SEDIMENT CHARACTERIZATION AND ZOOBENTHOS COMMUNITY OF AGHUAKUARI RIVER, EDO STATE, NIGERIA

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UNIVERSITY OF BENIN

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DEDICATION

This work is dedicated to God Almighty

CERTIFICATION

This is to certify that this project work was carried out by Chioma Alexa Ani in the Department of Animal and Environmental Biology, University of Benin, Benin City, Edo state, Nigeria.

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ABSTRACT

The sediment characterization and evaluation of Zoobenthos community in Aghuakuari River, Edo State, Nigeria was carried out for four (4) months across three (3) stations from April 2023 through July, 2023. The heavy metals of the sediment were analyzed and studied and they include, Iron (Fe) (310.11– 411.0 mg/kg), Copper (Cu) (10.05 – 29.00 mg/kg), Manganese (Mn) (0.13 – 0.60 mg/kg), Lead (Pb) (0.30 – 1.20 mg/kg), Cadmium (Cd) (0.12 – 0.23 mg/kg), and Zinc (Zn) (7.63 – 14.00 mg/kg) and also the Particle size distribution and Organic content (% organic carbon and % organic matter) were also analyzed. Heavy metals apart from iron parameters were within the allowable limits of USEPA for fresh water bodies. A total of 19 taxa comprising of 394 individuals were recorded during the study. Hemiptera accounted for 1%, Coleoptera accounted for 7%, Odonata accounted for 1%, Diptera accounted for 57%, Ephemeroptera accounted for 3%, Decapoda accounted for 5%, Amphibia accounted for 26%, and Araneae accounted for 0.1%. The total number of taxa in station 1 were 8 with 181 total number of individuals. In station 2, 16 taxa were recorded and individuals were 83 while in station 3, the total number of taxa and individuals were 6 and 130 respectively. From the coefficient correlation analysis, it was observed that the distribution and abundance of some benthic macroinvertebrates by changes in some physico-chemical parameters. Factors which influenced the abundance and distribution of the benthic macroinvertebrates includes the nature of the water body, habitat richness and stability, immediate substrate of occupation, the heavy metal composition, anthropogenic activities, tropic condition, resource partitioning and predation.

CHAPTER ONE

INTRODUCTION

1.1 Background

Sediment; a collection of loosely aggregated particles, encompassing elements like sand, clay, silt, and various soil constituents, tend to settle at the bed of a water body. This intricate mixture embodies a blend of both organic and inorganic matter, primarily sourced from the river itself and the surrounding catchment area. It's worth noting that even minute traces of material may find their way into sediment from the atmospheric realm (Avramidis, 2013). The characterization of bottom sediments stands as a pivotal element in the study of water quality. It serves as a repository of crucial insights into the origin of settling materials, the impact of sediment on the quality of the overlying water, and the predominant biological systems at play. This analytical lens grants us the ability to fathom the intricate interplay between sediment and its surrounding aquatic ecosystem.

Delving into sediment holds significance not just for analytical purposes, but also for its ecological contributions. Sediment serves as a veritable cornerstone for the creation of diverse habitats and environments. These unique settings harbor a multitude of species, notably including benthos - organisms that thrive in sediment habitats (Olomukoro and Azubuike, 2009). The study of sediment thus unfurls a tapestry of ecological interactions and interconnected systems, enriching our understanding of the intricate web of life within aquatic environments.

They act as both sinks and sources of nutrients, depending on the prevailing redox conditions (Olomukoro and Ezemonye, 2000; Sahoo, 2007). Aquatic ecosystems experience varying flow rates, substance inputs, transport, and sedimentation. Therefore, sediment analysis has become increasingly important for assessing the overall quality of a water body's ecosystem. Both suspended and precipitated substances, including organic matter, have the ability to adsorb pollutant particles in water. These sediments, comprising suspended and precipitated materials deposited on the water bottom, serve as a reservoir for various pollutants and trace substances with low solubility and degradability (Asibor, 2016). Freshwater ecosystems exhibit considerable natural variability in their physicochemical properties due to local geological and climatic differences. Consequently, they are more susceptible to human-induced influences compared to the more consistent and stable marine environment, as highlighted by Rainbow and Dallinger (1993).

Heavy metal analysis is a vital aspect of studying river systems as heavy metals, such as lead, mercury, cadmium, and copper, are frequently present as contaminants in water bodies due to human activities such as industrial discharges, mining, and agriculture. These heavy metals can accumulate in sediments and pose serious threats to aquatic organisms, including benthic macroinvertebrates, which are highly sensitive to changes in their environment. Understanding the levels and distribution of heavy metals in the Aghuakuari River is crucial for assessing the potential risks to both the ecosystem and human health. Heavy metals accumulate in sediments through complex physical and chemical adsorption mechanisms depending on the nature of the sediment matrix and the properties of the adsorbed compounds (Asibor, 2016).

Benthic macroinvertebrates or Zoobenthos are animals without backbone that live on or in the sediment of the water body or attached to rocks or debris at the bottom. The minimum size is 0.55mm in diameter. They include crustaceans, molluscs, aquatic worms and larval forms of aquatic insects. They are important in the aquatic ecosystem because they form part of the aquatic food chain. They are also used to assess water quality and as pollution indicators.

Biological communities have been seen as effective tools for assessing organic pollution. Macrobenthic animals are easy to monitor, because they can be sampled quantitatively and also respond to man-made disturbance (Otway *et al*., 1996).

In polluted lotic ecosystems and intolerant macroinvertebrates may be eliminated and tolerant remain abundant due to less competition and /or tolerance to adverse conditions (Myslinski and Ginsburg,1977). Thus, benthic macro-invertebrate or zoobenthos communities play a twofold role: First, they act as a connecting link in the food web and secondly, they purify the polluted water (Brraich and Kaur, 2017). Various methods have been applied to measure the impacts of human activities on the integrity of water resources such as chemical, physical and biological measures. Benthic macro-invertebrates have largely been used due to their very slow movements or static nature (Mason 2002). Biological communities integrate the effects of different stressors such as reduced oxygen, excessive nutrients; toxic chemicals and habitat degradation that water resource agencies are struggling to address (Tamiru *et al*., 2017). There are many studies that used macroinvertebrates assemblages for assessing the ecological quality of aquatic ecosystems, as they are affected by the physical, chemical and biological conditions of the stream (Menetrey *et al*., 2011). Also, some of the macro-invertebrates are extremely sensitive to organic pollutants, are widely distributed, easy and economical to sample and show clear responses encountering any adverse environmental conditions (Setiawan, 2009; Kalyoncu and Gulboy, 2009; Moreno *et al*., 2009). They may show the cumulative impacts of multiple stressors, like habitat loss, which are not always detected by the traditional water quality assessments using physico-chemical measurements.

Moreover, benthic macroinvertebrates are excellent indicators of water quality and ecosystem health. Their presence, abundance, and diversity can provide valuable information about the ecological conditions of the Aghuakuari River.

1.1 Justification of the Study

The Aghuakuari River, located in the Ovia North East Local Government Area of Benin City, holds significant ecological importance in the region. As a freshwater system, the river supports diverse aquatic life and plays a crucial role in providing water resources for both human and natural habitats. However, the health of the river ecosystem may be compromised due to various anthropogenic activities and environmental pressures. Understanding the specific problems and potential threats to the Aghuakuari River is essential for effective management and conservation efforts.

Sediment characterization, heavy metal analysis, and the study of benthic macroinvertebrates are essential components in understanding the ecological health and water quality of rivers. Sediments act as repositories of various substances, including organic matter, nutrients, and potentially harmful pollutants such as heavy metals. By analyzing sediment characteristics, researchers can gain insights into the physical and chemical properties of the riverbed, including grain size distribution and organic matter content (Menetrey *et al*., 2011).

By addressing these problems and understanding the specific challenges faced by the Aghuakuari River, this study aims to contribute valuable insights into the current state of the river ecosystem. The findings will support evidence-based decision-making for river management, pollution control, and conservation strategies in the Ovia North East Local Government Area of Benin City.

1.2 Aim and Objectives of Study

The aim of this study was to determine the sediment characterization and Zoobenthos community in Aghuakuari River, Ovia North East Local Government Area of Benin City

The specific objectives were to:

1. Determine the heavy metals of the bottom sediment of the River.

2. Evaluate sediment characteristics, such as grain size, Total organic carbon, Total organic matter, particulate matter of the Waterbody.

3. Determine the species composition, relative abundance, and species diversity of Benthic macroinvertebrates of the Waterbody

CHAPTER TWO

LITERATURE REVIEW

Numerous studies have been conducted on the benthic macroinvertebrate fauna in water bodies across Nigeria. These studies include the works of Ogbeibu and Oribhabor (2002), Ibemenuga and Inyang (2006), Olomukoro (2008), Omoigberale and Ogbeibu (2010), and Omoigberale *et al*. (2012). These literature sources have examined and documented the benthic macroinvertebrate fauna present in various water bodies within Nigeria. The literature review aims to gather and analyze existing knowledge and research findings to establish a foundation for the current study. By reviewing relevant literature, the chapter seeks to gain insights into the state of knowledge in the field, identify research gaps, and build upon existing studies to contribute new knowledge.

2.1 Heavy Metal

Heavy metal analysis is a critical component of sediment characterization, focusing on the identification and quantification of heavy metal contaminants present in sediment samples. Heavy metals, including elements such as lead (Pb), mercury (Hg), cadmium (Cd), arsenic (As), and chromium (Cr), pose significant risks to aquatic ecosystems and human health due to their toxicity and persistence in the environment. Sediments are considered as a sink for pollutants, as they tend to accumulate pollutants based on the levels of pollution (Ogbeibu and Oribhabor, 2002).

While heavy metals serve important roles in various industries and are essential for certain metabolic activities in the human body (such as copper, selenium, zinc, etc.), some heavy metals, at certain concentrations, have been associated with health complications in organs such as the liver, lungs, intestines, and blood. Sediments serve as repositories for the accumulation of heavy metals through complex physical and chemical adsorption mechanisms, which depend on the properties of the sediment matrix and the adsorbed compounds (Nazarova *et al*., 2004). Therefore, assessing the chemical characteristics of sediments, where benthic invertebrate animals reside, is crucial for evaluating the overall health of the aquatic environment (Meng, 2017).

Particles containing heavy metals can enter water bodies either directly or indirectly, through runoff or other means, and interact with the water's constituents or settle at the bottom where they react with the sediments (Olomukoro and Azubuike, 2009). The high contamination of aquatic system with toxic heavy metals is of major concern to the society because these elements are not biodegradable and their elevated uptake by crops and aquatic organisms may also affect food quality and safety is a source of serious concern to government regulatory agencies and environmentalist (Olomukoro, 2016).

Gijo and Alagoa (2022) studied the Concentration of Heavy Metals across three stations in the Sediments of the River Nun Estuary, Around Akassa, Niger Delta, Nigeria. The result shows that Pb has the highest concentration, followed by Zn, Ni, Cd, and Mn respectively. The lowest values of all metals were observed at station 2, while the highest concentrations of metals were recorded at sampling stations 1. The results show that the value of Pb was highest in station 1(1.347±0.001), followed by Station 3 (1.24±0.001). Station 2 had the least mean value of Pb (0.884±0.001). Cd showed similar patterns across the three sampling stations 1, 2 and 3, with the values 0.068±0.002, 0.046±0.001, and 0.054±0.002 respectively. Ni also presented slight difference across the three sampling stations. Concentration of Zn were higher in station 1 and 2 (1.265±0.002 and 1.038±0.002), than in station 3 (0.725±0.001). All metal concentration was however lower than the international permissible limited. The concentrations of Mn were also observed to present a similar pattern across the sampling stations. There is a significant difference ($P < 0.05$) in all heavy metal parameters across all stations.

Anani and Olomukoro (2017) from their study in Ossiomo river discovered that the concentrations of Fe, Mn, Zn, Cu, Cr, Cd, Pb, Ni and V, varied individually with a significant difference ($p < 0.05$) and no significant difference ($p > 0.05$) values across the stations with their ranks in this order Fe > Mn > Zn > Cu > Cr > Cd > Pb > Ni > V. Most of the environmental computed heavy metals in their current study were above the national and international unity standards as compared with their standard limits. The Enrichment Factors, Pollution Index (PI) and Nemerow Integrated Pollution Index (NIPI) were used to assess heavy metals contamination in the river bed. All the indices showed varied grades of characterized pollution with EF values >1, PI and NIPI values >3. The sources of pollution were mainly from lithogenic (crustal origin) and anthropogenic activities.

Paulinus *et al*. (2015) carried out a study to assess the contamination of the water sources as a result of mining of lead and zinc minerals in Ebonyi State, southeastern Nigeria. A total of thirty (30) water samples were collected from the Enyigba Pb/Zn mining district. This comprises of 12 samples of surface water, 14 from mine ponds and 4 from underground (borehole) water. The samples were acidified to stabilize the metals for periods more than four days without the use of refrigeration. The acidified water samples were analysed by a commercial laboratory at Projects Development Institute (PRODA), Enugu using Atomic Absorption Spectroscopy (AAS). The elements determined by this method are lead (Pb), zinc (Zn), copper (Cu), arsenic (As), cadmium (Cd), nickel (Ni), manganese (Mn) and cobalt (Co). The result and analysis of contamination factor showed that in surface water, Cd had the highest concentration followed by As and Pb, while Ni had the lowest. In mine ponds, Cd also had the highest concentration and followed by

Pb and As and Ni the lowest. In borehole water, Cd has the highest concentration followed by Pb and As, while Ni had the lowest concentration. Compared to WHO permissible limits, the contamination of the heavy metals in all water sources are in order Cd>>>As>>Pb>Ni>Zn>Cu. In surface water, the order is Cd>>>As>>Pb>Ni>Zn>Cu; in mine ponds, it is Cd>>>Pb>>As>Ni>Zn>Cu, and in borehole water, the order is Cd>>>As>>Pb>Zn>Ni>Cu. The calculated contamination factors show very high contamination status for Cd, Pb and As. These levels of contamination and values indicate that under the prevailing conditions and environmental regulations in Nigeria, the mining district would face major and hazardous discharges of these metals to the water sources. Edori *et al*. (2019) studied the status of heavy metals contamination in water from the Elelenwo River, Obio-Akpor, Rivers State, Nigeria. Water samples were collected between the periods of three months (June – August year) and analyzed for heavy metal content. The concentrations of the metal observed within the period showed the order of concentration as; iron (Fe) > zinc (Zn) > silver (Ag) > chromium (Cr) > copper (Cu) > cobalt (Co) > lead (Pb) > cadmium (Cd) > nickel (Ni) > Arsenic (As). The mean concentrations of the examined metals in mg/Kg within the period were Cd (0.251±0.000), Pb (0.428±0.001), Cr (0.139±0.001), Ag (1.428±0.384), Ni (0.184±0.000), Fe (5.910±0.008), As (undetected), Zn (1.324±0.320), Cu (0.781±0.003) and Co (0.672±0.002). All the examined metals were detected in the Elelenwo River except As. The concentrations of the heavy metals were all above the individual standard limits in drinking water stipulated by WHO except Zn, Cu and As. The values obtained for the different metals examined revealed that the concentrations of the metals were as a result of anthropogenic input sources rather than natural influence. The high values observed for the metals call for proper investigation on the input sources so as to provide preventive measures in order to curb further increase that can lead to fatal conditions in the environment.

