WATER QUALITY EVALUATION OF AMAGBA-OKOROMA RIVER, AMAGBA, AND OKOROMA COMMUNITY, BENIN CITY, EDO STATE, NIGERIA

BY

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BENIN CITY

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A PROJECT SUBMITTED TO THE DEPARTMENT OF ANIMAL AND ENVIRONMENTAL BIOLOGY, IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE AWARD OF BACHELOR OF SCIENCE DEGREE (BSc. HONS) IN ANIMAL AND ENVIRONMENTAL BIOLOGY, OF THE UNIVERSITY OF BENIN, BENIN CITY.

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CERTIFICATION

We certify that this project was done by **Uche AWOKE** with the matriculation number **LSC1806089** in the Department of Animal and Environmental Biology, University of Benin, Benin city, Nigeria.

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EXTERNAL EXAMINER **DATE**

DEDICATION

This project work is dedicated to the God Almighty for giving me the knowledge and guidance to carry this work.

ACKNOWLEDGEMENT

I wish to specially acknowledge God almighty for the strength he gave to me to complete this course and report. I want to also thank my Supervisor Dr. S.O. Ikhuoriah for dedicating his time and effort in teaching and directing me throughout this project.

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I want to specially thank my parents Mr & Mrs Awoke for their support and love to me throughout this journey and to my siblings Emi Osunbor, Ngozi Awoke and Ebuka Awoke for their words of encouragement.

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ABSTRACT

River systems are valuable to human beings; meanwhile, they are intensively influenced by human activities. especially urbanization. In this study, we evaluated water quality of Amagba-Okoroma River, Benin City using analysis of water physico-chemical parameters recorded seasonally from March to April 2023 (dry season) and June and July 2023 (rainy season). Three sampling sites were selected along the course of the river from upstream (site 1) to downstream (site 3) associated with various anthropogenic activities. Water samples were collected and anlysed using standard procedure. Of the 21 water physico-chemical parameters anlysed, 5 parameters namely, turbidity (15.5 NTU), pH (5.4), Cr (0.15 mg/L), Cu (0.34 mg/L) and Zn (0.66 mg/L) exceeded the stipulated Nigerian Industrial Standard (NIS) guidelines. The result revealed that 3 parameters, namely, air temperature, water depth, and transparency showed significant spatial variation across the three sites. Additionally, statistically significant seasonal variation was observed in 2 parameters in dry and rainy season namely, nitrate-nitrogen and sulphate. Water quality index (WQI) results reveal that water samples from each site were rated to be of excellent water quality, however, site 1 upstream had the best quality followed by site 2 and site 3 respectively. To preserve this water resource against pollution, the implementation of stringent guidelines as well as routine biomonitoring are needed to enhance its health status.

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CHAPTER ONE

1.0 INTRODUCTION

1.1 Background of Study

Water is an essential resource for all life forms, and its quality directly affects the well-being of both humans and the environment. Evaluating the parameters that determine water quality is crucial in understanding the overall health and suitability of a water body for various purposes. This project focuses on the evaluation of a river. Water is of crucial importance to the environment, but then ground and surface water have been deteriorating because of human activities. Natural factors that influence water quality are hydrological, atmospheric, climatic, topographical and lithological factors (Magesh *et al.,* 2013; Uddin *et al.,* 2018). Human activities that affect water quality are farming, mining, waste disposal (industrial and agricultural waste), run-off from soil and heavy metal pollution (Sanchez *et al.,* 2017).

Water is one of the most important components for life on earth, the quality of any surface water body is influenced by both natural and human activities. In as much as the earth's surface is covered with water, only a small portion of it is usable thus, one can say it is a limited resource (Roy *et al.,* 2019). Water is needed for different purposes, the quality of it must be checked before use, also health status of it should be checked regularly. Poor water quality is not only a sign of environmental degradation but also affects the ecosystem, thus water quality analysis is important to humans and also to the environment.

Groundwater and surface water which includes river, streams and atmospheric water which includes rain are the main source of water available to humans generally. The quality of these water depends on the environmental activities surrounding it. The main source of groundwater is rainfall which flows through soil, the analyzing of ground water quality for its physical and chemical properties is very important in health studies. The groundwater contains dissolved solids and has physical characteristics which includes taste, odor and temperature.

The proportion of freshwater on the surface of the earth is about 2.5% in which only 1% is accessible for use. Lakes are one of the most important resources of water which is used as a source of water available for human use accounts for 0.3% of the total surface body sources, the status of lakes has deteriorated due to a constant increase of human activities surrounding it.

Water is a vital component of the earth surface which occupies about three quarters of it and it occurs on land, underground. Without water, life would not be possible on earth, it makes up about 90% of the cell and acts as a medium for transport of body nutrients. The human body needs water for survival and to stay healthy, without it the human body will get dehydrated, water helps to regulate body temperature. In developing countries, thousands of children under five years die every day due to drinking contaminated water (WHO, 2004). Water borne diseases affect around 250 million each year resulting in 10-20 million deaths worldwide. An estimated 80% of an illness in developing countries is related to water and sanitation and 15% of all child deaths under the age of five years in developing countries results from diarrhea diseases (WHO, 2004).

This project focuses on the water quality parameters in Amagba-Okoroma River, located in Amagba community of Edo State, Nigeria. Amagba-Okoroma River River plays a vital role in supporting the livelihoods of local community, serves as a source of drinking water, washing and other human activities. However, these continuous human activities have brought concerns about its impact on the river and how it is affecting its quality. The evaluation of water quality will provide information about the current state of the quality of the river. This project aims to assess key physico-chemical parameters such as pH, temperature, total dissolved solids, dissolved oxygen, biochemical oxygen demand, flow rate, transparency, electrical conductivity. Understanding these parameters will help in assessing the ecological state of the river and provide information about its health status and to know if its safe for human use and consumption.

Water quality analysis consists of some certain standard protocols, procedures for collection and sampling, preservation and analyzing of the samples.

1.2 Justification of Study

The importance of clean water to human health cannot be overemphasized (Mandalam *et al*., 2009). Rivers, lake, ponds, streams etc. are important water bodies of every country, and it can be inferred that the long-term development of every country is dependent on the water quality of that country's water bodies. Knowing the quality of water in the various water bodies is therefore important as it helps legislative bodies in taking the relevant steps towards the sustainable usage of the water bodies. The Amagba-Okoroma River plays a vital role in supporting the livelihoods of the people of Amagba-Okoroma community, Ikpoba-Okha LGA, Edo State, Nigeria, serving as a source of drinking water, irrigation and other activities. This therefore gives rise a need to assess the water quality of the river to ensure effective river management.

1.3 Aim and Objectives of Study

The aim of this study is to determine the current water quality of the River, Amagba- Okoroma community, Benin City, Edo State, Nigeria.

The objectives of this study were;

I) Obtain quantitative information on the physico-chemical characteristics of the river through sampling.

II) determine the seasonal and spatial variation of the physico-chemical parameters of the river;

III) assess water quality in the selected sites using Water Quality Index (WQI).

CHAPTER TWO

LITERATURE REVIEW

2.1 Water Quality

Water quality of a water body is always changing due to the influence of climatic conditions, different seasons, disposing of waste into it, run-off from soil, agricultural and industrial production etc. These activities can affect the physico-chemical properties of the water body and can lead to pollution.

2.1.1 Overview of Previous Studies on Water Quality.

Many assessments have been carried out on water quality across different water bodies in Nigeria which helps to promote understanding on issues focusing around it and how the issue can be resolved.

Moshood (2008) carried out an assessment of the water quality of Oyun reservoir, Offa, Kwara State, Nigeria. Three stations were chosen in the reservoir to determine the influence of human activities. The physicochemical parameters were analyzed within a period of two years using standard method and procedures It was reported that eutrophication was pronounced at station 1because of the impact of human activities. The study concludes that the Oyun reservoir has excellent water quality, high ecological status and passes chemical status. Eutrophication which was noticed was said that it should be treated quickly through denitrification and nutrient control in order to prevent degradation of the water quality.

Amadi *et al.,* (2010) carried out an assessment of the Water Quality Index of Otamiri and Oramiriukwa Rivers in Minna Nigeria. The study used the application of the Water Quality

Index in evaluating the quality of the rivers for public usage. The study was done by collecting 180 samples and carrying out comprehensive physical, chemical, and bacteriological analysis using APHA standard methods of analysis. The overall WQI for the samples was 174.49. The high concentration of conductivity, color, total solids turbidity, total coliform, iron, manganese, COD, BOD and nitrate which may be caused by the anthropogenic activities along the river bank. The result of the analysis when compared with the Nigerian Standard for Drinking Water Quality (NSDWQ) permissible limit showed that the rivers were polluted and considered not safe for domestic use and would need treatment.

Yisa. and Jimoh (2010) carried an assessment of the Water Quality Index of River Landzu, Minna, Niger State, Nigeria. The study aimed at evaluating the water quality of the river for public usage using the application of the WQI. It as done by subjecting the 120 water samples collected to comprehensive analysis using the APHA standard method. The WQI result for the samples was 171.85, it was said that high value of the WQI was as a result of higher values iron, chromium and manganese, COD and turbidity. The result was compared with the WHO and NIS permissible limit and it was given that the river is polluted and not safe for domestic use and would need further treatment.

Assessment of Okpauku River in Cross River State, Nigeria was done by Ahpan-Idiok *et al.,* (2012). to determine its water quality for drinking and irrigation uses. Water samples were collected from seventeen different locations along the river and were analyzed for various water quality parameters following standard given by American Public Health Association/American Water Works Association/Water Environment Federation (APHA/AWWA/WEF). The result revealed that water quality parameters showed significant variations among the different locations except for ammonia-nitrogen and iron. It was given that the physicochemical parameters of the river at the different locations were below WHO and FAO limits for drinking and irrigation water uses except for temperature, turbidity and pH. It was also reported that the mean concentrations of major ions, nutrients and heavy metals in all locations were low when compared to acceptable standards for drinking water (WHO) except for ammonia-nitrogen and iron in location 2, but fall within the allowable for irrigation (FAO). It was said that the river water may be regarded as a suitable source of water, irrigation and other domestic uses. They recommended that a dam could be constructed across to river in order to subject it to treatment processes to reduce turbidity to meet the required standard before use.

An assessment of the water quality of river Asa, Ilorin, Nigeria was carried by Ahaneku. (2013). The aim of the study was to assess some physicochemical parameters of the Asa river in a form that can be easily understood. The CCME WQI was applied on the results of the parameters to get a single value which was used to rank the river at each of the four sampling site. The results which were 41.3, 42.3, 43.6, and 52.9 showed that three of the four sampling sites were ranked as poor while the last one ranked as marginal. The conclusion given was that the river failed the Drinking Water Quality Index and so not suitable for drinking.

The water quality assessment of the Siluko River, Edo State, Nigeria was carried by Oboh, I.P and Agbala, C.S in 2017. The water quality of the river was assessed within a period of March to August to determine its its suitability and domestic purposes. Water samples were collected from three sampling sites and a total of thirteen parameters were analyzed using standard analytical procedures. They reported that temperature, phosphate and chloride were significantly different across all three stations and that all the other parameters except turbidity, dissolved oxygen and phosphate were within the permissible limit recommended by NSDWQ. The result of the values of Water Quality Index ranged from 11.24 t0 16.15 indicating excellent water quality. They recommended that regulatory authorities monitor effluents discharged into river from human activities.

Oluwafisayo *et al.,* (2017). carried an assessment of the Water Quality of Saba River, Osogbo, Nigeria in The aim of this study was to assess the water quality and concentrations of heavy metals in the river. Three sampling sites were selected across the river. It was reported that the DO level within the period of march and April in all sampling the sampling points were in the limit of putting aquatic life under stress. It was also reported that alkalinity level in station B between February and June and in station C from February till May were above the maximum allowable desirable range of EPA (2001) and WHO (2011). The study concluded that the physicochemical indices of the water quality indicated that the water is slightly polluted.

