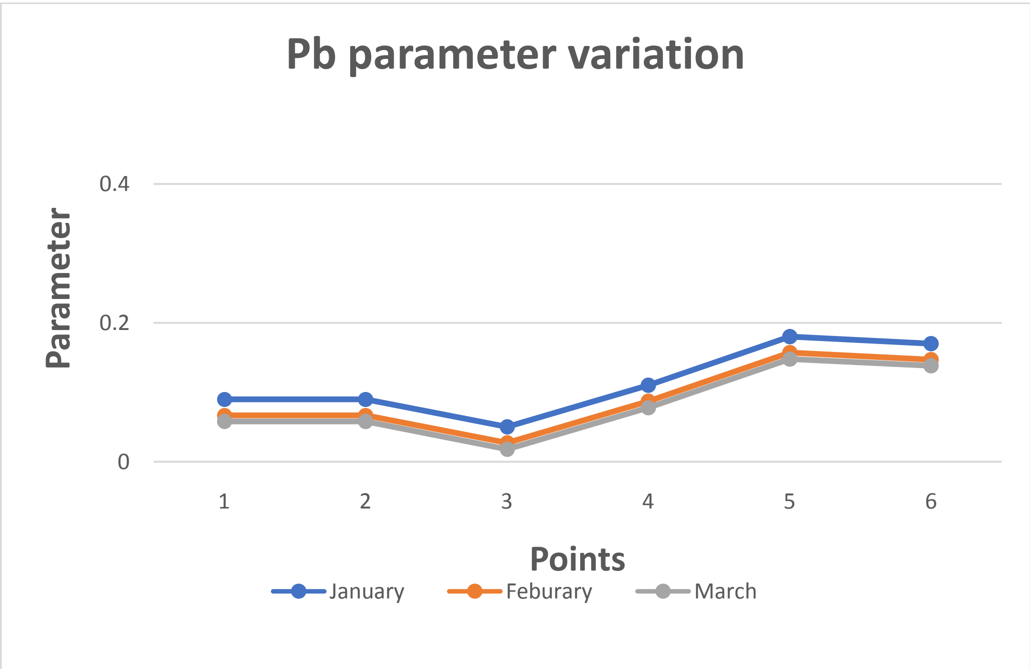

Figure 3.1: Comparative plots of water quality parameters

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5. **Dissolved Oxygen (DO):**
   - There was a noticeable variation in DO levels between January and March at most points, with some points showing decreases.
   - Points with higher anthropogenic activities tended to show lower DO levels, especially in March, indicating potential oxygen depletion due to pollution.

6. **Chemical Oxygen Demand (COD):**
   - Generally, there was a decrease in COD levels from January to March at most points, suggesting a potential reduction in organic pollutant levels.
   - Points with higher anthropogenic activities consistently exhibited higher COD levels, especially in January and February, indicating potential pollution sources.

7. **Sodium (Na):**
   - Points 1-4 generally exhibited lower Na levels compared to Points 5 and 6, suggesting fewer anthropogenic influences.
   - Points 5 and 6 consistently showed significantly higher Na levels throughout the months, likely due to anthropogenic activities.

8. **Biological Oxygen Demand (BOD):**
   - Points 1-4 generally exhibited relatively stable BOD levels, while Points 5 and 6 consistently demonstrated higher BOD levels, indicating higher organic pollutant influx.

9. **Iron (Fe):**
   - Points 1-3 generally showed relatively consistent Fe levels, while Points 4-6 consistently exhibited higher Fe levels, suggesting different sources of contamination.

10. **Calcium (Ca):**
   - Points 1-4 generally exhibited relatively consistent Ca levels, while Points 5 and 6 consistently showed higher Ca levels, likely from geological or anthropogenic sources.

11. **Lead (Pb):**
   - Points 1-3 generally exhibited relatively consistent Pb levels, while Points 4-6 consistently demonstrated higher Pb levels, indicating potential industrial or anthropogenic inputs.