Jenyo-Oni and Oladele, (2016) evaluated iron, lead, cobalt, nickel, chromium and cadmium concentrations in water, sediment, Nile Tilapia (Oreochromis niloticus) and African river prawn (Macrobrachium vollenhovenii) samples of Lake Asejire, Oyo State, Nigeria. The concentration of these metals was determined spectrophotometrically in three locations along the course of the lake. Results revealed that only iron and lead were detected in water samples. However, all the metals were found in sediments, Nile Tilapia and African river prawn. Iron had the highest mean concentrations (mg kg-1) of 2.392±0.015, 7.4314±1.184, and 1.6100±0.099 in sediments, fish and prawn respectively. Significant differences was found across each sample type for the metals determined. The detection of these metals in Lake Asejire call for close environmental monitoring and adequate public awareness. This is necessary to discourage further pollution which could lead to high metal concentration and metal poisoning.

A study on the characteristic of sediment quality of Asejire Reservoir was conducted by Asibor (2016) to evaluate the heavy metal content of a reservoir. Twenty stations were selected, samples and analyzed using standard methods. The result showed that the sediment was slightly acidic across the study stations, with low conductivity and organic matter content. The heavy metals order of dominance was: Fe>Pb>Cu>Zn>Mn>Al>Ba>Ni>Cr. The mean concentration levels of all the heavy metals were lower than mean background value except Fe, Cu and Pb. However, calculated Enrichment Factor (EF) values for all the heavy metals investigated showed that they were less than 1.5.

The macrobenthic fauna in bottom sediments of Ekpan Creek was by Olomukoro and Azubike (2013) studied from January to June 2007. Analyzed heavy metals were Lead, Iron, Zinc, Copper, and Chromium. Variations in chemical parameters showed that station 2 had the highest values recorded in all parameters except for Iron and Zinc, where they were higher at station 1. A total of 1135 individual organisms were recorded. Nineteen (19) macroinvertebrate taxa belonging to four major groups were identified. Mollusca were the most dominant and constituted 92.51% density occurrence, while insecta, crustacean, and polychaeta constituted 1.94, 2.29, and 3.26% respectively. Diversity varied at the study stations, with the highest taxa richness recorded at station 1. Mollusca were positively significantly correlated with lead ($P < 0.05$, $r = 0.836$), and Zinc ($P < 0.05$, $r = 0.96$).

2.2 Sediment Characterization

Sediment characterization involves the assessment and analysis of various properties and components of sediments in aquatic environments (Anani and Olomukoro, 2017). By studying sediment characteristics, researchers can gain valuable insights into the composition, structure, and quality of the sediment, which can provide important information about the health and functioning of the surrounding aquatic ecosystem.

Grain size distribution is a fundamental parameter used in sediment characterization. It refers to the proportion and distribution of different-sized particles, such as sand, silt, and clay, within the sediment. The grain size distribution of sediments can influence various factors, including sediment stability, water flow dynamics, nutrient transport, and the availability of habitats for benthic organisms (Olomukoro and Azubuike, 2009).

The organic matter content of sediments is an essential component of sediment characterization. Organic matter, derived from decaying plants, animals, and other organic sources, plays a crucial role in sediment nutrient cycling, carbon storage, and the overall functioning of the ecosystem.

Assessing the organic matter content can provide insights into the nutrient availability and the potential for sediment decomposition and biogeochemical processes (Mushtaq *et al*., 2015).

Sediment composition refers to the types and proportions of mineral components present in the sediment. It includes the identification and quantification of minerals, such as quartz, feldspar, clay minerals, and others. Sediment composition analysis can provide information about the geological origin of sediments, sediment sources, and potential anthropogenic influences on sediment composition (Sahoo, 2007).

Studying sedimentation patterns is crucial for understanding the spatial and temporal distribution of sediments in a water body. Sedimentation processes, influenced by factors such as hydrodynamics, sediment transport, and land use practices, can have significant impacts on water quality, habitat availability, and ecosystem dynamics. Assessing sedimentation patterns helps in identifying areas of high sedimentation rates and potential sediment sources (Asibor, 2016).

2.3. Sediment-Related Contaminants

Sediments can act as reservoirs for various contaminants, including heavy metals, organic pollutants, and nutrients. Characterizing the presence and concentrations of these contaminants in sediments is important for assessing potential risks to the aquatic environment and the organisms residing in it. Heavy metal analysis and determination of other pollutant concentrations in sediments provide valuable information on the pollution status and potential sources of contamination.

Sediments interact with lake water and soluble constituents in such a manner that they give many unique insights into limnological processes. As a consequence, they provide important basic information on the geochemical origin, dispersion throughout the lake, and limnological fate of soluble and particulate constituents.

Bottom sediments serve as a sink for such contaminants in the aquatic environment (Mucha *et al*., 2000), Gianfreda and Bollag (1996) considers that sediments contain three major components: detritus material derived as a result of erosion, biogenic material formed by biological productivity and autogenous material formed insitu. The final character of the sediment is given by the relative proportion of these components. The sediments are extremely heterogeneous systems where the various phases (solid, liquid and gaseous), biotic components (many microorganisms), small organisms (enzymes) and abiotic components (minerals, humus, organo-mineral aggregates) are involved in physical, chemical and biological processes in these environments (Marcu *et al*., 2017). In addition to this, sediment also impact the quality of water as an outcome of their extremely dynamic nature due to variety of biogeochemical reactions and transformations (Bostrom *et al*., 1988).

Nkwoji and Awodeyi, (2018) studied the impacts of sediment mining on the hydrochemistry and macrozoobenthos community in a coastal lagoon, Lagos, Nigeria. The sediment grain size analysis of the study area indicated the dominance of sand in sediment. This could be as a result of the dredging of the study area as Lagos lagoon is originally known to have muddy substratum. A total of 1,237 organisms belonging to 3 phyla, 4 classes, 10 families and 10 Species were recorded during the study period. Analysis of benthic community structure of the study area reveals a community dominated by mollusks, with the Bivalve, Aloides trigona contributing 54% and the gastropod, Pachymelania aurita contributing 33% of the total benthic fauna assemblage during the period of study. The fluctuations in the physicochemical parameters, sediments, and the composition, abundance and diversity of the macrobenthic fauna of the study area were largely influenced by the anthropogenic activities. In particular, stations with pronounced sediment mining activities recorded highly turbid water, changed substratum type and defaunisation.

Variation of the bottom sediment characteristics such as grain size and moment measures demonstrates the transport processes, selective entrainment transport and deposition (Le Roux *et al*., 2002), as well as the ability of the sediments to absorb organic matter and nutrients onto mineral surfaces. Total organic carbon (TOC) is a measure of the amount of organic matter preserved within sediment, while the amount of sediment nutrients is assessed as total nitrogen (TN) and total phosphorus (TP) coming from organic and inorganic sources (Olomukoro, 2016). Organic matter breakdown (mineralisation) reduces sediment carbon, while nutrient concentrations and dissolved nutrients are released from the sediment to the water column (Olomukoro and Victor, 1999). Sediments are materials formed due to transportation and deposition of organic and mineral matter found at the bottom of oceans, lakes, ponds and rivers, these sediments could be formed from either from allochthonous or autochthonous materials or from both (Mushtaq *et al*., 2015; Gavrilescu *et al*., 2017). The materials ranged fine to coarse grain minerals. Data from sediments provide information on the impact of distant human activity on the wider ecosystem.

Kennedy *et al*., (2002) propose that abundant mineral surface area was a necessary starting condition for the burial and preservation of organic matter and that the bulk of theorganic matter is molecular-scale adsorbed and not particulate. Sedimentation of nutrients is the reverse process of internal loading. Nitrogen settles to the sediment in organic forms, while phosphorus is either sorbed in clay minerals and settles with them on the bed sediments or reacts with Fe, Al, Mn and Ca and mineralizes (Jonsson 1997).

With the increasing anthropogenic pressure on inland fresh water resources because of sewage pollution, ground water Pollution, soil erosion, agricultural and industrial dumping of waste etc., it become highly important to monitor the sediment quality which ultimately accumulate all of these excessive wastes (Olomukoro and Victor, 1999).

Pollutants are conserved in sediments over long periods of time according to their chemical persistence and the physical chemical and biochemical characteristics of the substrata. This can allow conclusions to be drawn regarding sources of contamination. Since sediments act as a sinks and sources of contaminants in aquatic systems, chemical analysis for characterization of sediments also provides environmentally significant information about natural and anthropogenic influence on the water bodies (Nkwoji *et al*., 2010). Understanding the extent to which dominant physical and chemical sediment characteristics influence benthic community structure should provide results that are not only good indicators of change, but are applicable to other systems (Odigie and Olomukoro, 2018).

The environmental quality of the water and the associate components of an aquatic ecosystem cannot be evaluated without the study of bottom sediments characteristics. The presence of organic matter in aquatic systems and liquid wastes has attracted an intensive research interest concerning environmental studies. Variation of the bottom sediment characteristics such as grain size and moment measures demonstrates the transport processes, selective entrainment transport and deposition (Le Roux *et al*., 2002; Gavrilescu *et al*., 2017), as well as the ability of the sediments to absorb organic matter and nutrients onto mineral surfaces (Olomukoro and Victor, 1999; Olomukoro, 2016).

Avramidis *et al*., (2013) carried out a study ascertain the sedimentological characteristics and the water physicochemical parameters of Lysimachia Lake, which is one of the most important lakes of Western Greece, as it is protected by international conventions and is listed in the Natura 2000 European Network. Sedimentological analysis involved grain size analyses, moment measures, total organic carbon (TOC), total nitrogen (TN) and total phosphorus (TP) measurements, as well as determination of the clay minerals content. Water physicochemical parameters such as pH, temperature, conductivity and dissolved oxygen were measured in situ with portable equipment, while nutrients such as nitrates, nitrites, phosphates and ammonium ions, as well as TOC and TN were analyzed in a time period of 1 year seasonal monitoring. Geographical distribution of grain size and geochemical parameters indicated a clear partition in the northern and southern parts of the lake. This phenomenon can related to the discharging of a channel into the lake, the discharging of sewage effluents from Agrinio city during the last years as well as the type of clay minerals distribution. Clay minerals analyses indicated that smectite predominates in the northern part of the lake, whereas chlorite is more abundant in the southern parts. This explain the higher amounts of TOC and TN observed in the northern part of the lake and can be correlated with the higher external surface and adsorption capacity of minerals in the smectite-rich sediments. The four seasons monitoring of water physicochemical parameters indicates a relatively higher values of TOC and TN in the northern part of the lake, while nutrient concentrations indicate a uniform geographical distribution along the lake.

Another study was carried out by Mushtaq *et al*., (2015) aimed at investigating various chemical parameters and to determine the levels of various contaminants in bottom sediments. The data was collected from six different sites for a period of one year (June 2010 to May 2011). pH of the sediment samples ranged from 6.2 (units) to 7.8 (units) and is significantly correlated with conductivity, chloride and nitrate. The range values of chloride, total phosphorus and sulphate of sediments showed wide fluctuations between different sites. Chloride showed significant correlation with total nitrogen and nitrate while total phosphorus was significantly related with sulphate. However, organic carbon, total nitrogen and Nitrate depicted less variation in range values with an overall average value of 8.0 ± 3.7, 1.5 ± 1.0 and 4.1 ± 4.4 respectively. The results of the present investigation suggesting increasing pollution load along the Dal Lake which need to be monitored for the conservation of lake ecology. This summary of the use of sediment information in understanding water quality issues in lakes has demonstrated the need to include sediment measurements and sampling into lake monitoring and assessment programs.

By conducting a comprehensive sediment characterization, this study aims to gain insights into the sediment properties, composition, and contamination levels in the Aghuakuari River. The results will contribute to a better understanding of the river's ecological health, sediment dynamics, and potential impacts on the associated biota, including benthic macroinvertebrates.

2.4 Zoobenthos

Zoobenthos, also known as benthic macroinvertebrates, are organisms that inhabit the sediment and benthic zones of aquatic ecosystems. They play a crucial role in the ecological functioning of rivers, serving as indicators of environmental quality and ecosystem health. The study of zoobenthos involves the identification, enumeration, and analysis of these organisms to assess the biological communities and their responses to environmental changes.

Zoobenthos serve as important ecological indicators due to their sensitivity to environmental changes and pollution. They can reflect the effects of habitat alteration, water quality degradation, and contamination on the ecosystem. By studying the composition, abundance, and diversity of benthic macroinvertebrates, researchers can infer the ecological condition and functioning of the river system. Changes in zoobenthic communities over time or across different sites can provide insights into the impacts of human activities and guide conservation and management efforts.

Amusan *et al*. (2018) analyzed heavy Metals Assessment in Water, Sediments and Selected Aquatic Organisms in Lake Asejire, Nigeria. A total of 617 individuals macroinvertebrate belonging to 29 species were collected. Ona River was dominated by Chironomid larvae while Opa River was dominated by Trichoptera species. Margalef' species richness and Shannon-wiener's species diversity indices both revealed that Opa River is higher in terms of species richness and diversity.

Neetu *et al*. (2019) studied the diversity, composition and abundance of benthic macroinvertebrates and water quality of a sewage fed fish pond located at Pahari close to south Patna for two years. This pond receives treated sewage from an aerated lagoon Sewage Treatment Plant of 25 MLD capacities. Samples were collected from September 2007 to August 2009 on monthly basis. Twelve species of benthic macro-invertebrates were recorded, out of which one belonged to Bryozoa, four to Oligochaeta, two Insecta and five Gastropoda. The range, mean and standard deviation of macro-benthos have been calculated. Species composition (%) was found to be highest in Gastropods (41.67) followed by Annelida (33.33), Insecta (16.67) and then Bryozoa (8.33). So far the number of individuals are concerned, insecta dominated the benthic community in the pond constituting 58.15% (2007-08) and 43.89% (2008-09) followed by Oligochaeta, Gastropoda and Bryozoa. The Shannon's species diversity index of benthic macro-invertebrates in the pond ranged between 0.9—2.1 with a mean value of 1.58 ±0.325 showed that the pond is moderately polluted.

Iloba *et al*. (2019) carried out a study to evaluate the Macroinvertebrate of river Ethiope, Delta state, Nigeria. Macroinvertebrate samples were collected from threes communities; Obi- Iloh, Ebedei-Adonishaka, Ebedei Obi-Ukwuole designated as Station 1, 2 and 3 respectively, that forbids women entrance but allows men folk to sand dredge. The survey conducted between March and April, 2015, identified 17 taxa of macro invertebrate with 219 individuals. Of the nine order, Hemiptera constituted the most abundant set 42.25%, followed by Decapoda 16.90%, Coleoptera 11.74%, Plecoptera and Arachnida 6.57%, Odonata 5.16%, Diptera 4.23%, Annelida (Lumbriculida and Arhynchobdelida) 3.76% and the least Trichoptera 2.82%. However, nonstatistical significant richness exists among these organisms at the stations ($p \geq 0.05$). Computed biological indices and lower macro invertebrates census revealed that the macro invertebrates were more abundant in stations 3 and 1 than in station 2, identifying the last two stations as unstable and moderately deteriorated. The enlisted significant correlated variables expressed manifold hydrological factors pinpointing human disturbance as impact. Relationships between environmental factors and benthic invertebrate communities are essential to understand how communities are structured by the physical and chemical properties of their environment (Idowu and Ugwumba, 2005). Bazzanti and Seminara (2004) state that differences in abundance and species composition of benthic organisms are due to differences in physical and chemical characteristics of individual aquatic systems.