Enuneku, *et al.* (2017) carried out a study to assess the water quality of Obueyinomo River of Ovia North East, Edo State Nigeria. A total of sixteen (16) physicochemical parameters were analyzed using the standard techniques. With the exception of DO, the other physicochemical parameters showed no significant difference ($p > 0.5$) across the stations. Distribution patterns of physicochemical parameters in stations 1, 2, 3 were analyzed using PCA. There was a strong association for stations 1, 2, 3 which was also highly associated with nitrates. Hardness, magnesium, calcium and phosphate formed a cluster showing the contributions of there ions to water hardness. Alkalinity, suspended solids and chloride formed a cluster suggesting that the suspended solids are largely composed of chlorides. Turbidity, pH, BOD and DO at all the stations exceeded the Federal Ministry of Environment standards for surface water. The water quality index (WQI) values at station 1 was given 138.45, while station 2 was given 122.70 and station 3 was 170.01. The parameters responsible for the high WQI values as indicated by the water quality rating include turbidity, pH, DO and BOD. The high WQI values in all the stations which exceeded the benchmark of 100 showed that the water from the river is unfit for drinking purposes and should be treated before consumption.

Nkonyeasua and Clarence (2018). assessed the water quality of the Okhuaihe River, Edo State, Nigeria was investigated from February to June 2016 to determine its suitability for drinking and other domestic purposes. Water samples collected from three stations were tested for fifteen physicochemical parameters using standard analytical procedures. Biochemical oxygen demand and sodium were significantly different across three stations. Except for calcium and iron, all other parameters were within the permissible limits recommended by the Nigerian Standard for Drinking Water Quality (NSDWQ) and World Health Organization (WHO). Water Quality Index (WQI) values ranged from 9.17-10.40 indicating excellent water quality. Although the quality of the water from the Okhuaihe River is suitable for drinking and domestic use, regular monitoring of human activities along the river front and control of effluent discharged into the river is recommended to sustain and improve water quality.

An assessment of the Oji River in Enugu State, Nigeria was carried out by Uzochukwu *et al.,* (2019). The study measured the physicochemical parameters and heavy metals concentration of the Oji River. The results revealed that the WQI of the river at the various sampling sites varied from 241-280 during the rainy season which indicates poor quality and unsuitable for drinking, while during the dry season, it ranged between 68-946 indicating good and 'unsuitable' for drinking. It was reported that it was only the location downstream the power Station during the dry season that was ranked good.

Ali *et al.,* (2019) worked on the assessment of some chemical contaminant in River Kaduna, Nigeria. The study assessed the contamination of river Kaduna by some chemical properties (Zn, Pb, Cu, Cd, Cr, Mn, Ni, Fe, TDS, EC, DO, pH and turbidity) on a monthly basis for a period of three months. Atomic Absorption Spectroscopy (AAS) technique was used to assess the concentration of the parameters in surface water samples from the section of the River Kaduna that traversed through Kaduna metropolis. The results shows that there is spatial variation of these contaminants between the upper, middle and lower regions of the river. The results also shows that Cd, Pd, Cr, Mn, Fe, and turbidity have higher concentrations above the WHO and NIS permissible limits, indicating that the river is getting polluted with these chemical properties and pointing to the existence of risks to public health. The result furthers shows that some of the contaminants are released from human activities such as industrial effluents, sewage input, pesticide and fertilizer usage among others. The study concludes that the river is becoming polluted due to increased human activities within the catchment area. The study recommends that authorities should take proactive control measures to protect the river and its potential for domestic water supply and irrigation, there is also need to be conscious of human activities that can result in the release of heavy metals inti the river.

Kalabgo *et al.,* (2020) carried an assessment of Ntawogba stream in Port Harcourt, River State, Nigeria. The analysis was carried out for three consecutive months across three sampling points (upstream, midstream and downstream). Physical parameters were determined using the standard analytical APHA method, spectroscopic analysis were carried out for nine heavy metals using AAS. It was reported that the stream is highly polluted and this problem should be treated urgently.

Nkonyeasua and Oboh (2021) carried out the assessment of the water quality of the Ikpoba reservoir Benin City, Nigeria was evaluated using various approaches to determine its suitability for human consumption and pollution status. Water sampling was carried out from February 2018 to January 2019, and fifteen (15) water quality indicators were determined using standard analytical procedures. All physicochemical parameters with the exception of water temperature, pH, dissolved oxygen, biochemical oxygen demand, turbidity, iron, copper, lead, and cadmium were within their permissible limits recommended by the NSDWQ and FMEnv. (2007). Water quality index value of 207.37 (WQI > 50) indicates that the water is unsuitable for drinking and other domestic purposes. The comprehensive Pollution Index value of 4.16 (CPI > 2.01) for Ikpoba reservoir indicates that the freshwater body is severely polluted, with turbidity, lead, iron, and cadmium identified as contributing significantly to the water pollution. Natural runoff and human activities within the area were identified sources of pollutants. The study provided updated valuable information for water quality monitoring, pollution control strategies and water resource management of the Ikpoba reservoir.

Sadiq *et al.,* (2022) studied the water quality of Kaduna River using the Canadian Council of Ministers the Environment (CCME) Water Quality Index. The study was done during both the rainy and dry season in 10 different sampling sites. Water parameters analyzed were turbidity, dissolved oxygen, pH, electrical conductivity, TDS, Zn, Pb, Cd, Cr, Cu, Mn, Fe, and Ni using standard laboratory techniques. The data obtained were used to develop Water Quality Index across the 10 sampling sites. The WQI result shows that the water quality at Barnawa, Kudenda, Tudun Wada, Makera and Anguwn Muazu were of poor quality as their index values ranged between 31.8-42 while the rest locations which include Kawo, Anguwn Dosa, Malali, Kigo, Anguwn Rimi were marginal as their index ranged were between 45-61.3. It was recommended that pollution be controlled at the source.

2.2 Water Quality Indices

Water quality indices (WQI) is one of the most important components in evaluating water quality it basis on physical, chemical, and biological factors that aggregate to form a single value which reduces a huge data collection into a simple and easy expression and it involves four processes. The primary aim of WQI is to present a single value for water quality by converting data and its concentration into a unique number making it easy to compare different samples on their quality based on each samples index value which usually ranges from 0-100. These values indicate the quality of the water based on defined limits. Globally, the WQI has been applied to evaluate the quality of surface and groundwater, since it was developed in the 1960s, it has become a popular tool because of its structure and easy use. The WQI model involves four processes which include; (1) Selection of water quality parameters, (2) Generation of sub-indices for each parameter, (3) Calculation of the parameter weighing values, and (4) Aggregation of sub-indices to compute the overall water quality index.

2.2.1 Brief History of WQI Development

WQI models has been developed over the last 50years, it was being used for classification of water quality as far back in the mid-1800s (Abbasi and Abbasi, 2012). Horton developed the first WQI models in the 1960s which he based on 10 water quality parameters significant in most water bodies (*Horton, 1965*). Brown with support of National Sanitation Foundation, developed a more rigorous version of Horton's WQI model, the NSF-WQI, for which a panel of 412 water quality experts informed the parameters selection and weighing (Abbasi and Abbasi, 2012). Several other WQI models have been based on the NSF-WQI. In 1973, the Scottish Resource Development Department (SRDD) developed the SRDD-WQI which was sort of based on Brown's model and used it for assessment of river quality. The Bascaron Index (1979), House Index (1986) and Dalmatian Index (*Stambuk-Giljanovic,* 2003) are all later derivatives of the SRDD-WQI. (Steinhart *et al* 1982) later developed the Environmental Quality Index model for the assessment of water quality in the Great Lakes ecosystem.

Another important development was the British Columbia WQI (BCWQI) which was developed by the British Columbia Ministry for Environment, Lands and Parks in the mid-90s and was used to evaluate the quality status of many waterbodies in the province of British Columbia, Canada (Saffran *et al.,* 2001). (Said *et al.,* 2004) noted that the BCWQI was found to have the highest sensitivity to sampling design and the highest dependency on the specific application of water quality objectives. The Water Quality Guidelines Task Group of the Canadian Council of Ministers of the Environment developed the CCME WQI in 2001 (Saffran *et al*., 2001) following a review of the BCWQI model (Lumb *et al*., 2011). The BCWQI model has been recognized sinve 1990 by the CCME (Dunn *et al*., 1995). In recent times, models such as the Liou Index, the Malaysian Index and the Almeida Index have also been developed. More than 35 models WQI models have been introduced by the countries and agencies to evaluate surface water quality around the world.

2.3 Water Quality Standard

Water Quality Standard are provisions of state, territorial, authorized tribal or federal law approved by Environmental Protection Agency (EPA) that describes the desired condition of a water body and the means by which that condition will be protected or achieved. Water bodies are used for various different purposes such as domestic usage, swimming, and are home to aquatic lives. In order to protect human health and these aquatic lives, states, territories and authorized bodies established Water Quality Standard (WQS). WQS forms the basis for controlling acceptable quality of water suitable for different purposes. WQS is developed to help protect and maintain water quality necessary to meet and maintain designated use.

CHAPTER THREE

3.0 MATERIALS AND METHOD

3.1 Description of Study Area

The study was conducted in Amagba-Okoroma community, Ikpoba-Okha LGA of Edo State, Nigeria. Amagba is found in the urban area, the landscape is dotted with farmlands, forest and rivers, the climate in this community is basically tropical having dry and wet season. The River plays a vital role in supporting the livelihoods of the local community, serving as a source of drinking water, irrigation and other activities.

3.1.1 Climatic Condition

The climatic condition of the sampling area is tropical with two different seasons; the dry and wet season. The dry seasons ranges from November to April while the wet seasons ranges from May to October. The rainy season starts fully in June all through to July with a break period in August and resuming fully again in September. Little rainfall is experienced in January and February.

3.1.2 Human Activities

The human activities observed around the river include; bathing, washing of cars, disposing of wastes including plastics, washing of clothes, cattle grazing, fetching for domestic usage. etc

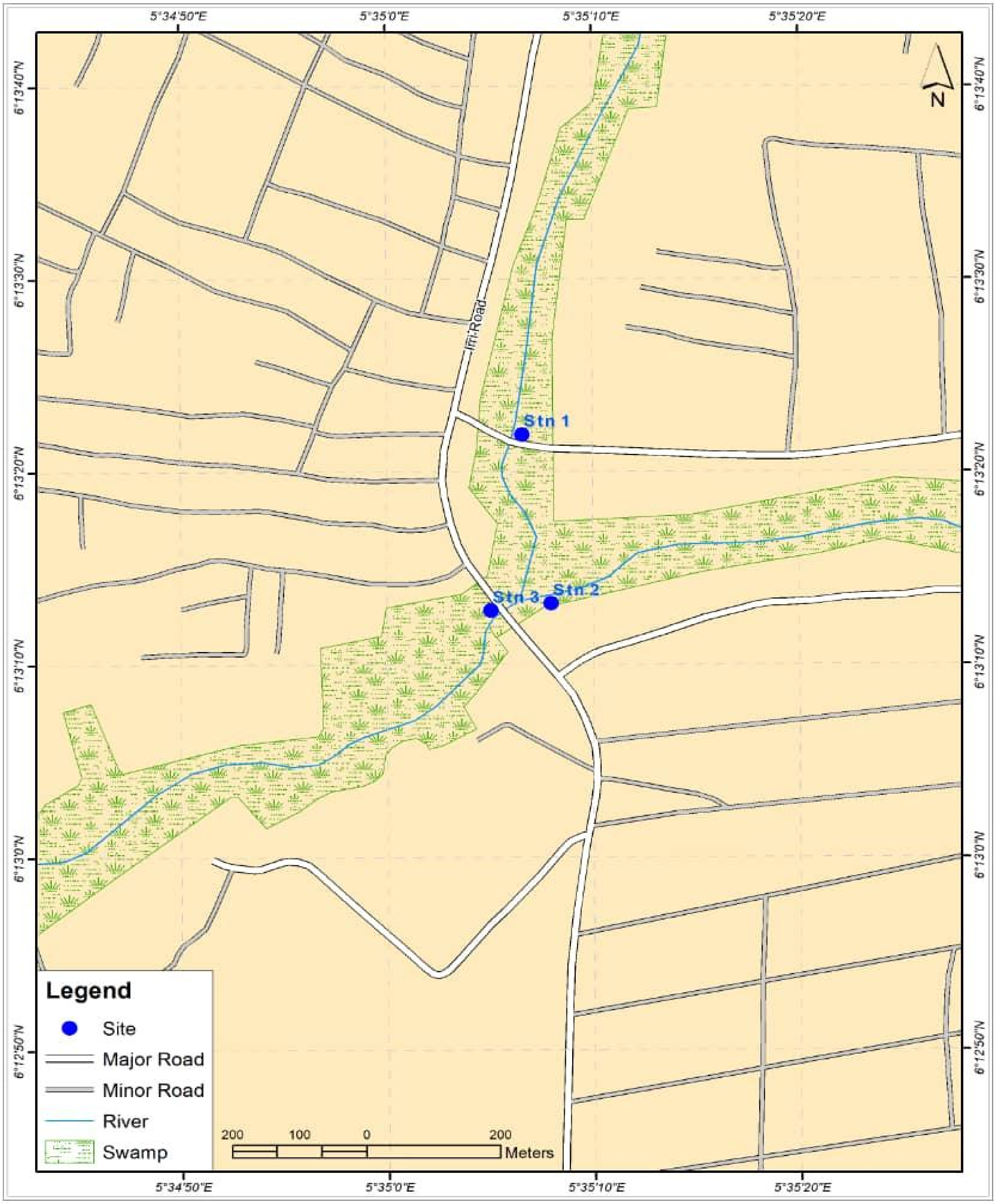

Figure 1: Map of Study Area Showing the Sampling Sites

3.2 Sampling Sites

Three sampling sites were used for the analysis of the water across the rivers found in the community from site 1 (upstream) to site 3 (downstream).