3.2 Analysis of variance

The two-way analysis of variance (ANOVA) conducted to assess water quality variations based on both months and points along the New Calabar River provides valuable insights into the spatial-temporal dynamics of various parameters. Here's a summary of the ANOVA results:

3.2.1 Month-wise ANOVA

1. Water Temperature and pH: Significant differences were observed between months for water temperature and pH levels, indicating substantial variations over the study period influenced by seasonal changes and environmental factors.
2. Total Dissolved Solids (TDS) and Electrical Conductivity (EC): TDS and EC did not show significant differences between months, suggesting relatively stable concentrations and conductivity over the sampled months.
3. Other Parameters (DO, COD, Na, BOD, Fe, Ca, Pb): These parameters did not exhibit significant differences between months, except for BOD, which showed a trend towards significance. This indicates that these parameters maintained relatively consistent levels over the study period, with minor variations in BOD that could be further investigated.

3.2.2 Point-wise ANOVA

1. Water Temperature: Significant differences were observed across the sampled points, indicating spatial variability influenced by factors such as pollution sources, flow dynamics, and local conditions.
2. TDS, EC, Na, BOD, Fe, Ca, Pb: These parameters showed significant differences between points, suggesting spatial variations in water quality influenced by different sources or activities at each point.
3. Other Parameters (pH, DO, COD): These parameters did not exhibit significant differences between points, indicating relatively uniform levels across the sampled points.

3.3 Water quality index

Table 3.2 presents individual WQI values calculated for each sampling point along the New Calabar River. The WQI values are derived from a comprehensive assessment of various water quality parameters such as pH, temperature, dissolved oxygen, total dissolved solids, and pollutants. By providing point-specific WQI values, this table offers insights into localized water quality conditions at specific locations along the river.

International Journal of Advances in Engineering and Management (IJAEM)
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The Water Quality Index (WQI) values on table 3.2 for each sampling point was compared with the WHO standard

- Point 1: WQI = 698.88 (Very bad)
- Point 2: WQI = 700.93 (Very bad)
- Point 3: WQI = 315.89 (Bad)
- Point 4: WQI = 905.16 (Very bad)
- Point 5: WQI = 1623.48 (Very bad)
- Point 6: WQI = 1539.46 (Very bad)