Usman and Adakole (2017), evaluated the diversity of some benthic macroinvertebrates in Ajiwa reservoir, Kastina State. The study was spanned from September, 2014 to August, 2015. Benthic macro invertebrate samples were collected with the aid ofEkman grab at 5different sampling locations once monthly. Samples collected were sieved with a set of Tyler sieves of 20cm diameter and mesh sizes of 2mm, 1mm, and 150µm respectively and transferred into labelled plastic storage bottle and preserved with 4% formalin prior to sorting and identification with the aid of some keys. Twenty-four (24) taxa from a total of 1420 individual’s organisms were recorded. These include 5 species each of Mollusca and Diptera, 1 species of Odonata, 4 species of Hemiptera and 3 species each of Coleoptera, Oligochaete and Nematoda. The relative percentage composition of the major taxonomic groups to the overall macro benthic population at the different stations revealed that the study area was inhabited by Oligochaete (40.28%), Molluscs (24.08%), Diptera (19.29%), Odonata (5.78%), Coleoptera (3.94%), Nematodes (3.38%) and Hemiptera (3.24%).The indices of general diversity (H), evenness (E), dominance and relative abundance were in the following order of increasing magnitude: station 5 > station 1 > station 4 > station 2 and > station 3 respectively. Factors which influenced the abundance and distribution of invertebrates; including the nature of the water body, habitat richness and stability, immediate substrate, tropic condition, resourcepartitioning and predation coupled with habitat differences observed in this study, acted singly or in combination to influence the variation in abundance of benthic macro invertebrate of Ajiwa Reservoir.

Benhtic Macroinvertebrates forms an integral part of an aquatic environment and are of ecological and economic importance (Efitre, *et al*., 2001). They also play a key role in mineralization of organic matter and serve as food for economically important fish and shellfish species in most aquatic environments (Olomukoro and Egborge 2003). The relative stability of benthic communities and their sensitivity to changes in the aquatic environment have made many species as bio-indicators of water quality (Ogbeibu and Oribhabor, 2001). Their long larval life cycles allow studies conducted by aquatic ecologists to determine any decline in environmental quality (Ajao and Fagade, 2002).

Nkwoji *et al*., (2010), studied the water chemistry and benthic macroinvertebrates of a south-western lagoon, Lagos, Nigeria was studied in July, 2008 and March, 2009 representing wet and dry seasons respectively. The salinity ranged from 0.0 0/00 in the wet season indicating a typical freshwater condition to 32.0 0/00 in the dry season indicating a marine condition. Higher Dissolved Oxygen values were recorded in the wet season than in the dry season.47.47% of the total organisms was sampled in the wet season while 52.53% was collected in the dry season. Species diversity was also higher in the dry season than the wet season. Tellina nymphalis, Clibanarius africana, and Penaus notialis sampled in the dry season were absent in the wet season. Only one species (Crassostrea gazar) sampled in the wet season was absent in the dry season. There was an indication of a general defaunisation of this lagoon for which reasons including pollution of the lagoon are plausible.

Odigie and Olomukoro, (2017) carried out research to ascertain the evaluation of Oligochaeta fauna of Ozomu Lake. The research spanned for twelve months. From the research, it can be deducted that a total of 23 Oligochaeta taxa from a total of 271 individuals comprising of 14 species of Naididae family, 2 species of Aeolosomatidae family, and 7 species of Tubificidae family. It was observed from the research that the impact of seasonal variations, human activities and environmental factors influencing the distribution and abundance of Oligochaeta.

Udaghe, (2019) conducted a study on Ozomu Lake in Edo state, between March and December 2013. It aimed at determining the macroinvertebrate community structure of the lake. From the research, a total of thirty-eight (38) taxa which comprises of 2276 individuals were collected. Plesiopora accounted for 1.14%, Haplotaxida 3.29%, Cyclopoidea 0.57%, Odonata 9.62%, Ephemeroptera 13.32%, Hemiptera 20.12%, Coleoptera 9.62%, Trichoptera 0.70%, Diptera 30.71%, Araneida 8.40%, Prostigmata 2.33%, Mesogastropoda 0.18%. The family Baetidae (Ephemeroptera), Culicidae, Chironomidae (Diptera), Gerridae, Pleidae (Hemiptera), and Dytiscidae (Coleoptera) were the most abundant species. The diversity indices revealed that taxa richness was highest in station 1 and lowest in station 2. Shannon- Wiener and Evenness index were higher in stations 1 and 3 than station 2. The macro invertebrate fauna was abundant during the rainy season than the dry season because the volume of water in the lake was reduced during the dry season. The dipterans of Ozomu Lake preferred bottom sediment habitat, surface water habitat than allochthonous habitat. The highest number of macrobenthic invertebrate was recorded in stations1 and 3, where there was restriction of human activities. However, human activities disturb the community of macro-benthic invertebrates in this ecosystem.

There is a need for freshwater ecologists to investigate the developments in zoobenthos ecology in Lakes and other freshwater ecosystems. Furthermore, zoobenthos plays a vital role biomonitoring, as their presence or absence in a water body serves as a pointer to the true quality of water, be it in a fresh, brackish or, marine water ecosystem (Odigie and Olomukoro, 2017; Udaghe, 2019).

Nkwoji *et al*. (2010) studied the water chemistry and benthic macroinvertebrates of a south-western lagoon, Lagos, Nigeria. The salinity ranged from 0.0 0/00 in the wet season indicating a typical freshwater condition to 32.0 0/00 in the dry season indicating a marine condition. Higher Dissolved Oxygen values were recorded in the wet season than in the dry season.47.47% of the total organisms was sampled in the wet season while 52.53% was collected in the dry season. Species diversity was also higher in the dry season than the wet season. Tellina nymphalis, Clibanarius africana, and Penaus notialis sampled in the dry season were absent in the wet season. Only one species (Crassostrea gazar) sampled in the wet season was absent in the dry season. There was an indication of a general defaunisation of this lagoon for which reasons including pollution of the lagoon are plausible.

Iyagbaye *et al*. (2017) studied the diversity and seasonal variation of benthic macroinvertebrates of Ovia River (Iguoriakhi), Edo State, Southern Nigerian. Four stations were selected and sampled monthly and investigated for benthic macro-invertebrates' community structure using basic statistical measurement of abundance and diversity indices to characterize the benthic macroinvertebrates. The species richness, evenness and diversity of the benthic macro-invertebrates in the study area were high and typical of a tropical fast-flowing freshwater river. There was a total of 45 taxa, made up of 1,135 individuals; 10 Ephemeroptera, 10 Diptera, 7 Coleoptera, 7 Odonata, 4 Hemiptera, plasiopora, Haplotaixa, Decapoda, Hydrachnellae, Lepidoptera, Gastropoda, and Trichoptera were represented with a taxon each. The dominant taxa include Ephemeroptera, while the Diptera was the only sub-dominant order identified. Analysis of Variance (ANOVA) revealed that the overall density was significantly different ($P < 0.05$) in the study stations. A posteriori Duncan Multiple Range (DMR) test indicated that the abundance of Dipterans and

Ephemeropterans at station 2 and 4 respectively were the source of the significant difference. The

EPT to total ratio indicated that the water quality of all the studied stations were non impacted.

The study concluded that benthic macro-invertebrates are good candidate and less expensive

indices for water quality monitoring.

Andem *et al*. (2014) studied the macroinvertebrates community of Ediba River in Cross River State. Sixteen genera, belonging to nine orders and a total of 289 individuals were encountered. The dominant groups in the order were Oligochaeta (29.1%)>Diptera (24.62%)>Odonata (20.3%), showing insignificant difference between the three stations at $p>0.05$. Taxa richness was highest in Station 1 (2.985) and least in Station 3 (1.008) showing insignificant differences across station ($p>0.05$). Evenness ranges from 0.337 to 0.369 showing significant difference across stations (p >0.05. Taxa richness was highest in Station 1 (2.985) and least in Station 3 (1.008) showing insignificant differences across station ($p>0.05$). Evenness ranges from 0.337 to 0.369 showing significant difference across stations ($p<0.05$). Station 1 had a PTI value of 39 indicating good quality water status, while Stations 2 and Station 3 had PTI values of 6 and 4 respectively indicating poor quality water status. The abundance of pollution tolerance species of the orders, Odonata Zygoptera, Oligochaeta, Diptera and the absence of pollution sensitive species of the orders, Ephemeroptera and Trichoptera in Stations 2 and 3 indicated the poor waters quality, coupled with the low PTI values in both stations, hence need for proper management of the river.

CHAPTER THREE

MATERIALS AND METHODS

3.1 Study Area

3.1.1 Geographical Location of study area

The study was carried Aghuakuari community situated in Ovia North East Local Government Area, Edo State, within the rainforest belt of Southern Nigeria lies between Latitude $6^0$182'11''N Longitude $5^0$50.13''E. The river flows into Ogba River and is feed by several surrounding waterbodies. The river is most characterized by sandy and coarse substratum, with three sampling stations chosen. The map of the study areas is shown in Figure 1

3.1.2 Climate

The climate of the Edo state and its surrounding regions is tropical, but it exhibits variations that prevent complete uniformity. This study area experiences two distinct seasons. The dry season, spanning from November to either early or late March, is characterized by reduced humidity levels and elevated atmospheric temperatures. On the other hand, the rainy season takes place from April to November across.

Rainfall patterns demonstrate diversity across the region, ranging from approximately 150cm in the northern parts of the state to around 250cm in the southern areas. Temperature profiles exhibit fluctuations as well, with average readings ranging from 25°C during the rainy season to 28°C throughout the dry season. The climate is generally classified as humid tropical in the southern portions of the state and sub-humid in the northern regions.

April stands out as the warmest month, boasting an average temperature of 27.5°C. In contrast, July records the lowest average temperature of the entire year, at 24.5°C. Notably, January emerges as the driest month, receiving a mere 9mm of rainfall. Conversely, September experiences the highest precipitation levels, averaging around 338mm (Floyd and Ekene, 2016).

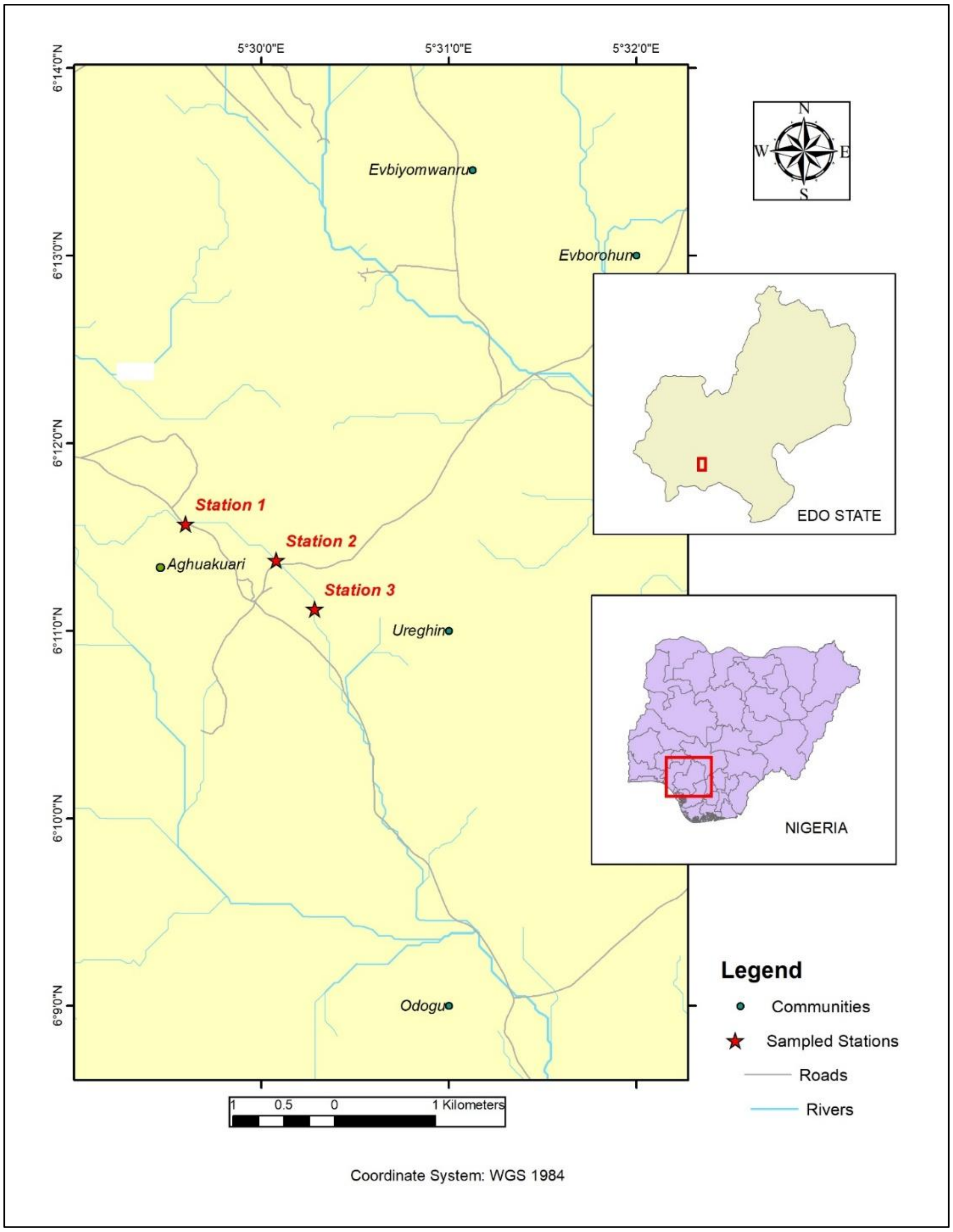

Figure 3.1: Map of Study area showing the three stations sampled during the period of study.

3.1.3 Vegetation and land use

The study area finds itself encompassed by towering trees, particularly palm trees, which consequently drive the primary activity in the community – the production of palm wine. The prevailing vegetation encircling the station encompasses the rubber plant (*Hevea brasiliensis*) and bamboo trees (*Bambus* sp). Some of these trees naturally shed their leaves into the water, contributing to a heightened accumulation of decomposing organic matter. Additionally, there exists an assortment of shrubs and grasses, prominently featuring *Nephrolepis biserrata* (sword fern) and *Axonopus compressus*. The aquatic environment is further adorned by substantial floating aquatic plants, including Nymphaea lotus (water lily) and *Eichhornia* sp (water hyacinth).

The river serves as a vital natural water source for both agricultural and domestic purposes. It can be categorized into three distinct zones: the littoral zone, the photic or open water zone, and the profundal or benthic zone.

3.2 Description of sampling stations

For the purpose of this study, three locations were chosen and the co-ordinates of the sampling stations were taken using Geographic Positioning System (GPS).

3.2.1 Station 1

Station 1 is positioned between Latitude 6° 192' 072"N and Longitude 5° 496' 292"E (as depicted in Plate 1). This particular station features an average depth of approximately 2.5 meters. The prevailing plant species at this location are primarily ferns, accompanied by the presence of *Elaeis guineensis* (palm trees) and several types of grasses. Human activities with potential environmental impacts are noticeable, including the consistent disposal of waste by neighboring households situated in close proximity to the River.

3.2.2 Station 2

Station 2 is situated between Latitude 6° 188' 624"N and Longitude 5° 500' 392"E (as illustrated in Plate 2). This station exhibits an average depth of approximately 2.3 meters. Human interactions leave their mark on this location, with occasional fishing activities occurring, particularly during the wet seasons. Additionally, traditional worship practices take place in the vicinity.