3.2.1 Site 1

This site is located close to a bridge, it lies between latitude 06`27.1990'N and longitude 005`36.5665'E. The river is shallow having an approximate width of 8.5m and the depth varied from 0.34m-0.5m. Grasses are seen along the river sides. The river having a flow velocity ranging from 0.01m/s -0.133m/s from the dry season to the wet season. The bottom of the river is made up of sediment in which samples of the sediment were also collected. Human activities seen include washing, bathing etc.

3.2.2 Site 2

This site is located in an open area. It is located at quite a distance from site 1. It lies between latitude 06`27.oo85'N and longitude 005`36'6764'E. The site 2 river is wider that that of the site having an approximate width of 10m. The river is shallow, depth ranging between 0.48m-0.6m from the different sampling periods. The river is linked to a bridge and have a flow velocity which ranged from 0.02m/s-0.07m/s. Human activities seen in this site includes washing of cars etc.

Plate 3.1: Site 1

Plate 3.2: Site 2

3.2.3 Site 3

This site is located at the opposite side of the bridge of site 2. It has a latitude of 06`26.8226'N and a longitude of 005`36.7597'E. This site 3 river is not very wide have an approximate width of 9.3m. The river is shallow having a flow velocity ranging from 0.03m/s-0.2m/s. This river is surrounded by much more vegetation and it is more polluted. Plastic pollution were seen towards an area in the river (Plate 3.4). Human activities seen here include cattle grazing.

Plate 3.3: Site 3

Plate 3.4: Plastic Pollution seen in site 3

3.3 Sampling Period

Water samples were collected seasonally during the dry and wet season. The first two collection was done in the month of March and one sampling collection was done in April for the dry season, two sampling collection was done in June and the last collection was done in the month of July for the wet season. Collection was done at the three sampling sites and *in-situ* parameters like temperature, pH, TDS, depth, flow rate, and electrical conductivity were carried out and analyzed at the sites immediately, while samples for *ex-situ* analysis which include DO, BOD, phosphate, calcium, nitrate were collected and transported to the laboratory for analysis

3.3.1 Collection of Samples

Water samples for physico-chemical parameters were collected using a 75ml plastic bottle which was selected, washed, dried and labeled properly. Water sample collection was done by immersing the bottle into the river, filling the plastic with water and then it was covered and kept aside before transporting to the laboratory for analysis.

Dissolved Oxygen (DO) was collected using 250ml transparent bottle. The bottle was first rinsed with river water before immersing it into the river to fill and was covered under the river water to avoid gas bubbles. The DO sample was then fixed with Winkler A solution which is manganese (II) sulfate (MnSO4) and Winkler B solution of potassium hydroxide and potassium iodide (KOH and KI). This process traps in oxygen and a brown precipitate is formed.

Biochemical Oxygen Demand (BOD) was collected using a 250ml amber glass bottle. The bottle was rinsed with the river water before immersing in the river to fill and was covered under the water to prevent atmospheric air entering the sample. The BOD sample was not fixed with any

Winkler solution, it was wrapped in a black nylon bag to prevent sunlight and transported to the laboratory for analysis.

3.3.2 Determination of *In-situ* Parameters

Some of the parameters to be evaluated were done in-situ and they include; air temperature, water temperature, depth, transparency, depth, flow rate, pH, total dissolved solid (TDS), electrical conductivity (EC), and width.

3.3.2.1 Air Temperature

The air temperature was determined using a mercury-in-glass thermometer. This was done by holding the thermometer in air for five minutes and then the reading from the thermometer was taken.

3.3.2.2 Water Temperature

Water temperature was also done using a mercury-in-glass thermometer. It was done by placing and holding the thermometer in the river for five minutes and then take the thermometer reading.

3.3.2.3 pH (Hydrogen Ion Concentration)

The pH was determined using a pH meter. This was done by taking the pH meter and immersing it in a bucket of the river water, the pH meter is held slightly bent in the water sample for some minutes until a stabilized reading is displayed on the pH meter. Then the reading is recoded.

3.3.2.4 Transparency

The transparency of the river was determined using a secchi disc. The secchi disc was slowly and gradually placed in the river. The point between were the secchi disc disappeared from sight and reappeared was marked and both points were measured using a measuring tape. The two points were added together and divided by 2 to give the transparency value which was then recorded.

3.3.2.5 Water depth

Water depth was measured using a secchi disc which was immersed in the river, brought and the water level was measured using a measuring tape attached to the secchi disc. The depth level was taken at the middle of the river. Water depth is measured is meters (m).

3.3.2.6 Flow Rate

The flow rate was determined by placing a floatable material and in the river allowed to flow through a known distance for a certain period of time. The flow rate was then calculated by using the formulae; Flow velocity = distance/time taken.

3.3.2.7 Electrical conductivity

Electrical conductivity was done using the Hanna device. The device was placed in the water sample and held slightly bent and moved gently until a stabilized reading is displayed. The reading on the meter is taken, the value is then multiplied by 10 to give to you the electrical conductivity.

3.3.2.8 Total Dissolved Solid

The TDS was calculated from the EC value using the formulae;

Conductivity = 2 x TDS

3.3.2.9 Width

The width was measured using a measuring tape. It was done by holding the tape from each end across the river and the measurement was taken.

3.3.3 Determination of *Ex-situ* Parameters

Some other parameters that were determined ex-situ and they include; DO, BOD, phosphate, magnesium, calcium, sulphate, nitrate and heavy metals.

3.3.3.1 Dissolved Oxygen (DO) (mg/L)

The brown solid was dissolved by adding 2ml of H2SO4 and using a measuring cylinder, 100ml of the solution was measured and transferred into a conical flask. Afterwards, 1ml of starch solution indicator was introduced, resulting in a transformation of the sample's color to a dark blue shade. The burette was filled with sodium thiosulphate (Na2S2O3), and the initial volume was recorded. The sample was then titrated until a point where the color disappeared, indicating the endpoint. Finally, the final volume of sodium thiosulphate required for titration was noted.

3.3.3.2 Biochemical Oxygen Demand (BOD) (mg/L)

The given sample was stabilized by adding 1ml of a solution containing winker A and B. The resulting brown solid was dissolved by adding 2ml of H2SO4. Next, a measuring cylinder was utilized to accurately measure 100ml of the stabilized sample, which was then transferred into a conical flask. To indicate the presence of the sample, 1ml of starch solution was added, causing the color to change to dark blue. The burette was filled with sodium thiosulphate (Na2S2O3), and the initial value of the volume (titre) was recorded. The titration process was carried out until the sample turned colorless, and the final volume (titre) was noted.

3.3.3.3 Phosphate (mg/L)

Phosphate levels were assessed utilizing the ascorbic acid technique as described in the APHA (1998) guidelines. A 5ml portion of the sample was placed in a 50ml flask, followed by the addition of 1ml of ascorbic acid. Distilled water was added to bring the total volume of the sample to 25ml. After 30 minutes, the blue-colored sample was measured using a visible spectrophotometer (VS721G) at a wavelength of 660nm, according to the methodology outlined by Beauchemin and Berman (1989).

3.3.3.4 Nitrate (mg/L)

Using a measuring cylinder, 10ml of the sample was measured and transferred into a conical flask. Then, a syringe was used to add 1ml of bromocresol, and a measuring cylinder was used to add 10ml of sulphuric acid. The resulting solution was left undisturbed for 10 minutes. The visible spectrophotometer VS721G was adjusted to a wavelength between 460nm and 570nm, and before conducting the actual experiment with 3ml of the sample, it was calibrated using 3ml of distilled water.

3.3.3.5 Chloride (mg/L)

A measuring cylinder was employed to gauge 50ml of the specimen, which was subsequently transferred into a conical flask. Then, 1ml of K2CrO7 indicator was introduced. The burette was filled with silver nitrate, and the initial value of the burette reading was observed prior to the process of titration until an orange endpoint was reached. Finally, the concluding value of the burette reading was documented.

3.3.3.6 Sulphate (mg/L)

The device was activated and the cells were thoroughly rinsed with distilled water. Using a measuring cylinder, 25ml of purified water was measured and added to one cell. Additionally, 25ml of the sample was measured and mixed with a spoonful of Barium Chloride dihydrate salt using a spatula. Then, 1ml of conditioning reagent was added using a syringe, and the mixture was shaken until dissolved. Next, 25ml of the resulting mixture was poured into the second cell. The device was set to follow Standard Operating Procedure (SOP) 92, and the enter button was pressed. Subsequently, the meter was uncovered, exposing the cell holder, and the cells were wiped clean with a wiper to remove fingerprints and any spills. The cell containing 25ml of deionized water was inserted and covered, followed by pressing the zero button to establish a blank reference. The display screen indicated zero, and the same process was repeated for the 25ml sample, except this time the read button was pressed and the displayed reading was recorded.

3.3.3.7 Turbidity

To begin, turn on the meter and cleanse the cells using distilled water. Take 10ml of de-ionized water and pour it into one cell. Measure 10ml of the sample and pour it into the other cell. Set the meter to an SOP value of 95, then press the enter button. Remove the cover from the meter to expose the cell holder, and wipe the cells with a wiper to remove fingerprints and dry any spills. Place the cell containing 10ml of de-ionized water into the cell holder and cover it before pressing the zero button to establish a blank reading. Repeat the same process for the cell containing the 10ml sample, but this time press the read button. Record the displayed readings. Rinse the cells before using them again. The device was activated and the cells were thoroughly rinsed with distilled water. Using a measuring cylinder, 10ml of de-ionized water was measured and added to one cell. Similarly, 10ml of the sample was measured and added to the other cell. The device was then programmed to SOP 95 and the enter button was pressed. Next, the meter was uncovered, revealing the cell holder, and the cells were wiped clean to eliminate fingerprints and dry any spills. The cell containing 10ml of de-ionized water was placed in the holder, covered, and the zero button was pressed to establish a blank reference. The meter displayed zero, and the same procedure was repeated for the cell containing the 10ml sample, except this time the read button was pressed and the displayed reading was recorded.

3.3.3.8 Heavy Metal

The heavy metals that were examined included chromium, cadmium, copper, cobalt, manganese, nickel, zinc, and lead. To analyze these metals, a water sample was passed through a Whatman No. 42 filter paper and then adjusted to a volume of 50ml using distilled water. The sample was analyzed using a buck scientific atomic absorption spectrophotometer. The digestion process of the water sample was performed using an aluminum block digester 110. A 100ml portion of the sample was measured, and 4ml of perchloric acid, 20ml of concentrated nitric acid, and 2ml of concentrated tetraoxosulphate VI acid were added. The solution was digested and heated until white fumes were released and a clear solution was obtained. After cooling, the sample was transferred to a 100ml volumetric flask and made up to the mark with distilled water. The sample was thoroughly mixed and allowed to stand overnight instead of using a centrifuge to separate insoluble materials. Finally, the sample was filtered through a 0.45μ millipore type filter.

The metals of interest were measured using the Atomic Absorption Spectrophotometer (ASS) Solar 969 Unicam Series Model. Each metal had a specific hollow cathode lamp for its analysis.

The instrument was configured to the appropriate wavelength for each metal being analyzed. Distilled de-ionized water aspiration was carried out between each reading. The absorbance reading was determined by observing a stable galvanometer reading for approximately 1-2 minutes. The concentration of the metals was calculated using a standard calibration plot, as described by Beauchemin and Berman (1989).