Table 3.2: Water Quality Index for the six points

Points	WQI
1	698.88
2	700.93
3	315.89
4	905.16
5	1623.48
6	1539.46

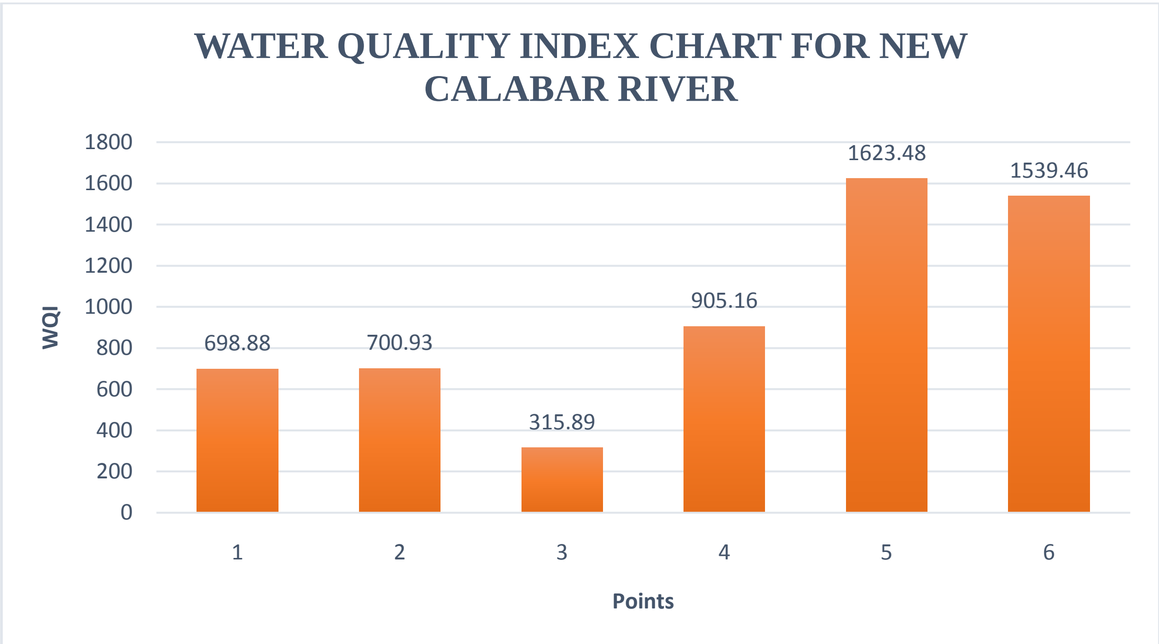

Figure 3.2: Water Quality Index for the various points on the New Calabar River

The analysis from Figure 3.2 paints a concerning picture of water quality degradation along the New Calabar River, with several points exhibiting very poor water quality status. Here's a breakdown of the observations:

- **Points 1 and 2:** These points show "Very bad" water quality, likely influenced by various anthropogenic activities such as urban runoff and agricultural practices. Proximity to urban areas may contribute to elevated pollutant levels, leading to this classification.
- **Point 3:** Located under the Choba bridge, this point indicates "Bad" water quality. The lower WQI value suggests relatively poorer water quality compared to other points, possibly due to localized pollution sources like runoff from nearby roads, waste disposal, or direct anthropogenic activities along the riverbank.
- **Point 4:** Exhibits "Very bad" water quality status, indicating significant pollution or environmental stressors such as industrial effluents, agricultural runoff, or contamination from nearby urban areas.
- **Points 5 and 6:** Close to the Choba market and an abattoir, these points also show "Very bad" water quality. Potential sources of pollution from agricultural activities, waste disposal, and runoff carrying organic matter

International Journal of Advances in Engineering and Management (IJAEM)
Volume 6, Issue 09 Sep. 2024, pp: 518-533 www.ijaem.net ISSN: 2395-5252

and contaminants contribute to the elevated WQI values at these points.

The overall Water Quality Index (WQI) for the New Calabar River, calculated at approximately 5783.80, indicates a very poor water quality status. This comprehensive index considers the individual WQI values at different sampling points along the river, reflecting the collective impact of various pollution sources and environmental stressors.

Major contributors to this poor water quality include industrial discharge, urban runoff, agricultural activities, improper waste management, and contamination from nearby anthropogenic sources such as markets and abattoirs.

Such a high overall WQI value underscores severe pollution challenges facing the New Calabar River, posing risks to aquatic life, human health, and ecosystem integrity. The river may not meet the standards required for safe water use, especially for drinking, recreational activities, or sustaining aquatic habitats. Urgent measures are needed to address these pollution sources and restore the health of the river ecosystem.

IV. CONCLUSION

The comprehensive study of the New Calabar River has provided valuable insights into the complex dynamics of water quality, guided by specific objectives aimed at understanding and addressing environmental challenges. Here are the key discoveries that have emerged from our research:

Through stringent data analysis, significant seasonal fluctuations in key water quality parameterswas observed. Temperature variations ranging from 28.2°C to 30.24°C and pH levels fluctuating from 4.77 to 5.83 underscore the dynamic response of aquatic ecosystems to seasonal influences, including weather patterns and human activities.

Utilizing techniques such as Analysis of Variance (ANOVA), uncovered substantial differences in water quality metrics between months. Total Dissolved Solids (TDS) and Electrical Conductivity (EC) exhibited wide ranges, reflecting varying pollutant concentrations influenced by seasonal activities and land use changes.

Calculated WQI values provided a comprehensive assessment of overall water quality status, ranging from 315.89 (medium quality) to 1623.48 (very bad quality). These values offer a nuanced understanding of the diverse water quality conditions experienced along the river and serve as a basis for prioritizing remedial actions.

The study underscores the multifaceted nature of water quality dynamics in the New Calabar River and provides a foundation for informed decision-making and targeted interventions aimed at preserving and restoring the health of this vital aquatic ecosystem. By addressing the identified sources of pollution and implementing effective management strategies, working towards ensuring the sustainability and resilience of the New Calabar River for future generations.

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