The station's vegetation profile showcases a dense presence of *Hevea brasiliensis* (rubber plants) and *Bambusa* sp (bamboo trees). Amidst this verdant backdrop, a select few dominant aquatic plant species thrive, including *Nymphaea lotus* (water lily) and *Ludwigia decurrente* (water primrose).

3.2.3 Station 3

Station 3 occupies a distinct geographical position, precisely identified by its coordinates of Latitude 6° 188' 019"N and Longitude 5° ' 501. 132"E (depicted on Plate 3). The station's aquatic environment is characterized by an average depth of approximately 2.7 meters, contributing to its unique ecological profile. Notably, this station stands at a notable distance of 16 meters from station two, adding to the diversity of the study area.

Within this dynamic setting, a range of plant life thrives. *Bambusa* sp and *Hevea brasiliensis*, commonly known as rubber plants, are prominent components of the vegetation composition. Their presence interplays with the aquatic ecosystem, influencing its balance and interactions.

Furthermore, the aquatic environment at this station is also influenced by the presence of aquatic weed species. These submerged and floating plants contribute to the complex web of interactions within the water body. Such diversity of plant life not only shapes the physical landscape but also plays a pivotal role in the ecological dynamics of the station.

Plate 3.1: An overview of Station 1.

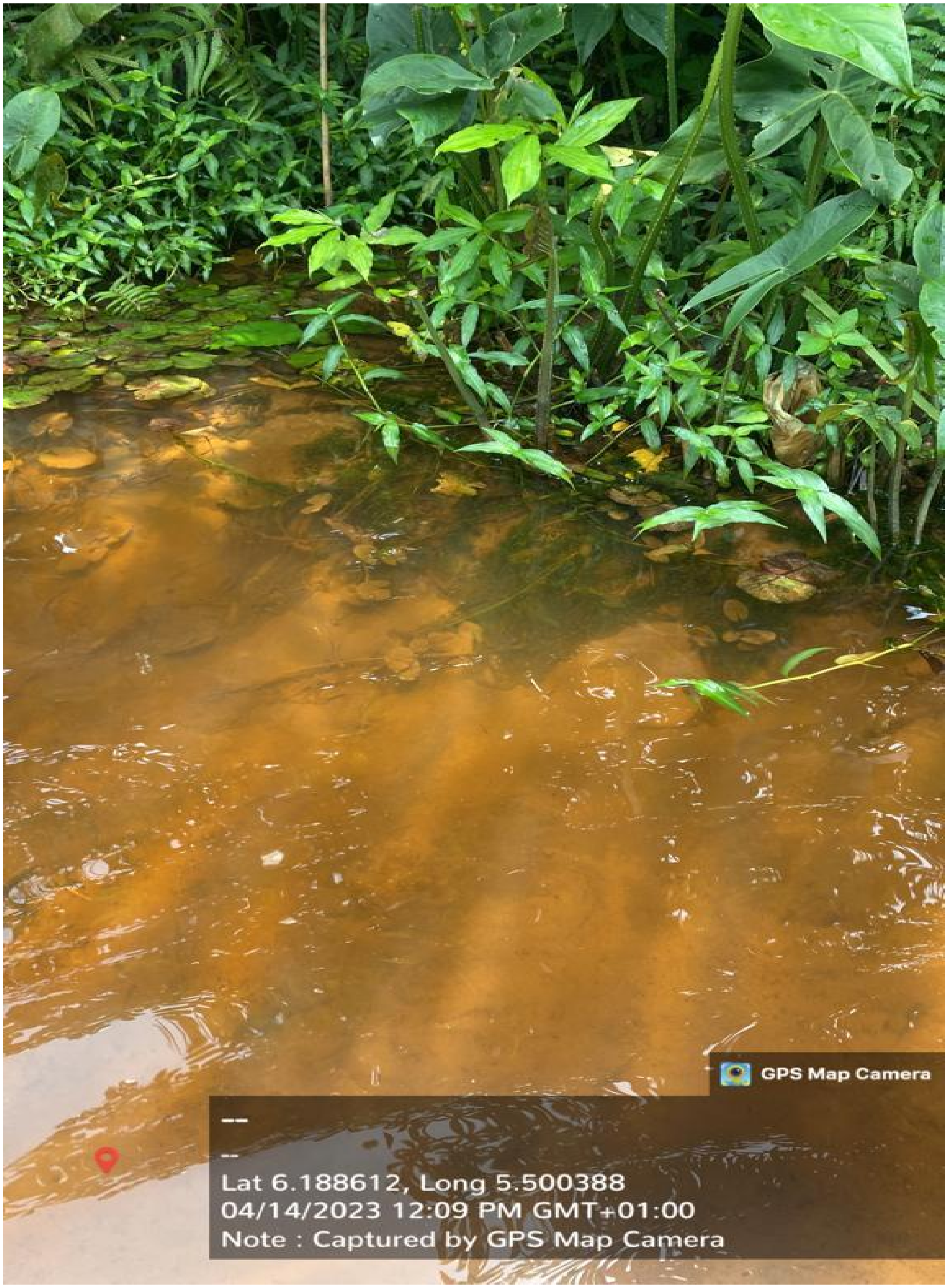

Plate 3.2: An overview of Station 2.

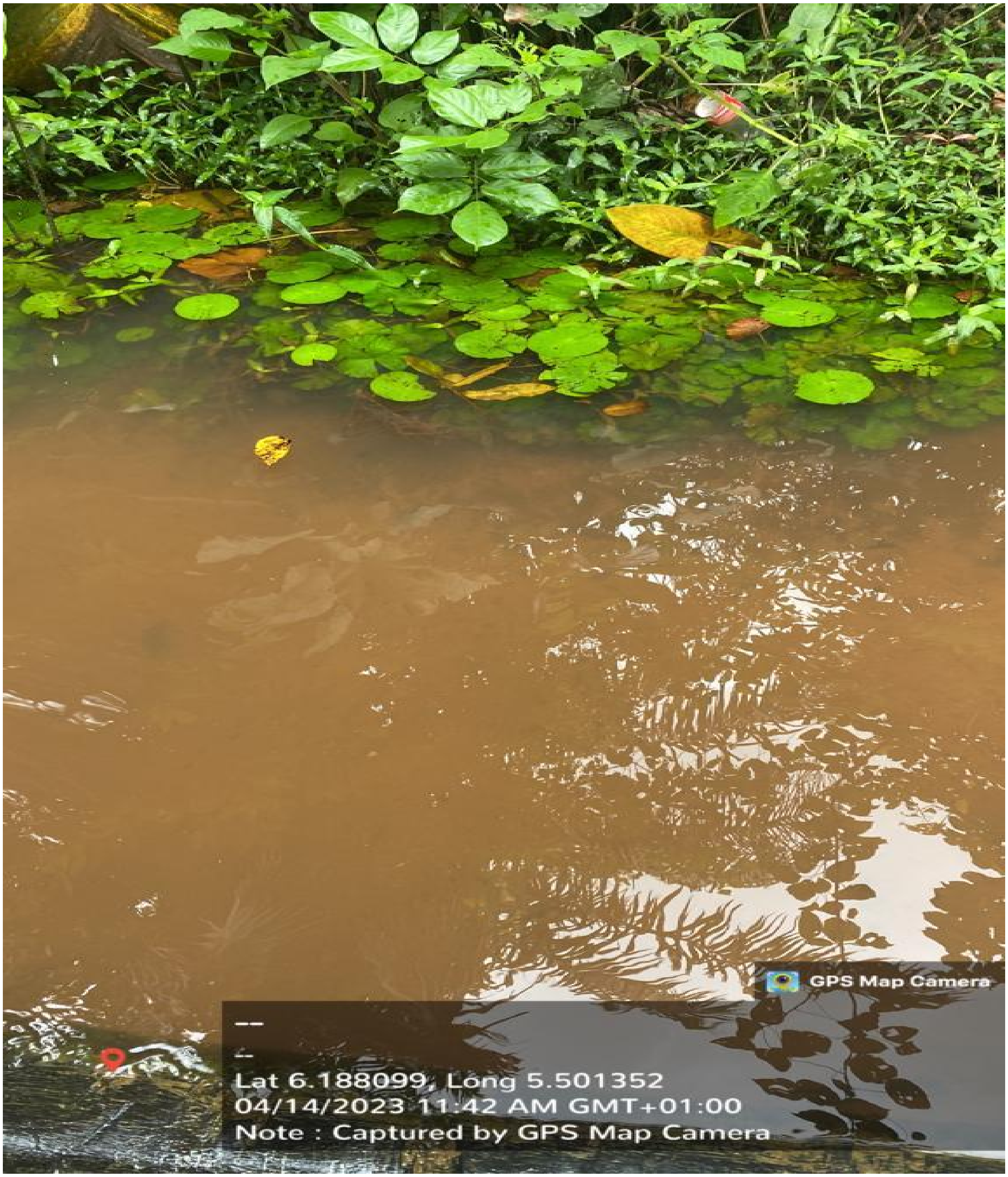

Plate 3.3: An overview of Station 3

3.3 Sampling techniques

Sampling activities encompassed both sediment and benthic organisms, diligently collected from the three predetermined sampling stations. This rigorous process was carried out bi-monthly, indicating a frequency of twice a month, specifically on a fortnightly basis. The comprehensive sampling efforts spanned over a span of four months, commencing from May 2023 and extending through August 2023.

3.3.1 Sediment sampling

Sediment samples were collected with an Ekman Grab as recommended for sand and silt (Hynes, 1961). Contents trapped by the grab were processed as described by Victor and Ogbeibu (1991) and Olomukoro and Victor (1999). Three hauls were made at each sampling stations by sending the grab down into the bottom and using the messenger to close and grab some quantity of sediment.

3.3.2. Determination of Heavy Metals in Soil/Sediments

Water samples were filtered through Whatman No. 42 filter paper and made up to 50ml with distilled water. It was then transferred for analysis using buck scientific atomic absorption spectrophotometer

Sediment samples were thawed and then dried at 100C for 24hrs. One gram (accurate to 0.01mg) of a finely ground, homogenized sediment sample was weighed into a 100ml Erlenmeyer flask to which 20ml concentrated nitric acid and 10ml perchloric acid were added.

The acid digestion was performed on a hot plate (200-250C) for at least 5hrs, during which clearing of the sample was achieved (Van Loon, 1980). Each sample was then made up to 50ml with double distilled water.

All heavy metals were measured with Buck Scientific 210VGP Atomic Absorption Spectrophotometer by specific cathode lamp using wavelength for respective heavy metals.

Conc. (ppm) = (A-B) x 100

A = Concentration of metal in sample

B = concentration of metal in the blank

100 = final volume of extract

3.4 Determination of Total organic carbon, Total organic matter, particulate matter in the soil samples

3.4.1 Determination of % Organic Carbon in Soil/Sediments

About 50g of air dried fine earth which has been passed through the 2mm sieve was ground to a fine consistency. The grounded sample was passed through the 0.5mm sieve. A sample of soil was weighed containing about 0.5g of carbon and put in a conical flask. 10ml of $K_2Cr_2O_7$ was added and then 10ml of concentrated H_2SO_4. It was then shaken for 1minute and the mixture was allowed to cool on an asbestos sheet. 60ml of distilled water was added and then 5ml of phosphoric acid and 10ml of diphenylamine solution till it become dark violet colour, it was titrated with 0.4N ferron ammonium sulphur solution until the colour turned to green. Then a blank determination was carried out by using 10ml of $K_2Cr_2O_7$ solution. The blank determination must be carried out with each batch of determination.

Calculation: % C = Titer × 0.24

% C = BK – Titer × 0.24 (APHA, 1998).

3.4.2 Determination of % Particle Size Analysis for Soil Texture (Hydrometer Method)

Weighed 40.0 ± 0.05 g of air-dried soil pulverized passed 10 mesh sieve (<2.0mm) into 200mL container. The soil sample was oven dry soil moisture on a 2nd sample of soil. 100 mL of HMP solution was added then cap and placed on reciprocating horizontal shaker for sixteen (16) hours. The suspension was quantitatively transfered to the sedimentation cylinder and deionized water was added to bring to 1.0 L final volume. The suspension was allowed to equilibrate to room temperature for two (2) hours. The plunger was inserted and thoroughly mix contents, dislodging sediment from the bottom of the cylinder. As an alternative mixing procedure stopper the cylinder and use end over end shaking for one (1) minute. 2 mL of amyl alcohol was added to the surface to suspensions covered in foam. The process was repeated and determine hydrometer reading on a blank solution and to the nearest ±0.5 g L-1 as "RC1". Lower the hydrometer carefully into the suspension after thirty (30) second sand take a reading after forty (40) second sand record to the nearest ±0.5 g L-1 as "R sand". Remove the hydrometer carefully, rinse and wipe dry. After six (6) hours record temperature of the suspension to the nearest ±1oC. Based on time after initiation of settling, reinsert the hydrometer carefully and take a reading and record as "R clay" to the nearest ±0.5 g L-1. The process was repeated determining hydrometer reading on a blank solution and record as "RC2" to the nearest ±0.5 g L-1.

CALCULATIONS:

Report results to the nearest 0.1% content:

1. Sand % = ((oven dry soil mass) – (Rsand – RC1))/ (oven dry soil mass) x 100

2. Clay % = (Rclay – RC2) / (oven dry soil mass) x 100

3. Silt % = 100 – (Sand % + Clay %) (APHA, 1998).

3.5 Benthic Macroinvertebrates sampling

Sediment samples were composited and placed in a small bucket, Water was added to the sample and hand-mixed gently to break up lumps of sediment, the sample was mixed with salt to agitate the organism and then left to stay for like 10 minutes. The sample slurry was then poured from the sieve which was placed over a second bucket to catch the rinse water. The sediment was then washed through the mesh with water at very low pressure (Excessive pressure would result in damage to organisms, and could comprise taxonomic analysis of the sample). The sieve was gently agitated to aid in rinsing the fine sediment out of the sample. (It is also necessary to sieve the slurry in small portions to prevent clogging of the mesh). The sample was continuously rinsed with surface water until all sediments have been removed, leaving behind any sediment-dwelling invertebrates. The loosened organisms were collected into the labelled benthic bottles.

The benthic samples were transferred from the bucket to benthic bottles (i.e. the sample containers) and preserved in enough 10% formalin to cover the samples (Higher concentration of formalin may alter the taxonomic features of the benthic organisms). A sample identification label that includes date, sampling location and collector name is placed on the benthic bottle.

3.6 Sorting, identification and counting of Macrobenthic fauna

3.6.1 Sorting

The Benthic Macroinvertebrates were sorted into various using the American optical dissecting, with a magnification of 25 to 40x and also with the aid of the magnifying lens for the large organisms. The samples were put in a glass petridish and illumination from above was used to sort the organisms out of the samples. The samples sorted were preserved in 4% formalin.

3.6.2 Identification and Counting

The sorted organisms were identified with appropriate taxonomic keys of Ogbeibu, (2000) and Olomukoro, (1983) and to the lowest possible taxonomic level using the Olympus binocular compound microscope and magnifying lens.

3.7 Statistical analysis

Analysis of Variance (ANOVA) in addition to the computation of mean and standard deviation (SD) was used to test significant difference of the physical and chemical condition across the three stations using Statistical Package for Social Scientists (SPSS) 22 and the Microsoft Excel 2016, Windows 8 application.