3.4 Data Analysis

Inter-site comparisons namely descriptive statistics were conducted to assess notable differences in the physico-chemical characteristics of surface water. In doing this, One-way ANOVA was employed, followed by the post-hoc test to identify significant differences among the sites and pinpoint specific locations where these differences were observed. The One-way ANOVA analysis utilized SigmaPlot version 14.0 from Software, Inc. in San Jose, California, USA. Furthermore, a comparison of seasonal variation between the dry and wet season was performed using an unpaired t-Test with a significance level of $p < 0.05$. Other statistical calculations were carried out using Microsoft Office Excel 2019.

3.5 Water Quality Index

Water quality index is a valuable number that is used to give the overall information of a particular water body. In this study, the weighted arithmetic water quality index was applied. This method categorizes the water quality of aquatic systems based on the level of water body purity using frequently measured water parameters. The calculations follows a specific equation and was carried out as part of this study.

The Equation for calculating Water Quality Index is given below;

$$WQI = \sum QiWi / \sum Wi$$

The quality rating scale (Qi) for each parameter is calculated by using this expression:

$$Qi = 100[(Vi\text{-}Vo/Si\text{-}Vo)]$$

Where,

Vi is estimated concentration of nth parameter in the analyzed water

Vo is the ideal value of this parameter in pure water Vo = 0 (except pH =7.0 and DO = 14.6 mg/l)

Si is the recommended standard value of nth parameter

The unit weight (Wi) for each water quality Vo parameter is calculated by using the following formula: $Wi = K/Si$

Where; K = proportionality constant and can also be calculated by using the following equation:

$$K = 1/\sum(1/Si)$$

CHAPTER FOUR

RESULTS

4.1 PHYSICO-CHEMICAL CHARACTERISTICS OF THE WATER

Samples were collected in dry season (April) and wet season (June) 2023 and the results for the analysis carried out are given below in Table 4.1. The mean, standard deviation and other statistics which include minimum and maximum monthly values gotten are also given in Table 4.1.

Table 4.2 shows a correlation matrix of the surface water physico-chemical parameters in Amagba-Okoroma River during the study period.

Table 4.3 shows the seasonal variations values between the dry and wet season combined using the Unpaired T-test. The p-value for each of the parameters were also given.

Table 4.4, 4.5, and 4.6 shows the Water Quality Index (WQI) for Site 1, 2 and 3 respectively while Table 4.7 presents a summary of WQI results across the various sites.

Table 4.1 Summary of measured surface water physico-chemical parameters (n = 6) in Amagba-|Okoroma River during the study period.

Parameters	Site 1	Site 2	Site 3	P value	F value	Guideline
AT (°C)	**27.42AA±0.58** (26.5-28)	**27.7AA±1.0** (26-28.5)	**29.08BB± 0.66** (28-30)	**0.004**	8.027	Ambient
WT (°C)	25.67±0.41 (25-26)	26±0.55 (25-26.5)	26±0.32 (25.5-26.5)	0.335	1.176	Ambient
DP (m)	**0.42AA±0.071** (0.34-0.5)	**0.52AA±0.07** (0.44-0.6)	**0.67AB±0.06** (0.6-0.75)	**0.0001**	19.65	
FV (m/s)	0.125±0.096 (0.01-0.3)	0.055±0.03 0.02-0.09)	0.2±0.21 (0.3-0.5)	0.201	1.79	
Transp. (m)	**0.41AA±0.06** (0.34-0.5)	**0.52BB±0.07** (0.45-0.6)	**0.53CB±0.04** (0.5-0.6)	**0.003**	8.470	
DO (mg/L)	1.8±0.83 (0.5-2.8)	2.2±1.10 (0.8-3.4)	2.5±1.38 (1.2-4.8)	0.570	0.580	7.5
BOD_5 (mg/L)	2.57±1.91 (1-6.1)	2.68±0.59 (2-3.6)	3.07±0.93 (2.2-4.8)	0.778	0.254	6
EC (uS/cm)	20±8.94 (10-30)	11.67±4.08 (10-20)	11.67±4.08 (10-20)	0.050	3.670	1000
Turb. (NTU)	**15.33±4.32** (12-24)	**13.17±2.99** (8-17)	**18±13.14** (8-44)	**0.600**	**0.526**	**5**
TDS (mg/L)	10.4±4.65 (5.2-15.6)	6.07±2.12 (5.2-10.4)	6.07±2.12 (5.2-10.4)	0.050	3.670	500
pH	**5.52±0.26** (5.2-5.9)	**5.35±0.25** (4.9-5.6)	**5.35±0.21** (5.1-5.6)	**0.400**	**0.970**	**6.5-8.5**
NO_3-N (mg/L)	0.72±0.92 (0.01-2.35)	1.05±0.77 (0.06-1.9)	0.75±0.88 (0.04-2.1)	0.760	0.274	50
NH_4-N (mg/L)	0.12±0.02 (0.09-0.15)	0.09±0.07 (0.02-0.21)	0.05±0.06 (0.011-0.15)	0.190	1.830	2
PO_4 (mg/L)	0.17±0.10 (0.06-0.35)	0.11±0.05 (0.02-0.19)	0.13±0.013 (0.114-0.149)	0.224	1.655	3.5
SO_4 (mg/L)	11.77±5.76 (7.06-21.18)	14.12±2.88 (1-8)	6.67±1.21 (5-8)	0.169	2.002	
Cl (mg/L)	10.59± 3.87 (7.06-14. 12)	14.12±4.47 (7.06-14. 12)	3.866±4.47 (14. 12 -21.18)	0.133	2.317	200-250
Cd (mg/L)	BDL	BDL	BDL			0.003
Cr (mg/L)	**0.136±0.081** (0.065-0.228)	**0.173±0.036** (0.298-0.194)	**0.141±0.041** (0.071-0.183)	**0.67**	**0.53**	**0.05**
Cu (mg/L)	**0.347±0.025** (0.297-0.365)	**0.336±0.036** (0.298-0.396)	**0.335±0.019** (0.325-0.374)	**0.707**	**0.354**	**0.01**
Pb (mg/L)	0.008±0.004	0.003±0.004	0.004±0.005	0.154	2.121	0.01

Parameters	Site 1	Site 2	Site 3	P value	F value	Guideline
	(0.009-0.045)	(0-0.008)	(0-0.009)			
Zn (mg/L)	**0.683±0.083** (0.582-0.753)	**0.637±0.051** (0.574-0.698)	**0.651±0.038** (0.618-0.722)	**0.415**	**0.931**	**0.3**

NOTE: Values are mean ± SD; range in parenthesis**.** P and F values are indicated by ANOVA. Different superscript letters per variable across sites indicate significant differences ($p < 0.05$) revealed by Holm sidak post-hoc test. The same superscript letter between sites per variable indicates no significant differences ($p > 0.05$). NB: BDL means Below detectable limit

*Nigeria Industrial Guideline (NIS) 2015

*World Health Organisation (WHO) 2017

Table 4.2: Correlation matrix of the surface water physico-chemical parameters in Amagba-Okoroma River during the study period

	AT	*WT*	*DP*	*FV*	*Transp*	*DO*	*BOD5*	*EC*	*Turb*	*TDS*	*pH*	*NO3-N*	*NH4-N*	*PO4*	*SO4*	*Cl*	*Cr*	*Cu*	*Pb*	*Zn*
AT	1																			
WT	0.63	1.00																		
DP	**0.97**	**0.80**	1.00																	
FV	**0.79**	0.02	0.61	1.00																
Transp	0.69	**1.00**	**0.85**	0.09	1.00															
DO	**0.90**	**0.90**	**0.98**	0.45	**0.93**	1.00														
BOD5	**1.00**	0.67	**0.98**	0.76	0.72	**0.92**	1.00													
EC	-0.63	-1.00	-0.80	-0.02	-1.00	**-0.90**	-0.67	1.00												
Turb	0.81	0.06	0.64	**1.00**	0.14	0.48	**0.78**	-0.06	1.00											
TDS	-0.63	-1.00	-0.80	-0.02	-1.00	-0.90	-0.67	**1.00**	-0.06	1.00										
pH	-0.63	-1.00	-0.80	-0.02	-1.00	-0.90	-0.67	**1.00**	-0.06	**1.00**	1.00									
NO3-N	-0.28	0.57	-0.03	-0.81	0.51	0.16	-0.23	-0.57	-0.79	-0.57	-0.57	1.00								
NH4-N	-0.96	-0.82	-1.00	-0.59	-0.86	-0.99	-0.97	**0.82**	-0.62	0.82	**0.82**	0.00	1.00							
PO4	-0.34	-0.94	-0.56	0.31	-0.92	-0.71	-0.39	**0.94**	0.27	0.94	**0.94**	-0.81	0.59	1.00						
SO4	-0.89	-0.21	-0.75	-0.98	-0.28	-0.61	-0.87	0.21	-0.99	0.21	0.21	0.69	0.73	-0.12	1.00					
Cl	-0.88	-0.18	-0.73	-0.99	-0.25	-0.58	-0.85	0.18	-0.99	0.18	0.18	0.71	0.71	-0.15	**1.00**	1.00				
Cr	-0.24	0.60	0.01	-0.78	0.54	0.21	-0.19	-0.60	-0.76	-0.60	-0.60	1.00	-0.04	-0.83	0.65	0.68	1.00			
Cu	-0.69	-1.00	-0.85	-0.09	-1.00	-0.93	-0.72	**1.00**	-0.14	**1.00**	**1.00**	-0.51	**0.86**	0.92	0.28	0.25	-0.54	1.00		
Pb	-0.47	-0.98	-0.68	0.17	-0.97	-0.81	-0.52	**0.98**	0.13	**0.98**	**0.98**	-0.71	0.70	**0.99**	0.02	-0.01	-0.74	**0.97**	1.00	
Zn	-0.37	-0.95	-0.59	0.28	-0.93	-0.74	-0.42	**0.95**	0.24	**0.95**	**0.95**	-0.79	0.62	**1.00**	-0.09	-0.12	-0.81	**0.93**	**0.99**	1

Bold values indicate the correlation is significant at the 0.05 level

AT- Air temperature, WT-Water temperature, WL-Water level, Transp.-Transparency, EC-Electrical conductivity, TDS-Total dissolve solid, Turb-Turbidity,

Table 4.2 presents a correlation matrix that illustrates how surface water physico-chemical parameters relates to the water quality index value across the various sampled locations at the River. There was a positive correlation between (water temperature and depth, r =0.803), (depth and flow velocity, r = 0.612), (water temperature and DO, r = 0.904), (depth and transparency, r = 0.845), (depth and DO, r = 0.981), (depth and 5-day BOD, r = 0.981), (flow velocity and 5-day BOD, r = 0.755), (DO and 5-day BOD, r = 0.923), (5=day BOD and turbidity, r = 0.782), (EC and NH4-N, r = 0.822), (EC an PO4, r = 0.945), (EC and Cu, r = 0.997), (EC and Pb, r = 0.982), (EC and Zn, r = 0.955), (TDS and pH, r = 1.000), (TDS and NH4-N, r = 0.822), (TDS and PO4, r = 0.945), (TDS and Cu, r = 0.997), (TDS and Pb, r = 0.982), (TDS and Zn, r = 0.955), (pH and Cu, r = 0.997), (pH and Pb, r = 0.982), (pH and Zn, r = 0.955), (NO3-N and Cr, r = 0.999), (PO4 and Cu, r = 0.918), (PO4 and Pb, r = 0.990), (PO4 and Zn, r = 0.999), (SO4 and Cl, r = 0.999),s (Cu and Pb, r = 0.965), (Cu and Zn, r = 0.930), (lead and zinc, r = 0.994) etc.

Table 4.3: Variation between dry and wet season across the sites combined using Unpaired T-test.

Parameters	Dry seasom	(Min-Max)	Wet season	(Min-Max)	P value
AT (°C)	28.47±0.76	(27.5-30)	27.5±1.17	(26-29.5)	0.1
WT (°C)	26.06±0.30	(25.5-26.5)	25.72±0.51	(25-26.5)	0.11
WL (m)	0.57±0.07	(0.45-0.7)	0.51±0.15	(0.34-0.75)	0.31
FV (m/s)	0.06±0.42	(0.02-0.13)	0.19±0.17	(0.01-0.5)	0.05
Transp. (m)	0.53±0.07	(0.4-0.6)	0.44±0.07	(0.34-0.55)	0.02
DO (mg/L)	2.59±1.19	(1.3-4.8)	1.74±0.87	(0.5-2.9)	0.1
BOD_5 (mg/L)	2.39±0.77	(1-3.6)	3.15±1.49	(1.1-6.1)	0.19
EC (uS/cm)	16.67±8.67	(10-30)	12.22±4.41	(10-20)	0.19
Turb. (NTU)	18±10.68	(8-44)	13±2.44	(8-17)	0.189
TDS (mg/L)	8.67±4.50	(5.2-15.6)	6.36±2.29	(5.2-10.4)	0.189
pH	5.43±0.13	(5.3 -5.7)	5.37±0.32	(4.9-5.9)	0.64
NO_3-N (mg/L)	**0.21±0.27**	**(0.1-0.84)**	**1.46±0.69**	**(0.35-2.35**	**0.0001**
NH_4-N (mg/L)	0.06±0.05	(0.011-0.12)	0.119±0.052	(0.021-0.208)	0.015
PO_4 (mg/L)	0.15±0.08	(0.1-0.35)	0.119±0.05	(0.023-0.194)	0.29
SO_4 (mg/L)	**3.78±2.28**	**(1-7)**	**6.56±1.59**	**(3-8)**	**0.01**
Cl (mg/L)	16.47±4.99	(7.06-21.18)	12.55±4.71	(7.06-21.18)	0.11
Cd (mg/L)	BDL		BDL		
Cr (mg/L)	0.12±0.05	(0.065-0.183)	0.177±0.05	(0.065-0.228)	0.035
Cu (mg/L)	0.35±0.028	(0.297-0.396)	0.33±0.03	(0.298-0.365)	0.34
Pb (mg/L)	0.003±0.004	(0-0.009)	0.007±0.004	(0.009-0.061)	0.05

Zn (mg/L)	**0.691±0.043**	**(0.649-0.7753)**	**0.62±0.058**	**(0.574-0.753)**	**0.012**

NB: BDL means Below detectable limit

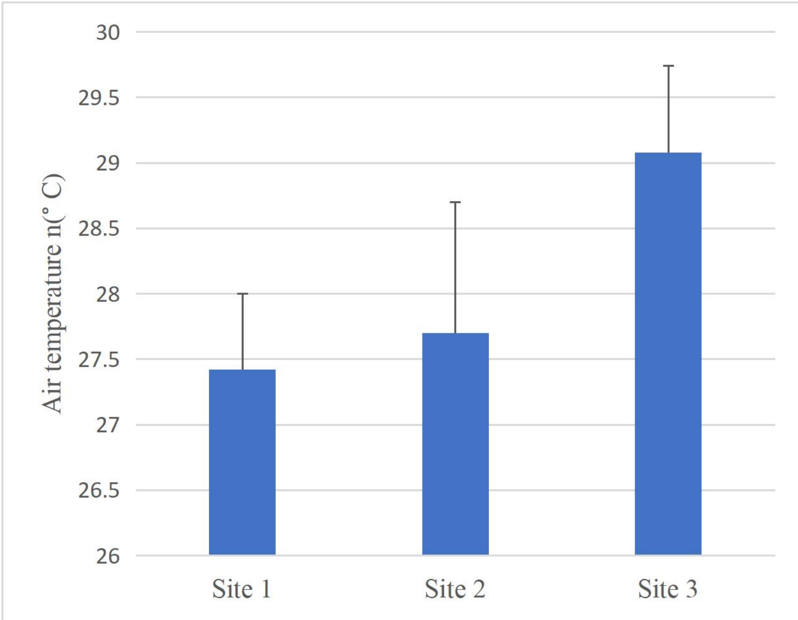

Figure 4.1 Graphical illustration of Air temperature across various sites.

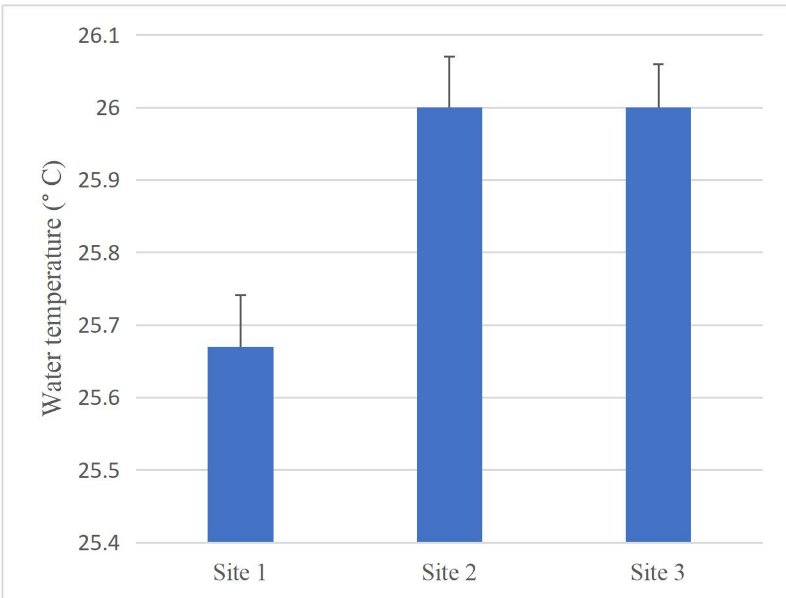

Figure 4.2 Graphical illustration of Water temperature across various sites.

4.1.1 Air Temperature

The spatial variations of air temperature i.e between sites is shown in table 4.1, while the seasonal variation is shown in table 4.3. There was a significant difference ($P < 0.05$) observed among the different study sites and the different seasons. The highest mean air temperature was observed in site 3, a mean of 29.08°C and the lowest mean value was observed in site 1, which had a mean of 27.42°C with site 2 being very close with a mean of 27.7°C. A value of 26°C which was the lowest recorded value was recorded in site 2, while the highest monthly value of 30°C was recorded at sites 3. The variation between the wet and dry season for the three sites combined was done using Unpaired T-test and the values obtained are 27.5°C for wet season and 28.47°C for dry season as shown in Table 3. There was no significant difference ($P < 0.05$) between both seasons.

4.1.2 Water Temperature

The water temperature recorded ranged between 25°C to 26°C in site 1, 25°C to 26.5°C in site 2 and 25.5°C to 26.5°C in site 3 as shown in Table 4.1 above. The seasonal variation in water temperature is shown in Table 4.3 above. There was no significant difference ($P < 0.05$) observed in water temperature values. The mean water temperature was found to be lowest in site 1 with 25.67°C while the highest mean water temperature was found at site 2 and 3 with 26°C respectively. The variation between the wet and dry season for the three sites combined was done using Unpaired T-test and the values obtained are 25.72 °C for wet season and 26.06 °C for dry season as shown in Table 3. There was no significant ($P < 0.05$) difference between both seasons.

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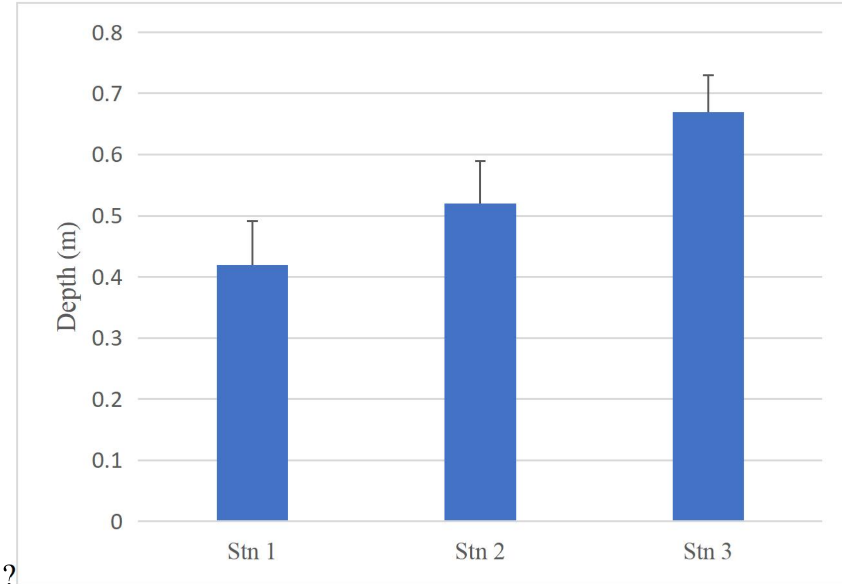

Figure 4.3 Graphical illustration of Depth across various sites.

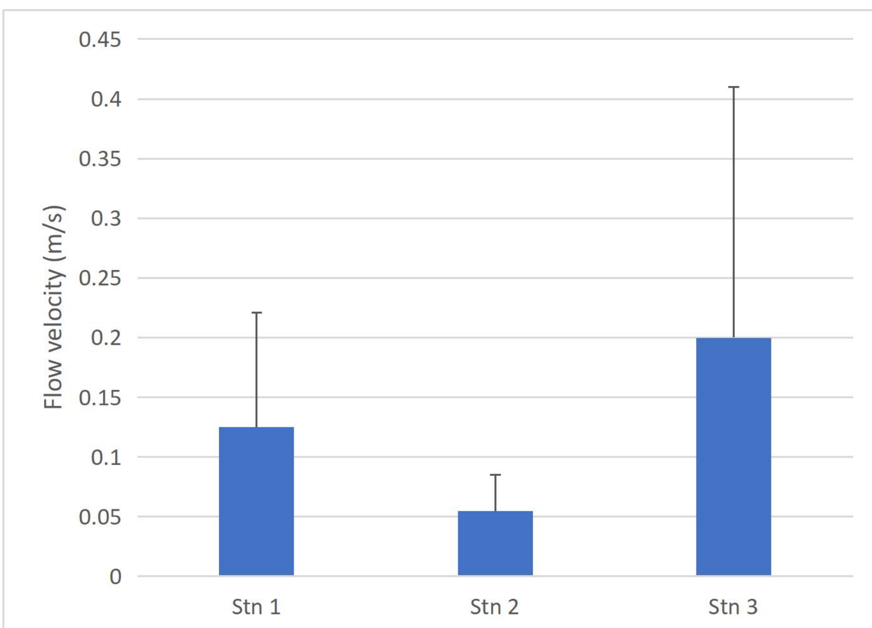

Figure 4.4 Graphical illustration of Flow velocity across various sites.

4.1.3 Depth

Site 1 had a depth range of 0.34m-0.5m, site 2, a depth range of 0.44m-0.6m and site 3, a depth range of 0.6m-0.75m. The highest mean water level was found in site 3 at 0.67m with site 1 and 2 having a mean depth of 0.42m and 0.52m respectively. There was a significant difference ($P < 0.0001$) among the depths recorded. The variation between the dry and wet season for the three sites combined was done using Unpaired T-test and the values obtained are 0.51m for wet season and 0.57m for dry season as shown in Table 4.3. There was a significant difference ($P < 0.05$) between both seasons.

4.1.4 Flow Velocity

The mean flow velocity for site 1,2, and 3 are 0.125m/s, 0.055m/s, and 0.2 respectively. The values recorded were in the range of site 1(0.01-0.3), site 2 (0.02-0.09), site 3 (0.3-0.5). The variation between the dry and wet season for the three sites combined was done using Unpaired T-test and the values obtained are 0.19m/s for wet season and 0.06m/s for dry season as shown in Table 4.3. There was no significant difference ($P < 0.05$) between both seasons.

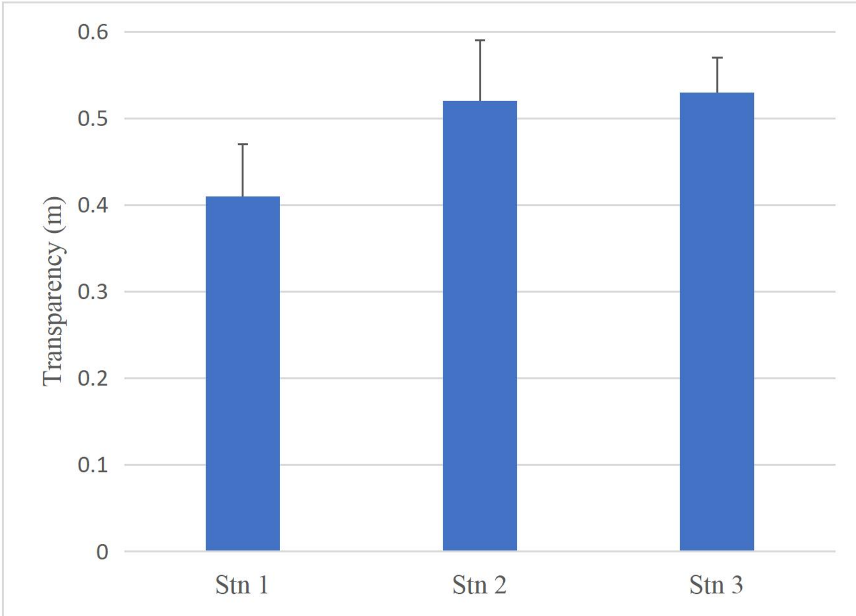

Figure 4.5 Graphical illustration of Transparency across various sites.