Correlation coefficient of physical and chemical parameters and benthic organisms of the River were computed using the Microsoft Excel 2016, Windows 10 application.

3.7.1 Estimation of fauna diversity

Hutcheson's t-test was used in calculating the significance of dominant taxa of Benthic Macroinvertebrates distribution and significant difference in their diversity indices by the application of the Paleontological Statistics software package for education and data analysis (PAST version 2.12).

The taxa richness of the Benthic Macroinvertebrates involves:

3.7.2 Shannon Weiner index

This was expressed using Shannon Weiner index as;

H =

Where N = sample size

ni = no of individual in a species

(Shannon and Weiner, 1963).

3.7.3 Evenness index

This expresses the degree of uniformity in the distribution among the species in the collections.

E =

Where H1 = Shannon Weiner's index

H*max* or logs = the maximum expected diversity (Zar, 1983).

K = number of species

3.7.4 Margalef index

This was calculated using the margalef's index (d).

d =

Where S = no of species

In = natural logarithm

N = total no of individuals (Margaleff, 1996).

CHAPTER FOUR

RESULTS

The Heavy metals and Sediment Characterization of soil/sediment of the study stations along a stretch of is Aghuakuari River presented in Table 4.1. The table shows the mean, standard deviation, minimum and maximum values for each parameter analysed for the different stations.

4.1 Heavy metal and Sediment Characterisation

4.1.2 Iron (Mg/L)

The ranges of iron concentration at stations 1, 2, and 3 were 310.11– 357.60 mg/l, 322.11 – 449.51 mg/l, and 323.43– 371.05 mg/l respectively. The mean iron concentration value at stations 1, 2, and 3 were 329.53 mg/l, 411.60 mg/l, and 337.56 mg/l respectively. No significant difference was obtained across the stations when the values were compared ($P>0.05$). Spatial and monthly variation in iron is shown in Fig. 4.1.

4.2.2 Lead (Mg/L)

The extent of lead spanned between 0.30 – 0.60 mg/l in station 1, 0.50 – 1.20 mg/l in station 2, and 0.50 – 0.91 mg/l in station 3. The mean values were 0.45 mg/l, 0.94 mg/l, and 0.69 mg/l respectively for stations 1, 2, and 3. No significant difference were obtained across the stations when the values were compared ($P>0.05$). Spatial and monthly variation in lead is shown in Fig. 4.2.

4.2.3 Copper (Mg/L)

The values of copper ranged between 13.95 – 29.00 mg/l in station 1, 10.05 – 22.00 mg/l in station 2, and 13.82 – 23.00 mg/l in station 3. The mean values were 24.72 mg/l, 17.23 mg/l, and 18.86 mg/l respectively for stations 1, 2, and 3. No significant difference were obtained a cross the stations when the values were compared (P>0.05). Spatial and monthly variation in copper is shown in Fig. 4.3.

4.1.4 Zinc (Mg/L)

The values of Zinc ranged between 27.95 – 43.69 mg/l in station 1, 19.10– 27.53 mg/l in station 2, and 19.62 – 32.97 mg/l in station 3. The mean values were 35.09 mg/l, 24.69 mg/l, and 29.19 mg/l respectively for stations 1, 2, and 3. No significant difference were obtained across the stations when the values were compared (P>0.05). Spatial and monthly variation in zinc is shown in Fig. 4.4.

4.1.5 Cadmium (Mg/L)

The highest mean concentration of Cadmium (0.24 mg/l) and the lowest mean concentration of (0.14 mg/l) were recorded at station 1 and 2 respectively. The values of Cadmium at station 1, 2 and 3 ranges from 0.19 – 0.29 mg/l, 0.12 – 0.21 mg/l and 0.20 – 0.23 mg/l respectively. No significant difference (P>0.05) was obtained when the values were subjected to one-way ANOVA. Spatial and monthly variation in Cadmium is shown in Fig. 4.5.

4.1.6 Manganese (Mg/L)

The highest mean concentration of manganese (0.42 mg/l) and the lowest mean concentration of manganese (0.41 mg/l) were recorded at station 2 and 1 and 2 respectively. The values of manganese at station 1, 2 and 3 ranges from 0.13 – 0.60 mg/l, 0.15 – 0.60 mg/l and 0.91 – 0.60 mg/l respectively. No significant difference (P>0.05) was obtained when the values were subjected to one-way ANOVA. Spatial and monthly variation in manganese is shown in Fig. 4.6.

4.1.7 % Organic Carbon (mg/kg)

The % organic carbon concentration in sediment varied from 0.23 – 1.40 mg/kg in station 1, 0.22 – 1.11 mg/kg in station 2 and 1.10 – 1.40 mg/kg in station 3. The mean values are 1.01 mg/kg, 0.68 mg/kg and 1.18 mg/kg for stations 1 to 3 respectively. Variation in the mean values of % organic carbon concentration showed no significant difference (P>0.05). Spatial and monthly variation in % organic carbon is shown in Fig. 4.7.

4.1.8 % Organic Matter (mg/kg)

The % organic matter concentration in sediment varied from 0.40 – 2.50 mg/kg in station 1, 0.30 – 2.20 mg/kg in station 2 and 1.94 mg/kg to 8.20 mg/kg in station 3. The mean values are 2.21mg/kg, 1.10 – 2.40 mg/kg for stations 1 to 3 respectively. Variation in the mean values of % organic matter concentration showed no significant difference (P>0.05). Spatial and monthly variation in % organic matter is shown in Fig. 4.8.

4.1.9 % Sand (mg/kg)

The % sand concentration in sediment varied from 90.00 – 97.00 mg/kg in station 1, 90.00– 97.00 mg/kg in station 2 and 90.00– 96.00 mg/kg in station 3. The mean values are 93.50 mg/kg, 92.25 mg/kg and 93.25 mg/kg for stations 1 to 3 respectively. Variation in the mean values of % sand concentration showed no significant difference (P>0.05). Spatial and monthly variation in % sand is shown in Fig. 4.9.

4.1.10 % Silt (mg/kg)

The % silt concentration in sediment varied from 3.00– 10.00 mg/kg in station 1, 3.00 –10.00 mg/kg in station 2 and 4.00 – 10.00 mg/kg in station 3. The mean values are 6.50 mg/kg, 7.75 mg/kg and 6.75mg/kg for stations 1 to 3 respectively. Variation in the mean values of % silt concentration showed no significant difference (P>0.05). Spatial and monthly variation in % silt is shown in Fig. 4.10.

4.1.11 % Clay (mg/kg)

The % clay concentration in sediment varied from 0.00– 0.00 mg/kg in station 1, and station 2 and 0.00– 0.20 mg/kg in station 3. The mean values are 0.00 mg/kg and 0.01 mg/kg for stations 1, 2 and 3 respectively. Variation in the mean values of % clay concentration showed no significant difference (P>0.05).

Table 4.1: Summary of Heavy Metals and Sediment Characterisation in Sediments of Aghuakuari River

Parameters	Station 1	Station 2	Station 3	P value
	Mean±SD (Min – Max)	Mean±SD (Min – Max)	Mean±SD (Min – Max)	
Iron	329.53±23.47	411.60±30.04	337.56±22.67	*p > 0.05*
	(310.11– 357.60)	(322.11 – 449.51)	(323.43– 371.05)	
Lead	0.45±0.13	0.94±0.32	0.69 – 0.17	*p > 0.05*
	(0.30 – 0.60)	(0.50 – 1.20)	(0.50 – 0.91)	
Copper	24.72±7.19	17.23±5.11	18.86±3.79	*p > 0.05*
	(13.95 – 29.00)	(10.05 – 22.00)	(13.82 – 23.00)	
Zinc	35.09±7.34	24.69±3.86	29.19±6.39	*p < 0.05*
	(27.95 – 43.69)	(19.10– 27.53)	(19.62 – 32.97)	
Cadmium	0.24±0.05	0.14±0.05	0.22±0.01	*p > 0.05*
	(0.19 – 0.29)	(0.12 – 0.21)	(0.20 – 0.23)	
Manganese	0.41±0.20	0.41±0.19	0.42±0.21	*p < 0.05*
	(0.13 – 0.60)	(0.15 – 0.60)	(0.91 – 0.60)	
Organic carbon	1.01±0.53	0.68±0.49	1.18±0.15	*p < 0.05*
	(0.23 – 1.40)	(0.22 – 1.11)	(1.10 – 1.40)	
Organic matter	1.80±0.97	1.22±0.96	1.83±0.54	*p < 0.05*
	(0.40 – 2.50)	(0.30 – 2.20)	(1.10 – 2.40)	
% Clay	0.00±0.00	0.03±0.05	0.08±0.09	*p < 0.05*
	(0.00– 0.00)	(0.00 – 0.10)	(0.00– 0.20)	
% Silt	6.50±3.10	7.75±3.20	6.75±2.50	*p < 0.05*
	(3.00– 10.00)	(3.00 –10.00)	(4.00 – 10.00)	
% Sand	93.50±3.10	92.25±3.20	93.25±2.50	*p < 0.05*
	(90.00 – 97.00)	(90.00– 97.00)	(90.00 – 96.00)	

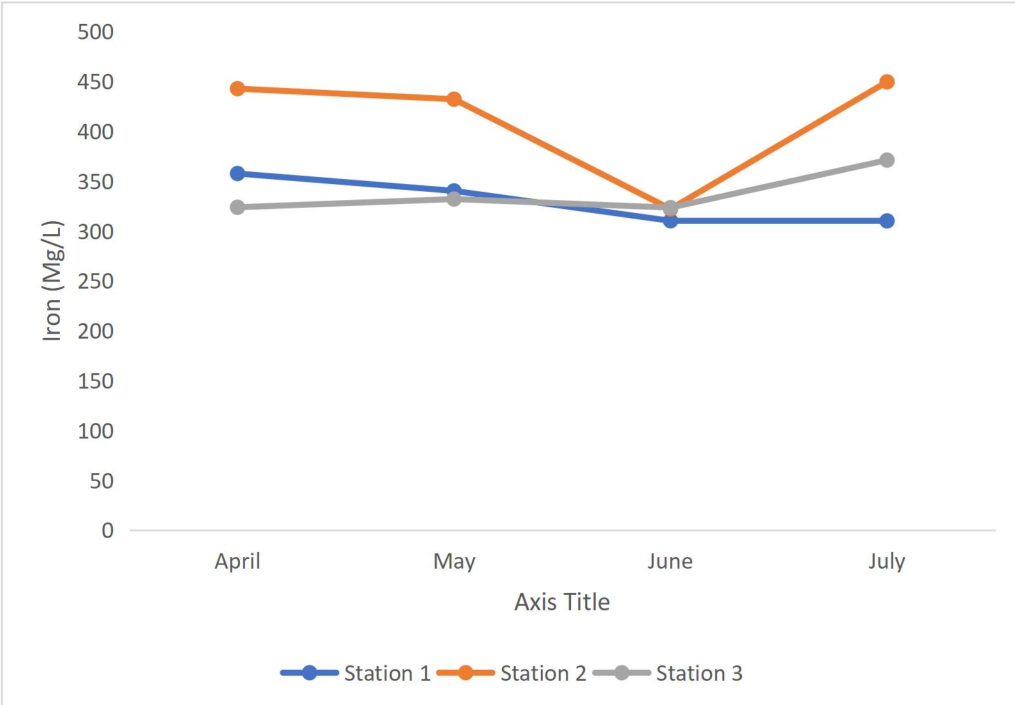

Figure 4.1: Spatial and Temporal Variation in Iron Concentration of Aghuakuari River

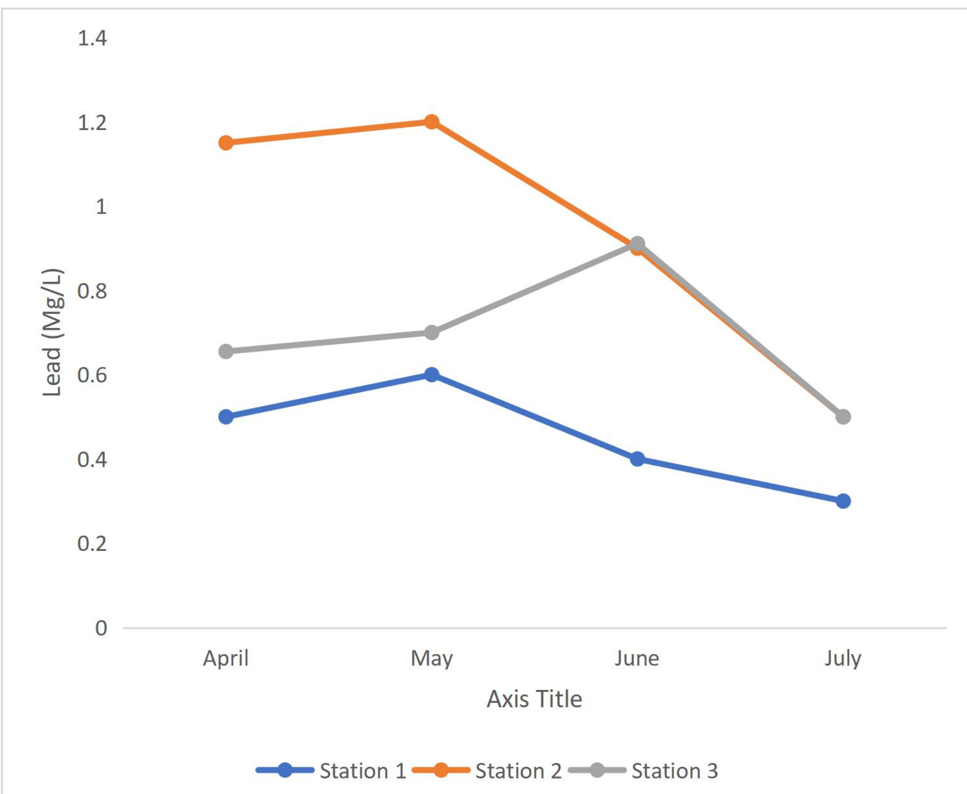

Figure 4.2: Spatial and Temporal Variation in Lead concentration of Aghuakuari River

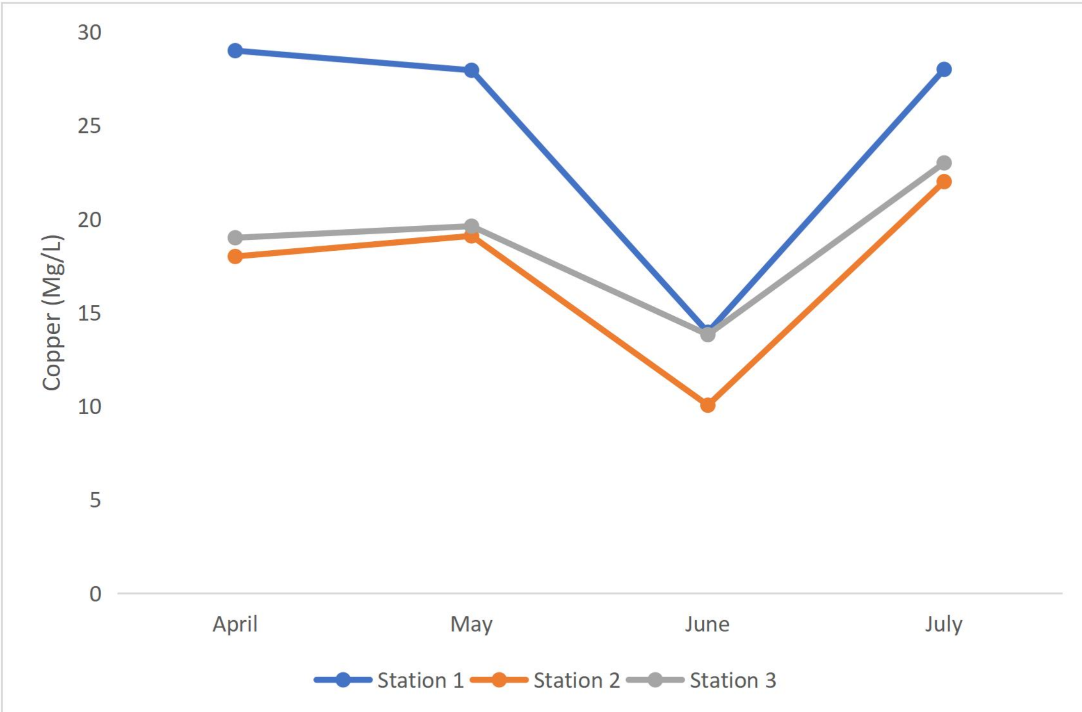

Figure 4.3: Spatial and Temporal Variation in Copper concentration of Aghuakuari River