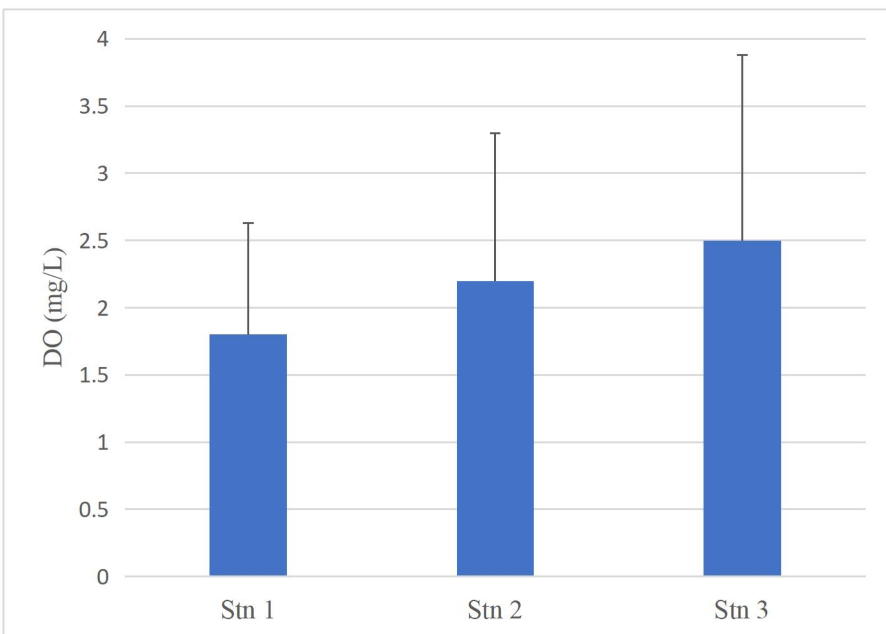

Figure 4.6 Graphical illustration of Dissolved Oxygen (DO) across various sites.

4.1.5. Transparency

The range values recorded for transparency were site 1 (0.34-0.5), site 2 (0.45-0.6), site 3 (0.5-0.6). The highest mean value of transparency was found in site 3 (0.53) while the lowest transparency mean value was found in site 1 (0.41). A significant difference was recorded across the sites. The variation between the dry and wet season for the three sites combined was done using Unpaired T-test and the values obtained are 0.44m for wet season and 0.53m for dry season as shown in Table 3. There was no significant difference ($P < 0.05$) between both seasons.

4.1.6 Dissolved Oxygen

The range values recorded for dissolved oxygen were (0.5-2.8) for site 1, (0.8-3.4) for site 2 and (1.2-4.8). The highest mean value for dissolved oxygen was found in site 3 (2.5) while the lowest mean value was found in site 1 (1.8). The variation between the dry and wet season for the three sites combined was done using the Unpaired T-test and the values obtained are 1.74mg/L for the wet season and 2.59mg/L for the dry season as shown in Table 3. There was no significant difference ($P < 0.05$) between both seasons.

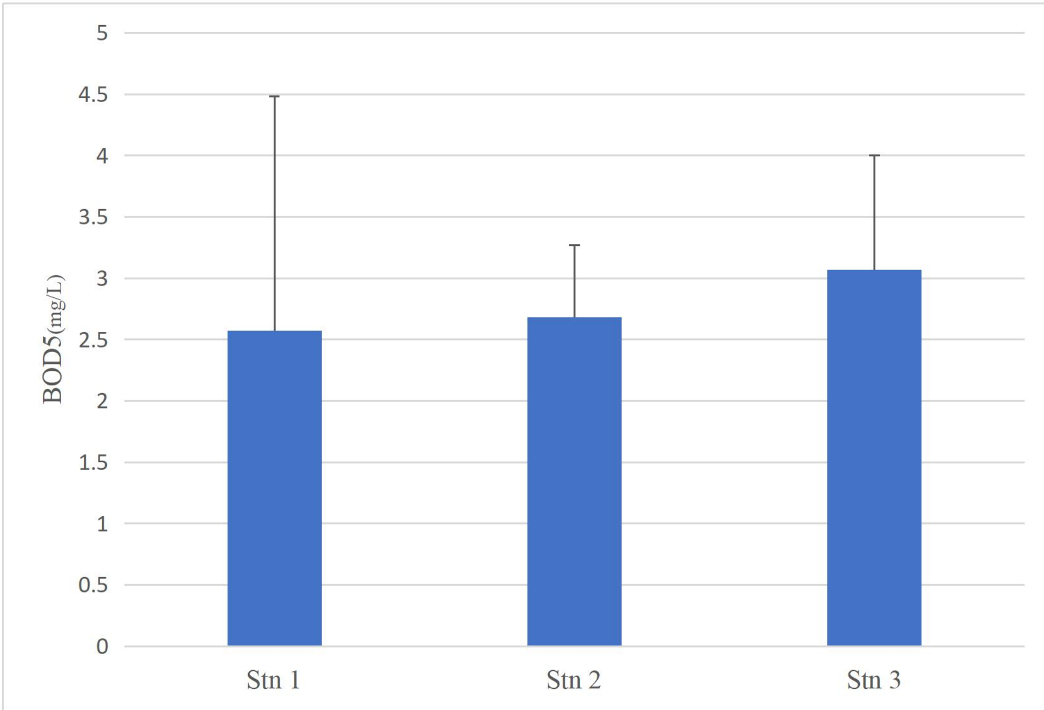

Figure 4.7 Graphical illustration of Biochemical Oxygen Demand across various sites.

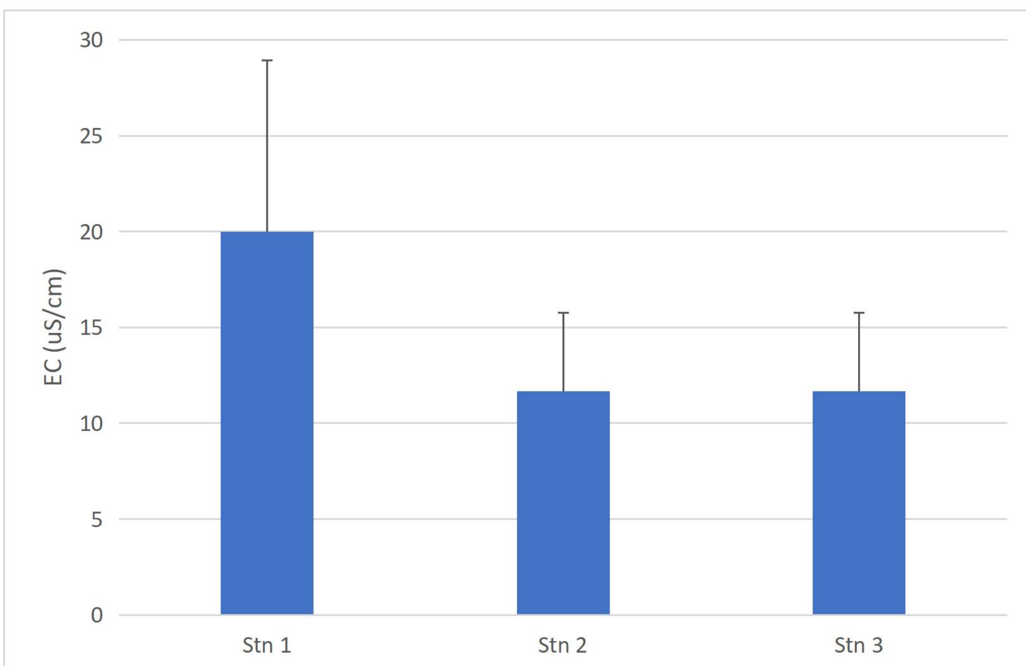

Figure 4.8 Graphical illustration of Electrical conductivity across various sites.

4.1.7 Biochemical Oxygen Demand

The range values recorded for biological oxygen demand were site 1 (1-6.1), site 2 (2-3.6), site 3 (2.2-4.8). The highest mean value of biological oxygen demand was found in site 3 (3.07) while the lowest transparency mean value was found in site 1 (2.57). No significant difference was recorded across the sites. The variation between the dry and wet season for the three sites combined was done using Unpaired T-test and the values obtained are 3.15mg/L for wet season and 2.39mg/L for dry season as shown in Table 3. There was no significant difference ($P< 0.05$) between both seasons.

4.1.8 Electrical Conductivity

The range values recorded for electrical conductivity were site 1 (10-30), site 2 (10-20), site 3 (10-20). The highest mean value of electrical conductivity was found in site 1 (20) while site 2 and 3 had same value of (11.67). No significant difference was recorded across the sites. The variation between the dry and wet season for the three sites combined was done using Unpaired T-test and the values obtained are 12.22 uS/cm for wet season and 16.67 uS/cm for dry season as shown in Table 3. There was no significant difference ($P< 0.05$) between both seasons.

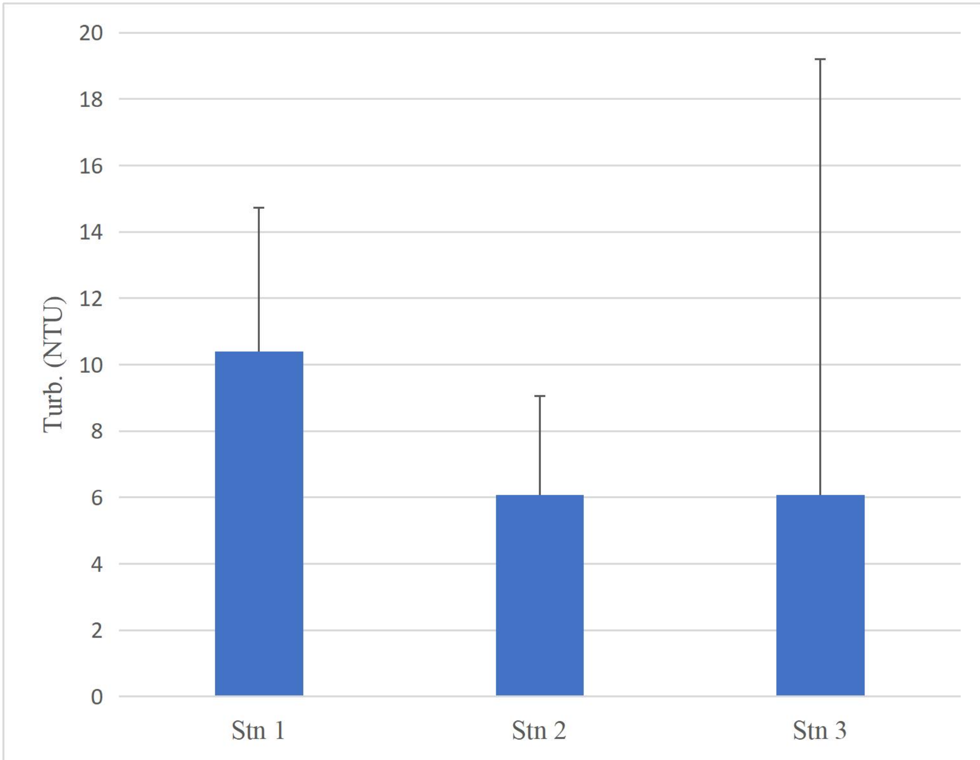

Figure 4.9 Graphical illustration of Turbidity across various sites.

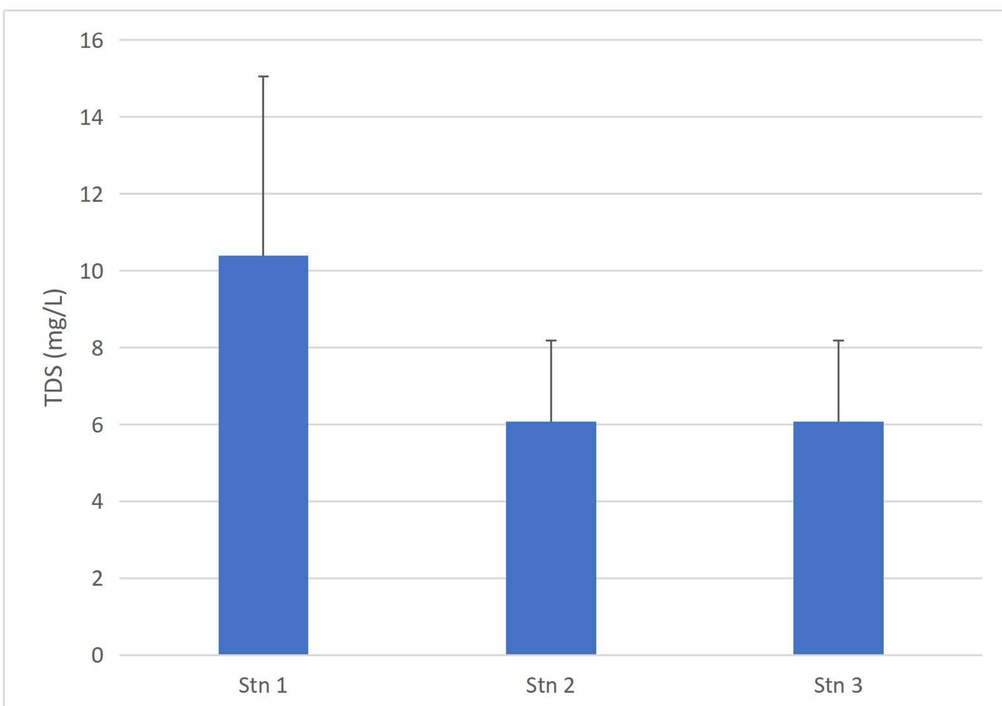

Figure 4.10 Graphical illustration of Total Dissolved Solid across various sites.

4.1.9 Turbidity

The range values recorded for turbidity were site 1 (12-24), site 2 (8-17), site 3 (8-44). The highest mean value of turbidity was found in site 3 (18) while the lowest transparency mean value was found in site 2 (13.17). There was a significant difference across all sites (P> 0.05). The variation between the dry and wet season for the three sites combined was done using Unpaired T-test and the values obtained are 13(NTU) for wet season and 18 (NTU) for dry season as shown in Table 3. There was no significant difference (P< 0.05) between both seasons.

4.1.10 Total Dissolved Solids

The range values recorded for total dissolved solids were site 1 (5.2-15.6), site 2 (5.2-10.4), site 3 (5.2-10.4). The highest mean value of total dissolved solids was found in site 1 (10.4) while site 2 and 3 had same mean value of (6.07). No significant difference was recorded across the sites. The variation between the dry and wet season for the three sites combined was done using Unpaired T-test and the values obtained are 6.36mg/L for wet season and 8.67mg/L for dry season as shown in Table 3. There was no significant difference (P< 0.05) between both seasons.

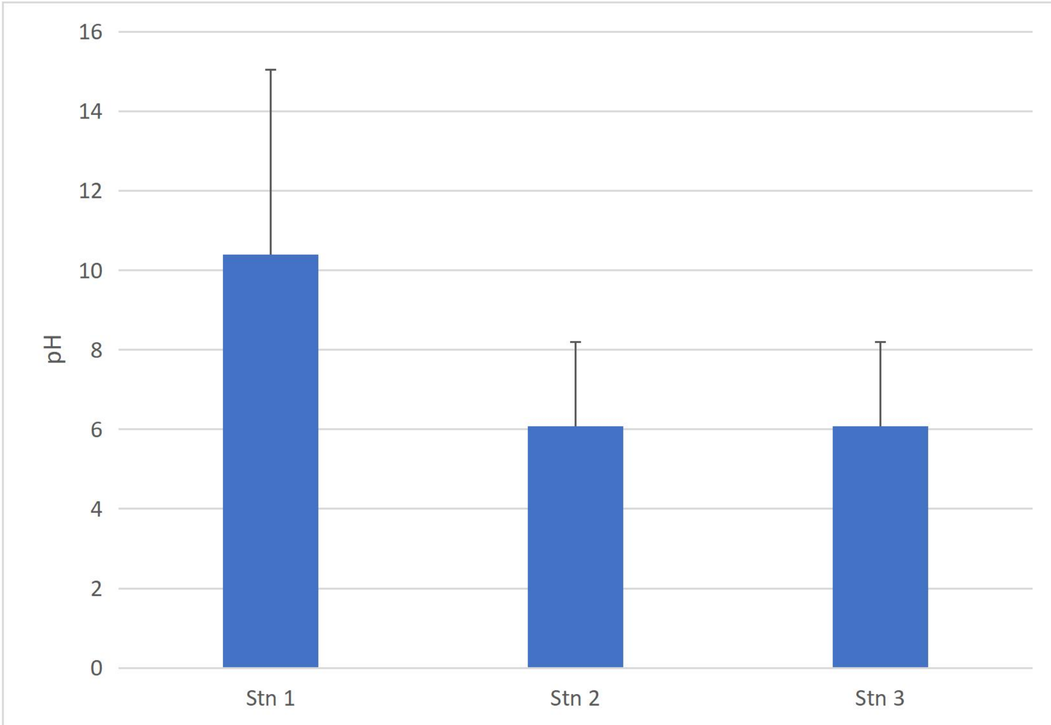

Figure 4.11 Graphical illustration of pH across various sites.

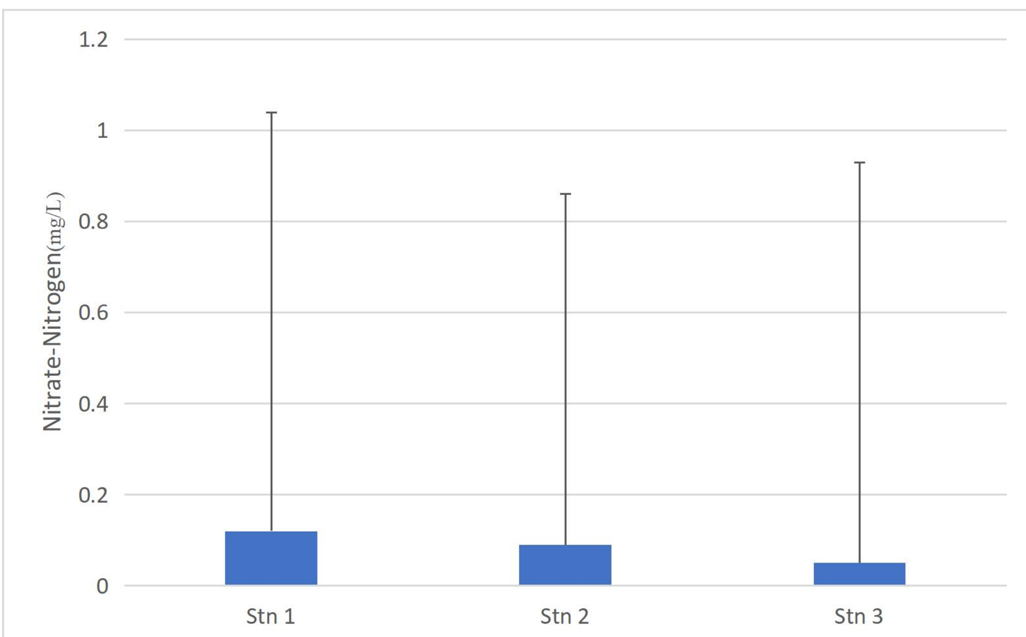

Figure 4.12 Graphical illustration of NO3-N across various sites.

4.1.11 Hydrogen Ion Concentration (pH)

The highest mean value of pH was found in site 1 with a value of 5.52, while the lowest mean value of pH was found in site and site 3 which recorded values of 5.35 respectively. There was a significant difference ($P > 0.05$) between site 1and the other sites. The variation between the dry and wet season for the three sites combined was done using Unpaired T-test and the values obtained are 5.37 for wet season and 5.43 for dry season as shown in Table 4. 4. There was significant difference ($P > 0.05$) between both seasons.

4.1.12 Nitrate-Nitrogen

The highest mean value of pH was found in site 1 with a value of 5.52, while the lowest mean value of pH was found in site and site 3 which recorded values of 5.35 respectively. There was no significant difference ($P < 0.05$) between site 1and the other sites. The variation between the dry and wet season for the three sites combined was done using Unpaired T-test and the values obtained are 5.37 for wet season and 5.43 for dry season as shown in Table 4. 4. There was significant difference ($P < 0.05$) between both seasons.

4.1.13 Heavy metals

The heavy metals analyzed in this study were Chromium, cadmium, copper, lead and zinc. Cadmium was found to be below detectable limit in all sites. The highest mean value was found in the heavy mental Zinc in site 1. The variation between the dry and wet season for all the sites combined was done using the Unpaired T-test and the values obtained for Chromium (Cr) were 0.12 for the dry season and 0.177 for the wet season and there was no significant difference ($P<0.05$) between both seasons. For Copper (Cu), values obtained were 0.35 for the dry season and 0.33 for the wet season, there was a significant difference ($P>0.05$) between both seasons.

For Lead (Pb), 0.003 for the dry season and 0.009 for the wet season, there was no significant difference ($P<0.05$) between both seasons, while for Zinc (Zn), 0.691 for the dry season and 0.62 for the wet season, there was no significant difference ($P<0.012$) between both season

Water Quality Index (WQI)

Table 4.4: Water Quality Index for Site 1 surface water sample in Amagba-|Oko-Oroma River

S/N	PARAMETER	Actual value (Va)	NESREA 2011 Guideline Vs	1/Si	K	WEIGHTAGE (Wi)	QUALITY RATING (Qi)	[(W1) (Q1)]
1	pH	5.52	6.5-8.5	0.153846154	0.003164	0.020566	296	6.087536
2	EC (uS/cm)	20	1000	0.001	0.003164	3.164	2	6.328
3	TDS (mg/l)	10.4	500	0.002	0.003164	1.582	2.08	3.29056
4	Turb. (NTU)	15.33	10	0.1	0.003164	0.03164	153.3	4.850412
5	DO (mg/l)	1.8	4	0.25	0.003164	0.012656	180.2816901	2.28164507
6	BOD_5 (mg/l)	2.57	6	0.166666667	0.003164	0.018984	42.83333333	0.813148
7	Nitrate-N (mg/l)	0.72	40	0.025	0.003164	0.12656	1.8	0.227808
8	Sulphate (mg/l)	11.77	500	0.002	0.003164	1.582	2.354	3.724028
9	Phosphate-P (mg/l)	0.17	3.5	0.285714286	0.003164	0.011074	4.857142857	0.053788
10	Ammonium (mg/l)	0.12	2	0.5	0.003164	0.006328	6	0.037968
11	Chromium (mg/l)	0.136	0.5	2	0.003164	0.001582	27.2	0.0430304
12	Copper (mg/l)	0.347	0.01	100	0.003164	0.00003164	3470	0.1097908
13	Lead (mg/l)	0.008	0.1	10	0.003164	0.0003164	8	0.0025312
14	Zinc (mg/l)	0.683	0.2	5	0.003164	0.0006328	341.5	0.2161012
					Wi=	**6.55837084**	**[(Wi) (Qi)]=**	**28.0663467**
						WQI=	**4.2794693**	

Table 4.5: Water Quality Index for Site 2 surface water sample in Amagba-|Oko-Oroma River

S/N	PARAMETER	Actual value (Va)	NESREA 2011 Guideline Vs	1/Si	K	WEIGHTAGE (Wi)	QUALITY RATING (Qi)	[(W1) (Q1)]
1	pH	5.35	6.5-8.5	0.153846	0.003164	0.020566	330	6.78678
2	EC (uS/cm)	11.67	1000	0.001	0.003164	3.164	1.167	3.692388
3	TDS (mg/l)	6.07	500	0.002	0.003164	1.582	1.214	1.920548
4	Turb. (NTU)	13.17	10	0.1	0.003164	0.03164	131.7	4.166988
5	DO (mg/l)	2.2	4	0.25	0.003164	0.012656	174.647887	2.210343662
6	BOD_5 (mg/l)	2.68	6	0.1667	0.003164	0.018984	44.666667	0.847952
7	Nitrate-N (mg/l)	1.05	40	0.025	0.003164	0.12656	2.625	0.33222
8	Sulphate (mg/l)	14.12	500	0.002	0.003164	1.582	2.824	4.467568
9	Phosphate-P (mg/l)	0.11	3.5	0.2857	0.003164	0.011074	3.142857143	0.034804
10	Ammonium (mg/l)	0.09	2	0.5	0.003164	0.006328	4.5	0.028476
11	Chromium (mg/l)	0.173	0.5	2	0.003164	0.001582	34.6	0.0547372
12	Copper (mg/l)	0.336	0.01	100	0.003164	0.00003164	3360	0.1063104
13	Lead (mg/l)	0.003	0.1	10	0.003164	0.0003164	3	0.0009492
14	Zinc (mg/l)	0.637	0.2	5	0.003164	0.0006328	318.5	0.2015468
					Wi=	**6.55837084**	**[(Wi) (Qi)]=**	**24.851611**