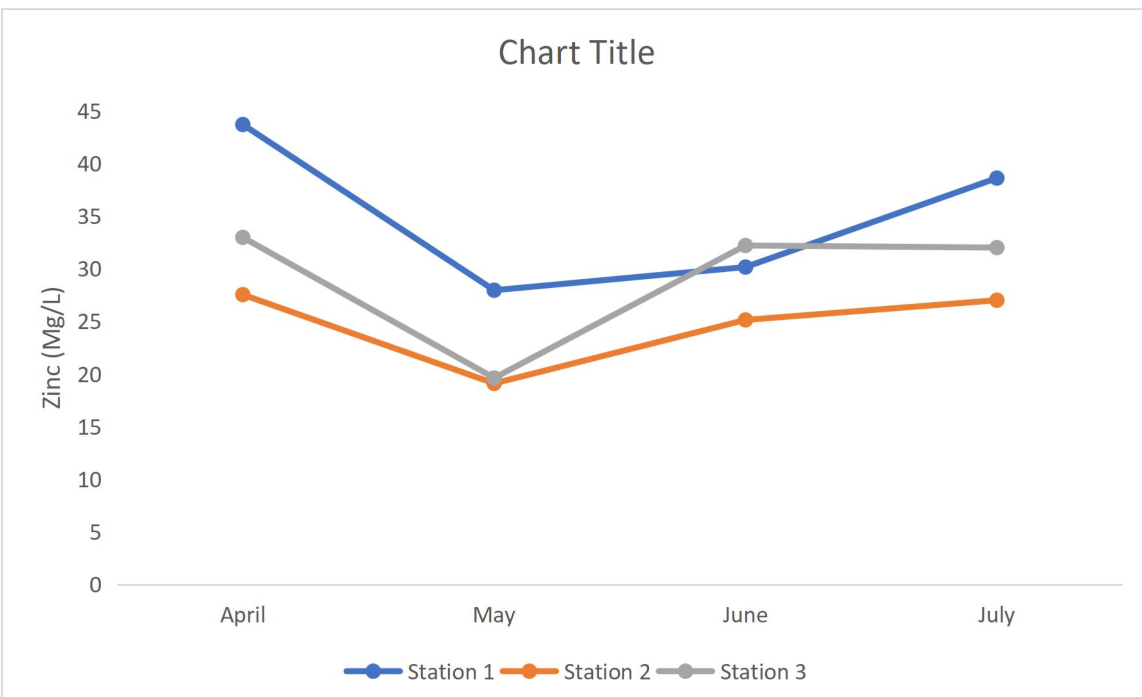

Figure 4.4: Spatial and Temporal Variation in Zinc concentration of Aghuakuari River

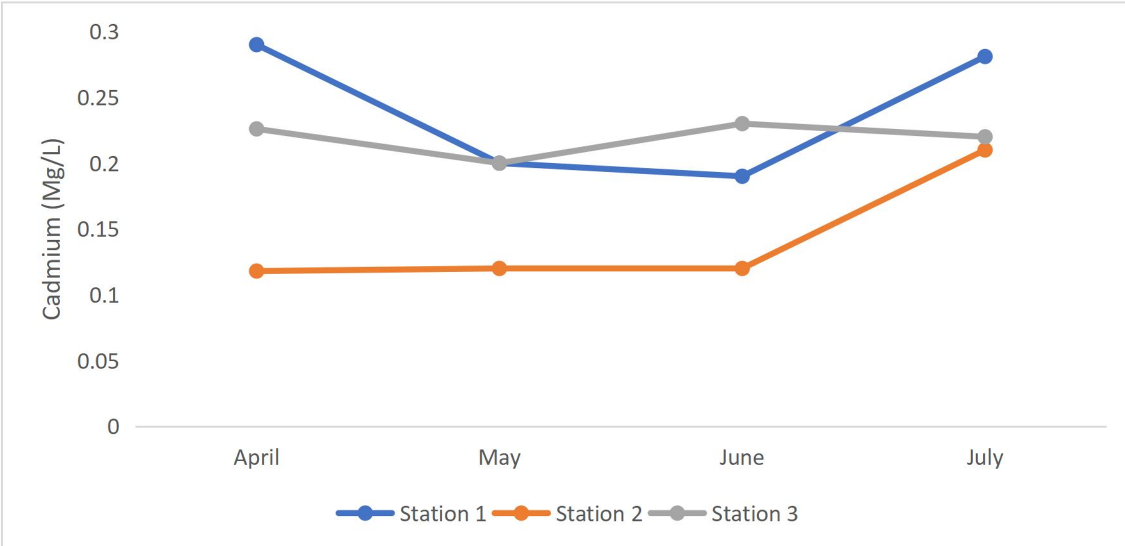

Figure 4.5: Spatial and Temporal Variation in Cadmium of Aghuakuari River

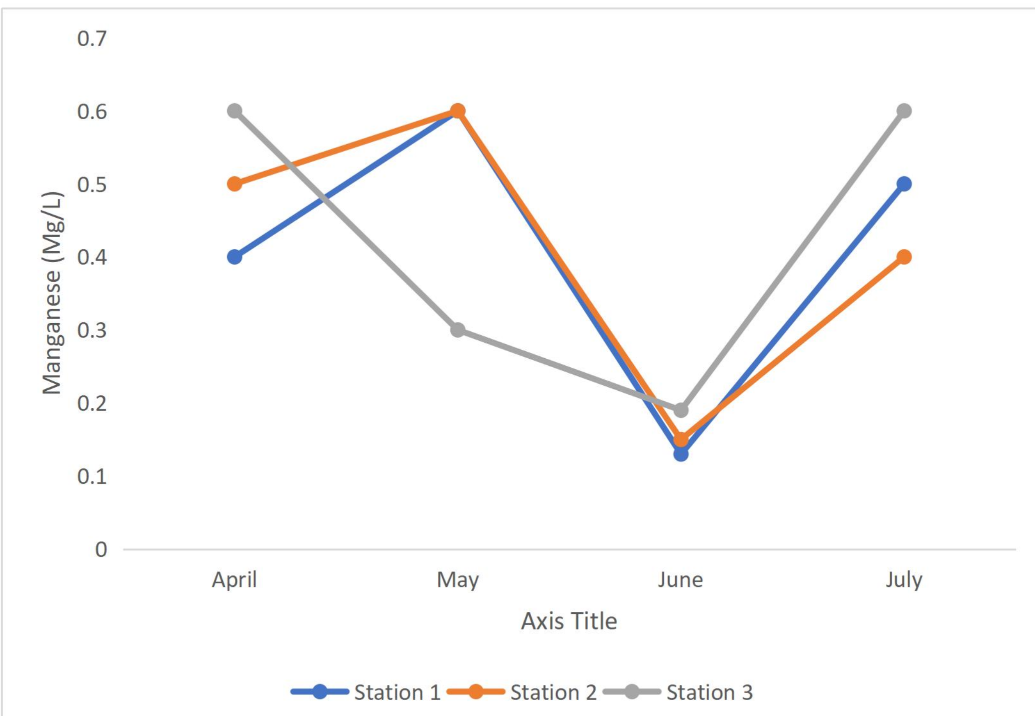

Figure 4.6: Spatial and Temporal Variation in Manganese of Aghuakuari River

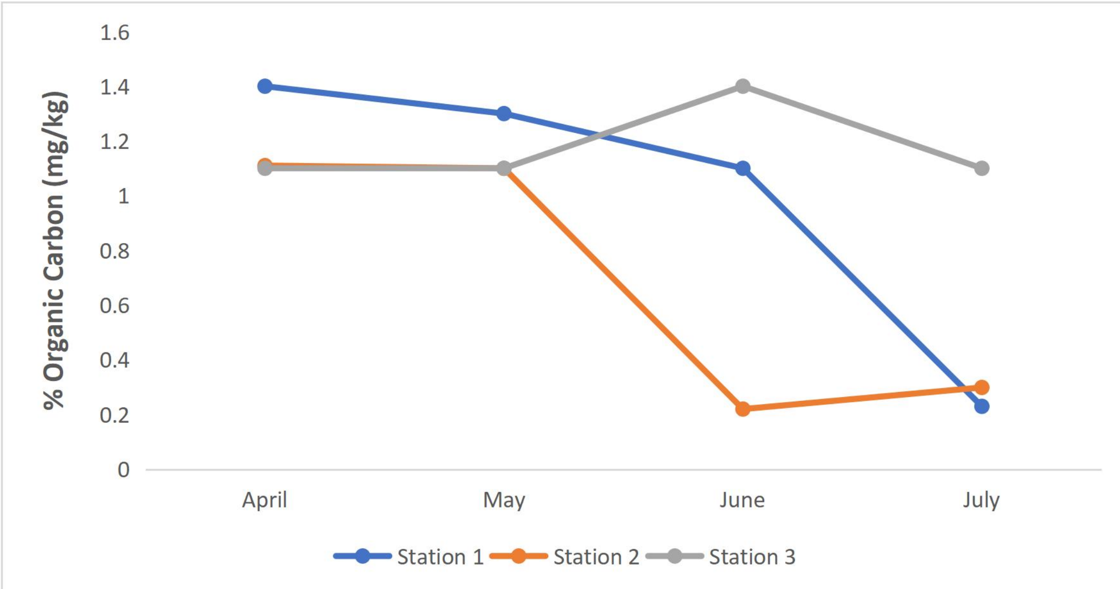

Figure 4.7: Spatial and Temporal Variation in Organic carbon concentration of Aghuakuari River

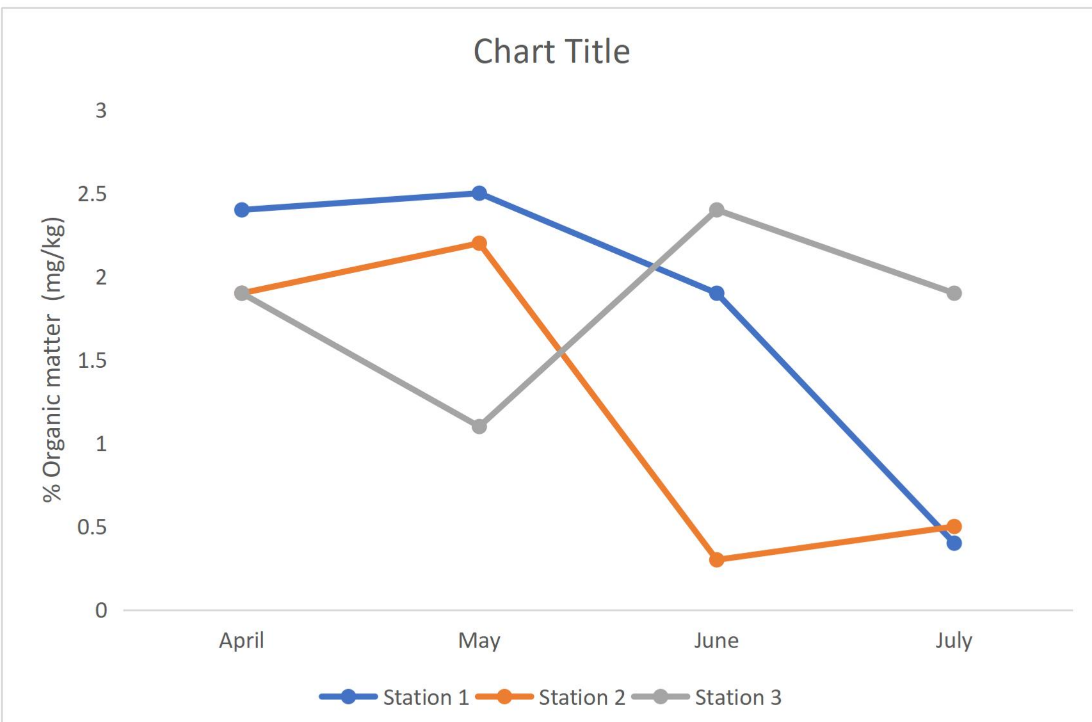

Figure 4.8: Spatial and Temporal Variation in Organic matter concentration of Aghuakuari River

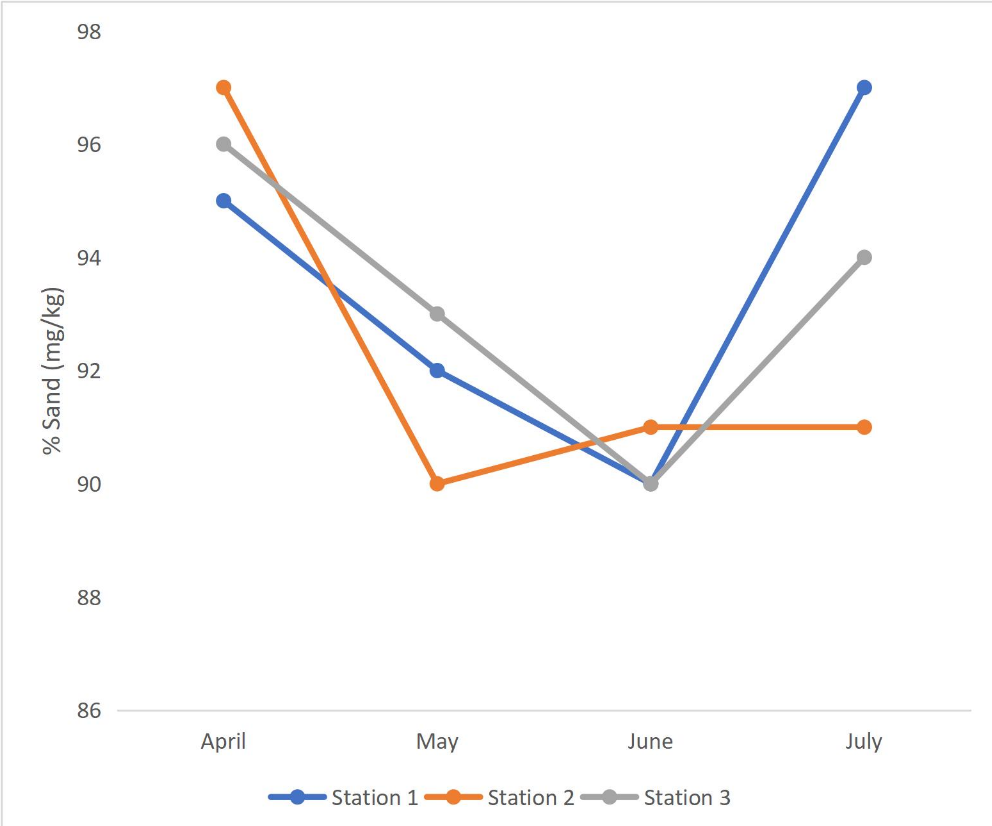

Figure 4.9: Spatial and Temporal Variation in % sand concentration of Aghuakuari River

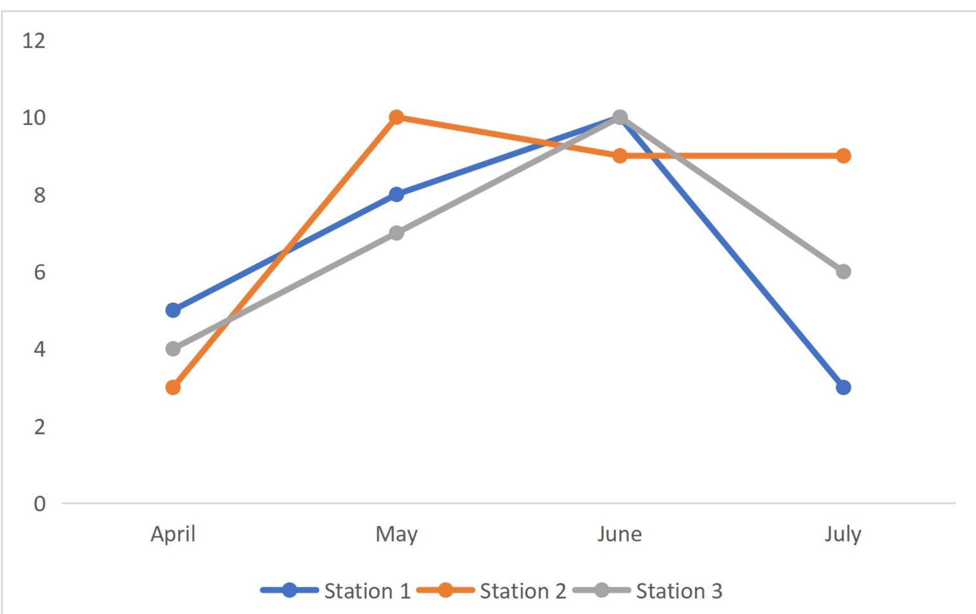

Figure 4.10: Spatial and Temporal Variation in %silt concentration of Aghuakuari River

4.2 The Zoobenthos community of Aghuakuari River

A total of 19 macroinvertebrate taxa were encountered during the study period comprising: 8 orders (Ephemeroptera, Odonata, Hemiptera, Coleoptera, Diptera, Malacostraca, Araneae, and Amphibia) classes (Insecta, Malacostraca, Amphibia) as revealed in Table 4.2

Table 4.2: Checklist of Benthic Macro-invertebrate Fauna of Aghuakuari River

TAXONOMY			
PHYLUM	Arthropoda		
CLASS	Insecta		
CLASS	MALACOSTRACA		
ORDER	DECAPODA		
FAMILY	*Caridina africana*		(Plate 4.10)
CLASS	ARACHNIDA		
ORDER	ARANEAE		
FAMILY	Pisauridae		
	Dolomedes sp	Latreille, 1804	(Plate 4.14)
	Dytiscus maginalis	Linnaeus, 1758	
FAMILY	NOTORIDEA		
	Hydrocauthus sp.	Muller, 1773	(Plate 4.3a)
FAMILY	Elmidae		
	Stenelmis sp	Dufour, 1835	(Plate 4.10)
	Elimidae sp	Linnaeus, 1758	
	Numorella sp		
Unidentified	*Antipodoclora* sp		(Plate 4.8)
ORDER	Odonata		
FAMILY	COENAGRIONIDAE		
	Enallagma glanucum	Freeman, 1962	(Plate 4.7)

FAMILY	AESHNIDAE		
	Boyeria sp.		
FAMILY	LIBELLULIDAE		
	Plathemis sp.	Linne, 1842	(Plate 4.12)
ORDER	Diptera		
FAMILY	CHIRONOMIDAE		
	Chironomus sp.	Meigen, 1803	(Plate 4.3)
	Chironomus fractilobus .		
FAMILY	CERATOPOGONIDAE		
	Ceratopogonid sp		(Plate 4.1)

Plate 4.1: Isopoda sp.

Plate 4.2: ***Hydrobiosidae*** sp.

Plate 4.3 (A and b) ***Hydrocanthus*** sp**. Ventral View** **Dorsal View**

Plate 4.4: *Chironomous* sp.

Plate 4.5: *Enallagma* sp.

Plate 4.6: *Stenelis* sp.

Plate 4.7: *Elimidae* sp.

Plate 4.8: *Antipodoclora* sp.

Plate 4.9: *Stenoperla* sp.

Plate 4.10: *Ceratopogonida* sp.

Plate 4.11: *Pelotydes* sp.

Plate 4.12: *Gammurus* sp.

Plate 4.13: *Delomedes* sp.

Plate 4.14: *Libelludidea* sp.

4.2.1 Community Structure

Zoobenthos samples collected from the three stations during this study belong to eight groups of invertebrates which include; Ephemeroptera, Coleoptera, Odonata, Hemiptera, Diptera, Decapoda, Areanea, and Amphibia. They were analyzed to determine the taxa composition, distribution, abundance and diversity.

4.3 Composition, Distribution and Abundance of Erosional Macrobenthic Invertebrates

The overall taxa composition, distribution and abundance of macrobenthic invertebrates collected during the study period is presented in Table 4.3. 19 taxa comprising of 394 individuals were recorded during the study. Hemiptera accounted for 1%, Coleoptera accounted for 7%, Odonata accounted for 1%, Diptera accounted for 57%, Ephemeroptera accounted for 3%, Decapoda accounted for 5%, Amphibia accounted for 26%, and Araneae accounted for 0.1%. The total number of taxa in station 1 were 8 with 181 total number of individuals. In station 2, 16 taxa were recorded and individuals were 83 while in station 3, the total number of taxa and individuals were 6 and 130 respectively.

Table 4.3. Composition, Distribution and Abundance of Macrobenthic Invertebrates in the Study Area, April to July.

Taxa	Station 1	Station 2	Station 3	Total
Stenelis sp	5	1	0	6
Elimidea sp	1	0	0	1
Hydrocanthus sp	3	7	0	10
Numorella sp	1	0	0	1
Unidentified Isopoda	1	0	0	1
Enallagama sp	1	1	0	2
Tadpole	20	38	5	62
Antipodoclora sp	0	1	1	2
Baetis sp	0	6	0	6
Chironomus sp	107	4	3	114
Caridina africana	0	9	4	13
Ceratopogonida sp	0	4	0	4
Unidentified Diptera Larva	0	1	0	1
Delomedes sp	0	0	1	1
Chironomous sp	0	0	19	19
Enalagna galanulum	0	2	0	2
Gammulus sp	0	1	0	1
Total	181	83	130	394

4.3.1 Ephemeroptera

Only One family was recorded under the order Ephemeroptera. The family include the Baetidae with two species representatives, *Cloeon* sp and *Baetis* sp. This species was randomly and evenly distributed across the stations with a total number of 4 and 6 individuals respectively. Ephemeroptera accounted for 3% of the total species abundance.

4.3.2 Coleoptera

The Coleoptera were also an abundant order, accounting for 7.00 % of the total species abundance. The Coleoptera comprises of four families and four species representatives. The families recorded were the Dytiscidae, Notoridea, Haliplidae and Elmidae. having the following respective species, *Hydrocauthus* sp., Gammulus sp sp. and *Stenelmis* sp. Station 1 had no representative, station 2 had 18 individuals and station 3 had 2 individuals.

4.3.3 Dipteran

Diptera are the most abundant of all the Macrobenthic invertebrates encountered with a 56% percent abundance. The Dipterans compromises of three families (Chironomidae, Ceratopogonidae and Culicidae) and five species, *Chironomous* sp, *Chironomus fractilobus,* found in the family Chironomidae, *Ceratopogonidae* sp. found in the family Ceratopogonidae, and Culicidae larvae found in the family Culicidae. The *Chironomous* sp dominating the Diptera with a total number of 114 individuals, 107 individuals of this species was recorded in in station 1, 4 individuals were recorded in station 2, and 3 individuals was recorded in station 3.

4.3.4 Decapoda

Only one family was recorded under the order Decapoda. The family include the Caridae with one species representative, *Caridina africana.* This species was randomly and evenly distributed across the stations with a total number of 4 and 6 individuals respectively. Decapoda accounted for 5% of the total species abundance. Station 1 had 9 individuals, station 2 had two individuals and station 3 with no individuals.

4.3.5 Odonata

The Odonata comprises of three families and four species representatives. The families recorded were the Coenagrionidae, Aeschnidae, Lubellulidae having the following respective species *Enallagama glanucum, Boyeria* sp. and *Plathemis* sp. The *Plathemis* sp dominating the odonata with a total number of 11 individuals, 10 individuals of this species were recorded in in station 3, 1 individual was recorded in in station 2, and was absent in station 1. Following the *Plathemis* sp. the next dominating was the *Boyeria* sp. With a total number of 5 species found in station 2 and 3 but absent in station 1. The *Enallagama glanucum*. had a total number of 3 species completely absent on station 1. Odonata accounted for 1% of the total species abundance.

4.3.6 Araneae

Only one family was recorded under the order Decapoda. The family include the Pisauridae with one species representative, *Dolomedes* sp. This species only is station 1 with two individuals. Araneae accounted for 0.1% of the total species abundance.

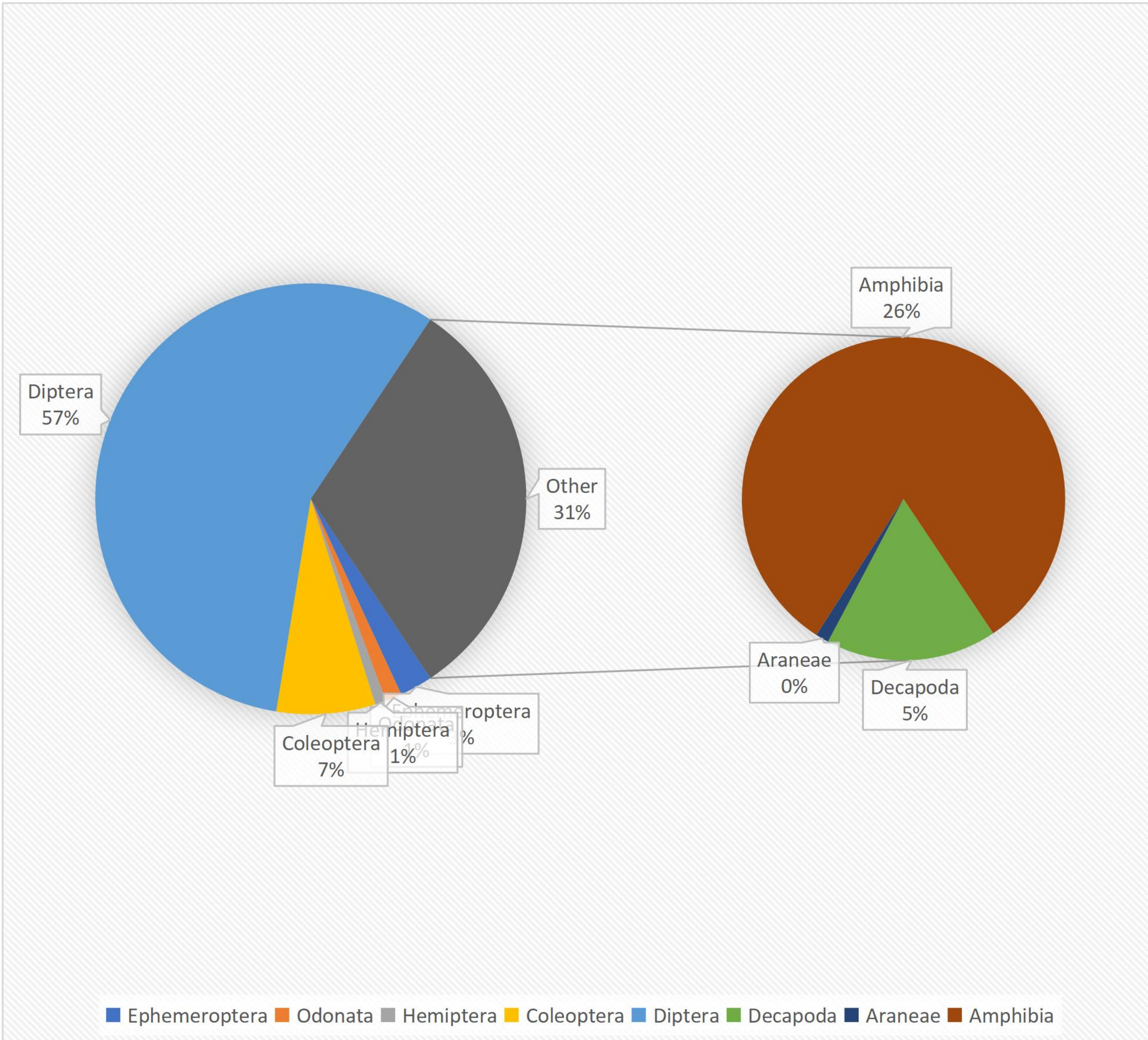

Figure 4.11: Percentage Composition of Benthic macroinvertebrates in Aghuakuari River

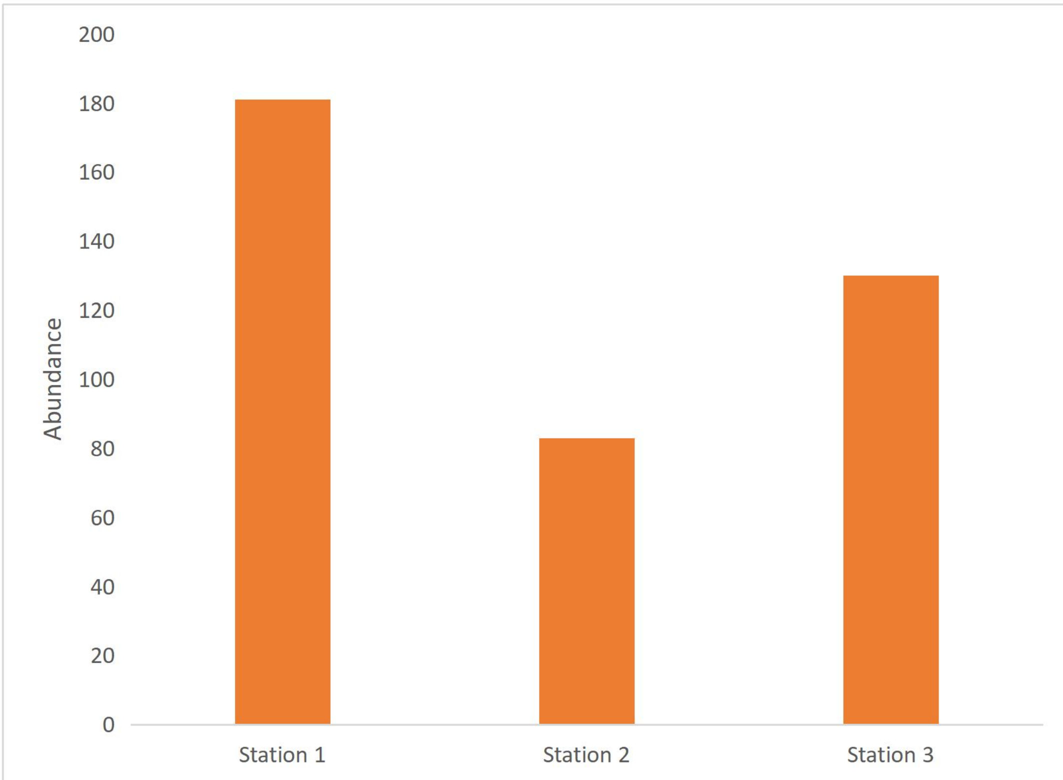

Figure 4.12: Abundance of Benthic macroinvertebrates recorded three stations in Aghuakuari River

4.5 Diversity of Fauna

The least number of taxa (6) was recorded in station 3, station 2 had the highest (13) and station 1 had 9 taxa (Table 4.4). In terms of diversity, the stations that were in order of importance were station 2, station 3 and station 1. The species richness calculated for the three stations using Margalef's index showed that station 2 had the highest species richness (2.748) and station 3 the lowest (1.43). Shannon Weiner's index was used to calculate general diversity and showed that Station 2 had the highest diversity (1.7) followed by station 3 (1.28) and station 1 (0.088). The evenness index showed that maximum evenness was in station 3 (0.6051) and the minimum in station 1 (0.2699).