Table 4.6: Water Quality Index for Site 3 surface water sample in Amagba-|Oko-Oroma River

S/N	PARAMETER	Actual value (Va)	NESREA 2011 Guideline Vs	1/Si	K	WEIGHTAGE (Wi)	QUALITY RATING (Qi)	[(W1) (Q1)]
1	pH	5.35	6.5-8.5	0.15384615	0.003164	0.020566	330	6.78678
2	EC (uS/cm)	11.67	1000	0.001	0.003164	3.164	1.167	3.692388
3	TDS (mg/l)	6.07	500	0.002	0.003164	1.582	1.214	1.920548
4	Turb. (NTU)	18	10	0.1	0.003164	0.03164	180	5.6952
5	DO (mg/l)	2.5	4	0.25	0.003164	0.012656	170.422535	2.1568676
6	BOD_5 (mg/l)	3.07	6	0.16666667	0.003164	0.018984	51.1666667	0.971348
7	Nitrate-N (mg/l)	0.75	40	0.025	0.003164	0.12656	1.875	0.2373
8	Sulphate (mg/l)	6.67	500	0.002	0.003164	1.582	1.334	2.110388
9	Phosphate-P (mg/l)	0.13	3.5	0.285714286	0.003164	0.011074	3.7142857	0.041132
10	Ammonium (mg/l)	0.05	2	0.5	0.003164	0.006328	2.5	0.01582
11	Chromium (mg/l)	0.141	0.5	2	0.003164	0.001582	28.2	0.04461
12	Copper (mg/l)	0.335	0.01	100	0.003164	0.00003164	3350	0.105994
13	Lead (mg/l)	0.004	0.1	10	0.003164	0.0003164	4	0.0012656
14	Zinc (mg/l)	0.651	0.2	5	0.003164	0.0006328	325.5	0.205976
					Wi=	**6.55837084**	**[(Wi) (Qi)]=**	**23.98562**
						WQI=	**3.65725278**	

Table 4.7: Summary of WQI values of water samples collected at various sites at Ogba River

Sites	WQI Value	Rating of water quality
Site 1	4.28	Excellent
Site 2	3.79	Excellent
Site 3	3.66	Excellent

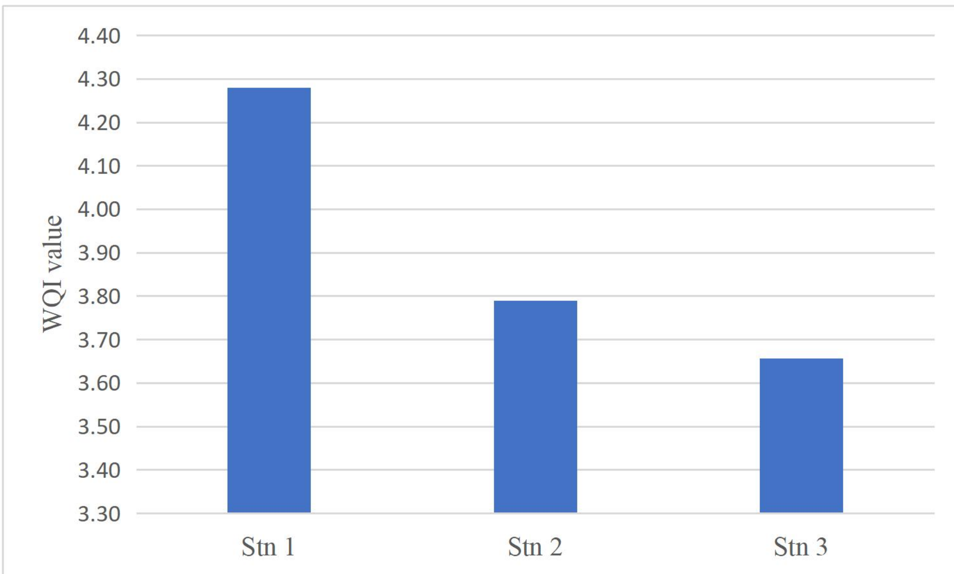

Figure 4.12 Graphical illustration of Water Quality Index (WQI) across various sites.

The WQI value for the three sampled sites calculated was given in table 4.7. The WQI values for the three sites were calculated as 4.28, 3.79 and 3.66 respectively. The water quality in all the sampled sites were within permissible limit (< 50) for excellent drinking water.

The graphical illustration of the Water Quality Index across all three sites is given above in Figure 4.12

CHAPTER FIVE

5.1 DISCUSSION

The assessed data from our study, emphasises the significance of assessing water quality for environmental protection and community well-being which covered various key parameters, pH, Electrical Conductivity (EC), Total Dissolved Solids (TDS), Turbidity, Dissolved Oxygen (DO), Biochemical Oxygen Demand (BOD_5), Nitrate-N, Sulphate, Phosphate-P, Zinc, Lead, and Ammonium. The evaluation was made against established guidelines, identify pollution sources, and implications for both the environment and human health. All analysis, stressed on the importance of our findings in informing decision-making, policy development, and future research for preserving and enhancing the water quality in Amagba-Okoroma River. The study also shed light on the implications and offer insights into the current state of water quality in the River, which is a vital source of water for the community.

Of the 21 water parameters analysed, 5 parameters namely turbidity (15.5 NTU), pH (5.4), Cr (0.15 mg/L), Cu (0.34 mg/L) and Zn (0.66 mg/L) were above Nigerian Industrial Standard (NIS) Guidelines. Edjere *et al.* (2016) in his studies in Ikpoba River, Benin City observed that six parameters which include, turbidity, nitrate, lead, iron, zinc and cadmium level were above the WHO guidelines while Ikhuoriah and Oronsaye (2016) observed that the pH level of Ossiomo River, was slightly below the World Health Organization (WHO) and Nigerian Industrial Standard (NIS) guidelines. The mean pH ranges for all three sites indicates a general acidic condition of the River. The acidic nature of Nigerian rivers had been observed by (Ogbonna 2010; Anyanwu 2012; Imoobe and Koye 2011).

From the result of the WQI gotten, dissolved Oxygen (DO) mean levels ranged from 1.8 mg/L to 2.5 mg/L across the three sites. These values are below the NESREA standard of 4 mg/L, indicating potential oxygen depletion in the Amagba-Okoroma River. The range of DO levels also suggests some variability in oxygen content, with site 3 exhibiting the highest average DO concentration. The values obtained in this study is similar to that obtained from Ogba River (Imoobe and Adeyinka, 2010; Anyamwu; 2012). This value is slightly less than the permissible limit (5mg/l) necessary to sustain aquatic life, an indication that the water quality was starting to deteriorate. The Biochemical Oxygen Demand BOD5 values vary from 2.57 mg/L to 3.07 mg/L, all below the NESREA guideline of 6 mg/L. This suggests that the river's organic pollution level, as indicated by BOD5, is reduced. Values less than 1.2mg/l are considered clean, 3mg/l fairly clean, 5mg/l doubtful and 10mg/l serious (Rim-Rukeh et al., 2006), thus high B.O.D is an indication of a fairly water quality. The Electrical Conductivity (EC) measurements fall within the range of 11.67 uS/cm to 20 uS/cm, all below the NESREA guideline of 1000 uS/cm. Low EC values indicate low levels of dissolved ions in the water, suggesting low salinity and ion concentration. The Turbidity values range from 13.17 NTU to 18 NTU, with all values exceeding the NESREA standard of 10 NTU. Elevated turbidity this could be attributed to the organic constituents and human activities in the river system (Anyanwu, 2012). The pH values fall within the range of 5.35 to 5.52, which is slightly below the NESREA guideline range of 6.5 to 8.5. The pH levels indicate slightly acidic conditions in the river, potentially impacting aquatic life. This is due to the humic acid content arising from the decompositions and oxidation of organic matter in them (Deekae, 2010). The Nitrate-N (NO3-N) and Ammonium-N (NH4-N), where the Nitrate-N concentrations are generally low, ranging from 0.72 mg/L to 1.05 mg/L, well below the NESREA guideline of 40 mg/L. unlike those reported for some in-land waters by Omoigberale and Ogbeibu 2007. Ammonium-N levels are also low, indicating minimal nitrogen pollution in the water. The Phosphate (PO_4) concentrations are within the range of 0.11 mg/L to 0.17 mg/L, well below the NESREA guideline of 3.5 mg/L, indicating low phosphorus pollution in the river. The heavy metals (Cd, Cr, Cu, Pb, Zn), where Cadmium (Cd) concentrations are below detection limits (BDL) for all locations. Concentrations of other metals such as Chromium (Cr), Copper (Cu), Lead (Pb), and Zinc (Zn) fall within acceptable ranges, indicating no immediate metal contamination issues in the river. Though, the presence of heavy metals, even at low levels, can pose long-term health risks. The average value fell within WHO standard but was relatively lower than the values obtained in Ogba river and Osse River in Benin City, Owo River and Ologe lagoon in Lagos (Omoigberale and Ogbeibu 2007; Yusuf and Osibango, 2007; Anyanwu, 2012) Monitoring and ensuring safe drinking water treatment are crucial to mitigate these risks.

5.2 Spatial and Seasonal Variations:

Of all the parameters, three parameters namely, air temperature (°C), depth (m), and transparency (m), varied spatially significantly across the three sites. ($p < 0.05$). Air temperature was significantly higher in site 3, this could be as a result of the location of the sun reaching more to site 3 than other sites. Site 3, downstream was significantly deeper than the other sites. Site 3, also had a higher transparency level than other sites.

These seasonal variations underscore the dynamic nature of aquatic systems and the influence of climatic and environmental factors. The wet season typically brings increased rainfall, higher water flow, and changes in land run-off patterns, leading to shifts in water quality parameters.

The result revealed that among all parameters, two parameters namely, Nitrate-Nitrogen (NO_3-N), and Sulphate (SO_4) varied seasonally significantly across all three sites, with both parameters having higher values during the wet season. These finding is similar to (Ikhuoriah and Oronsaye; 2016) which reported higher values of NO_3-N and SO_4 during the wet season in the study of Ossiomo River, southern Nigeria. Increase in NO_3-N levels during the wet season suggest increased nutrient inputs, possibly from runoff or agricultural activities. Finkler *et al.,*(2021). These nutrients can contribute to water eutrophication, algal blooms, and potential water quality issues, Ugochukwu *et al.,*(2019). Sulphate levels (SO_4) also show significant seasonal variation between the dry and wet season. Similar study Akhtar *et al.,* (2021). showed that elevated sulphate levels during the wet season may be related to geological factors, increased weathering, or the release of sulphates from sources such as industrial or agricultural runoff. These levels can affect the water's chemistry and may have implications for the health of aquatic organisms.

Also, in the study of the water quality in the Amagba-Okoroma River, the wet season tends to exhibit lower dissolved oxygen, higher BOD5, and increased nutrient levels, likely due to runoff and increased biological activity. These findings are essential for understanding the seasonal fluctuations in water quality and can inform strategies for managing water resources and addressing pollution sources in the region.

RECOMMENDATION AND CONCLUSION

Given the observed differences in water quality parameters between the dry and wet seasons, several recommendations and mitigation strategies can be proposed:

- **Enhanced Seasonal Monitoring**: To gain a better understanding of seasonal variations and pinpoint potential pollution sources unique to each season, it is advisable to expand seasonal monitoring efforts.
- **Source Identification**: Investigate whether agricultural runoff, industrial emissions, or other human activities are significant contributors to water quality changes.
- **Heavy Metal Control Strategies:** Develop strategies to manage heavy metal inputs such as chromium (Cr), copper (Cu), and lead (Pb) into the river. This might involve regulations on industrial discharges, the promotion of recycling practices, and educating local industries on pollution prevention.
- **Public Awareness Campaign:** Raise awareness among the public about the critical importance of water quality and encourage community engagement in efforts to protect and preserve the river.

In conclusion, the data analysis reveals noticeable variations in water quality parameters between the dry and wet seasons in the Amagba-OkoRoma River. While the dry season generally exhibits better water quality, the wet season shows increased levels of nutrients and some heavy metals. These findings highlight the need for tailored water quality management strategies that account for seasonal fluctuations and potential pollution sources.

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