4.6 Correlation Between the Physical and Chemical Characteristics and the Zoobenthos Found

The correlation coefficient analyses of Diptera, Hemiptera, Coleoptera, Odonata, Ephemeroptera and Decapoda was recorded variables and Heavy metals parameters of the study stations sampled Aghuakuari River was computed (Table 4.5 and 4.6). Ephemeropterans were found to be positively significant to iron, zinc, manganese, organic carbon and organic matter and negatively significant to lead, copper. Odonata was found to be positively significant to zinc, lead, copper, organic carbon and organic matter and negatively significant to iron, lead and manganese. Hemiptera was found to be positively significant to zinc, iron and manganese and negatively significant to lead and copper, organic carbon and organic matter. Coleoptera was found to be positively significant to zinc, iron and manganese, organic carbon and organic matter and negatively significant to lead, copper. Diptera was found to be positively significant to copper and negatively significant to zinc, iron and manganese, organic carbon and organic matter lead and conductivity, lead, copper and chromium.

Table 4.4: Diversity indices of Zoobenthos community

	Station 1	Station 2	Station 3
Taxa_S	9	13	6
Individuals	141	77	33
Dominance_D	0.5981	0.2791	0.3792
Simpson_1-D	0.4019	0.7209	0.6208
Shannon_H	0.8875	1.795	1.289
Evenness_e^H/S	0.2699	0.4632	0.6051
Brillouin	0.8107	1.584	1.09
Menhinick	0.7579	1.481	1.044
Margalef	1.617	2.763	1.43
Equitability_J	0.4039	0.6999	0.7197
Fisher_alpha	2.142	4.482	2.146
Berger-Parker	0.7589	0.4935	0.5758
Chao-1	12	16.33	7

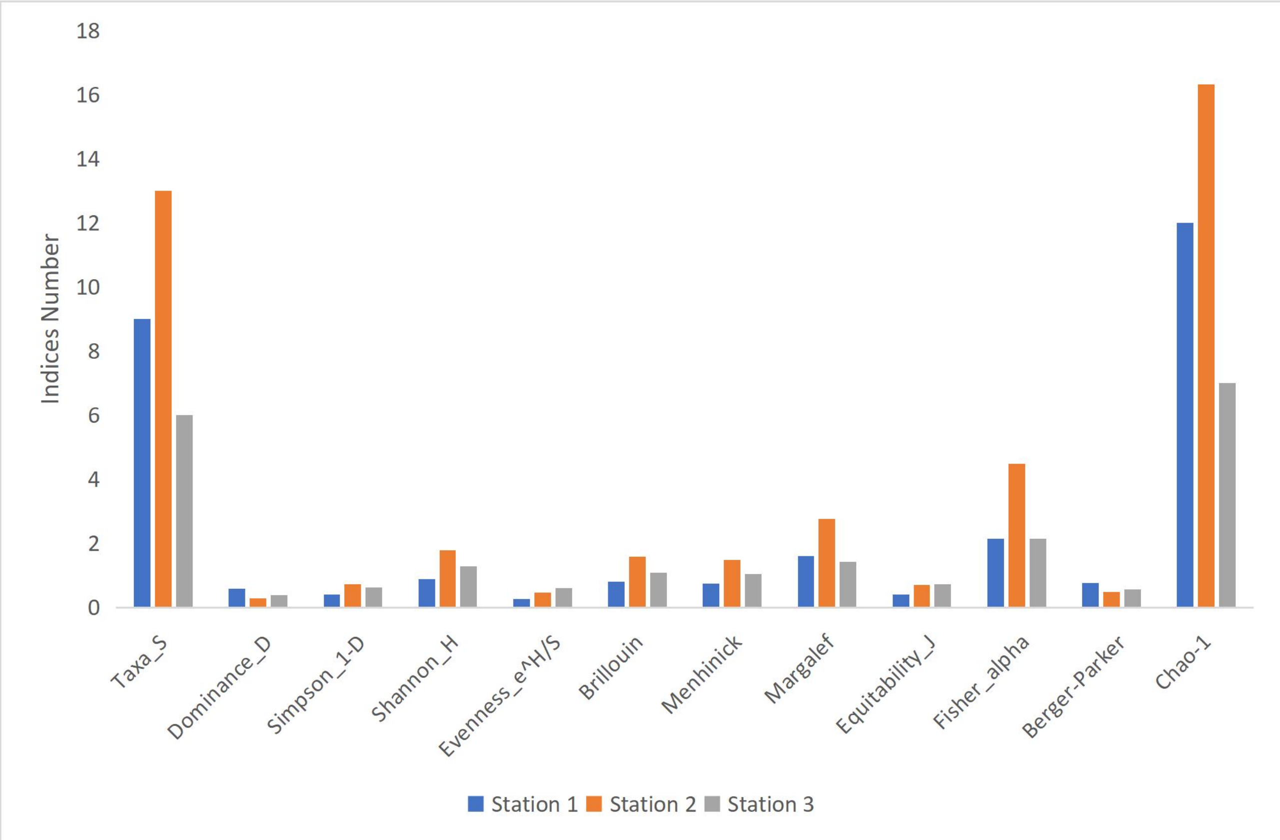

Figure 4.13: Diversity of Fauna found in Aghuakuari River

Table 4.5: Correlation between Zoobenthos and physicochemical parameters of sediment

	Iron	Lead	Copper	Zinc	Cadmium	Manganese	Organic Carbon	Organic Matter	Ephemeroptera	Odonata	Hemiptera	Coleoptera	Diptera	Mollusca	Amphibian
Iron	1														
Lead	-.173	1													
Copper	-.658	-.295	1												
Zinc	.660	.059	-.803**	1											
Cadmium	.186	.465	-.279	.135	1										
Manganese	.134	.549	-.519	.678*	.481	1									
Organic Carbon	.521	-.009	-.272	.277	.201	-.140	1								
Organic Matter	.523	-.010	-.271	.277	.202	-.140	1.000**	1							
Ephemeroptera	.372	-.250	-.360	.711*	-.515	.278	.023	.023	1						
Odonata	-.045	-.441	.116	.401	-.159	.369	-.261	-.261	.489	1					
Hemiptera	.186	-.415	-.143	.555	-.087	.478	-.412	-.411	.595	.878**	1				
Coleoptera	.561	-.566	-.329	.609	-.025	.097	.442	.440	.406	.604	.509	1			
Diptera	-.699*	-.334	.688*	-.502	-.099	-.262	-.400	-.401	-.253	.453	.187	-.021	1		
Mollusca	.355	-.198	-.134	.192	.109	-.216	.935**	.933**	-.037	-.075	-.322	.580	-.176	1	
Amphibian	.626	-.212	-.356	.351	.153	-.169	.941**	.940**	.042	-.128	-.251	.657	-.388	.945**	1

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

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

CHAPTER FIVE

DISCUSSION

This study focused on the Sediment characterisation and Zoobenthos community Aghuakuari River, Edo state, Nigeria for four months spanning April to June, 2023.

5.1 Heavy Metal Characteristics of Aghuakuari River

Many environmentalists have use water as pollution indicator by contaminants including heavy metals, but sediment can provide a deeper insight into long-term pollution state of aquatic environment (Asibor, 2016; Ogbeigbu *et al*., 2014). Sediments have been described as sink of pollutants whereby they concentrate according to the levels of pollution (Yah and Gray, 2005; Onyari, *et al*., 2014). The sediment of Aghuakuari River, is composed of sand, silt and clay. Sand accounted for the highest percentage composition while silt accounted for the least. The observed values of sand from station 2 and 3 were not significantly different from one another as compared to values obtained from station 1.

The result of the heavy metal analysis is reported in Table 4.2, high concentration of iron was recorded in the sediment and there was no significant difference ($p > 0.05$) across the stations. Station 1 recorded the lowest concentration with a mean value of 310.11 mg/kg compared to station 2 and station 3 with a mean value of 411.60 mg/kg and 337.56 mg/kg respectively. All the values are higher than the limits set by the Federal Environmental Protection Agency and National standard of drinking water quality sediment quality guideline and there was no significant difference ($p > 0.05$) across the stations for each parameter. This suggests the influx of human waste or anthropogenic products into the river. Higher values of iron were also recorded by Olomukoro and Azubuike, (2009) in Ekpan creek.

Concentration of Zinc Fluctuated between 19.20 mg/kg and 43.69 mg/kg across the three stations which was in line with standard set by Federal environmental protection agency and National standard of drinking water quality Sediment quality guideline.

High concentration of Copper was recorded in the sediment and there was no significant difference ($p > 0.05$) across the stations. Station 1 recorded the highest concentration with a mean value of 17.80 mg/kg compared to station 2 and station 3 with a mean value of 13.00 mg/kg and 13.47 mg/kg respectively. All the values are higher than the limits set by the Federal Environmental Protection Agency (0.05 – 1.5 mg/kg) and National standard of drinking water quality (1 mg/kg) sediment quality guideline.

Lead recorded low values in the sediment (ranging from 0.20 – 2.29 mg/kg) which is in line with the background values of the Federal Environmental Protection Agency (0.01 – 1 mg/kg) and National standard of drinking water quality (1 mg/kg) Sediment quality guideline. In relation to the lead concentration of Dandaru lake as reported by Ayoade and Nathaniel, (2018), lead concentration was extremely high in the reservoir (80 – 190 mg/kg).

Cadmium recorded the low values in the sediment (2.01 – 2.63mg/kg). All the values are in range with the limits set by the Federal environmental protection agency and National standard of drinking water quality Sediment quality guideline.

In summary, the heavy metals order of dominance includes Fe>Mg>Zn>Cu>Pb>Cd, the heavy metals investigated in this study means that Fe was the most dominant heavy metal in the river. during the period of study. This agrees with the report of Asonye *et al*., 2007 who also reported iron as the most dominant metal in the different rivers. They studied in this same zone but, seem relatively different with that of Kaizer and Osakwe (2010) who reported Zn as the most dominant in Ase River.

5.2 Zoobenthos Community of Aghuakuari River

Macrobenthic invertebrates of the river seem to be diverse in its community structure The class insecta dominated the fauna, and were recorded in relatively high number in all the stations. This is consistence with the finding of Mackie, (1998), Goedkoop and Johnson, (1996); Olomukoro, (1996); Olomukoro and Oviojie, (2015). A total number 218 individuals belonging to 6 groups were collected from the three stations thoughout the duration of the study. The overall Macrobenthic invertebrates fauna recorded in the study area are unique in its community structure.

The order Diptera was the most abundant taxa and recorded compromises of three families (Chironomidae, Ceratopogonidae and Culicidae) and five species, *Chironomous* sp, *Chironomus fractilobus,* found in the family Chironomidae, *Ceratopogonidae* sp. found in the family Ceratopogonidae, and Culicidae larvae found in the family Culicidae. which are a pollution tolerant species is an indication of the degenerating water quality (Saliu and Ekpo, 2006; Udaghe, 2019). The most abundant species in the taxa is the *Chironomous* sp which had the highest occurrence in stations 1 and 2, while *Chironomus fractilobus,*. accounted low in density. The dominance of dipterans may be attributed to morphological and physiological adaptations to various communities and availability of food. Species of Diptera recorded in this study have been documented elsewhere by Olomukoro and Ezemonye, (2006), Omoigberale and Ogbeibu, (2010), Olomukoro and Odigie (2019), and Udaghe (2019).

The presence of Odonata, Ephemeroptera and Coleoptera in the study stations is an indication that the lake is unpolluted with low organic waste. Order Odonata were dominant and were represented by the family, Coenagroinidae, Aeschnidae, Libellulidae and, they were widely distributed by *Enallagama glanucum, Boyeria* sp. and *Plathemis* sp which were abundant in this group and sparsely distributed among the study stations. *Plathemis* sp.

The Coleopteran were also an abundant order, accounting for 15% of the total species abundance. The Coleoptera comprises of four families and four species representatives. The families recorded were the Dytiscidae, Notoridea, Haliplidae and Elmidae. having the following respective species *Dysticus marginalis, Hydrocauthus* sp., *Peltodytes* sp. and *Stenelmis* sp. The *Hydrocauthus* sp dominating the Coleoptera with a total number of 12 individuals and was evenly distributed across all species.

The Hemipteran comprises of two species, the *Pelocoris femoratus* and *Lethocerus* sp. The *Lethocerus* sp. recorded the highest number of individuals in station 3, and had a total number of 10 individuals. The *Pelocoris femoratus* were absent in station 1 and 2 recording a total number of 1 individual. Hemiptera accounted for 6% of the total species abundance

Only One family was recorded under the order Ephemeroptera. The family include the Baetidae with one species representatives, *Cloeon* sp. This species was randomly and evenly distributed across the stations with a total number of 13 individuals. Ephemeroptera accounted for 7% of the total species abundance. The Ephemeroptera are good indicators of water qualities, according to Olomukoro and Ezemonye, (2007), Ephemeroptera is restricted to cool, clean streams and rivers with high dissolved oxygen content.

The diversity, species richness, dominance, similarity and evenness indices revealed that there are significant differences in species composition between stations. Stations 2 and 3 accounted for highest taxa richness, general diversity, dominance, equitability and similarity indices than station 3, while station 2 recorded the highest in evenness index.

CONCLUSION

The qualitative sampling of Aghuakuari River, Edo state, Nigeria yielded a highly diverse Zoobenthos community. The Heavy metal and bottom sediment characteristics of the lake have also analyzed and discussed. It was deducted that the sediment of Aghuakuari River, Edo state, is composed of sand, silt and clay. The high taxa recorded for this study may be due to the minimal effects of anthropogenic activities on the sampled water body. Factors which influenced the abundance and distribution of the benthic macroinvertebrates includes the nature of the water body, habitat richness and stability, immediate substrate of occupation, the heavy metal composition, anthropogenic activities, tropic condition, resource partitioning and predation. Future work on Aghuakuari River should be done and it would also be essential for a more comprehensive study to be done as the effects of heavy metals on the abundance and distribution of macrobenthic fauna seem on the increase on the River.

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