DIPTERAN LARVAE OF BANKROOT MACROPHYTES OF OKHIUHE RIVER, BENIN CITY, EDO STATE, NIGERIA

BY

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CERTIFICATION

This is to certify that this project work was carried out by EFE ITOHAN MERCY under

My supervision.

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DEDICATION

To my parent's MR and MRS EFE for their relentless support and sacrifices to make me a Better person.

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ABSTRACT

Dipterans are excellent indicators of water quality; hence, they are routinely used as bioindicators during monitoring of aquatic ecosystems. The study was therefore, executed to investigate the physico-chemical water quality and dipteran aquatic insect larvae community. Both water and benthic samples were collected between August 2021 and January 2022 at four designated sampling stations along the Okhuahie River at Ikpe in Ikpoba-Okha Local Government Area of Edo State, Nigeria, using standard procedures. A total of 22 physiochemical parameters were determined and measured. Among the physical and chemical parameters, Flow rate, Dissolved oxygen, and Phosphate showed highly significant differences ($P<0.001$) across the stations. A total of 3 taxa comprising 857 species were recorded. Abundance was highest in station 3 consisting of 146 individuals and the lowest in station 2 consisting of 77 individuals. The dominant taxon is Chironomid (98%), Culex (1.2%) and Tanyderidae (0.3%). Culex consisted of just 1 species and 11 individuals, Tanyderidae of 1 species and 3 individuals, whereas Chironomid comprised 5 species and 843 individuals. The diversity indices showed that station 3 was more diverse followed by station 4, while dipteran species in station 2 was least diverse. Culicidae and Tanyderidae showed positive critical correlation to sulphate and turbidity. The overall abundance showed no significant difference ($p > 0.05$) for all the four station. This study proved that Okhuaihe River is unperturbed and the Dipteran encountered are characteristics of a tropical freshwater habitat.

CHAPTER ONE: INTRODUCTION

1.1 Water Environment

Natural water is one of the most important substances for the maintenance of life. It was called "a primary source of all that exists" by an ancient Greek philosopher Thales of Miletus 2,600 years ago. Water is one of the most astonishing compounds on Earth, it is characterized by a complex of peculiar properties that make it very different from other substances (e.g. high melting, boiling, and evaporation points, and high dissolving ability). The hydrosphere contains the majority of water on Earth. The hydrosphere (from the Greek *hydro*, water, and *sphaira*, sphere) is not a continuous water cover of the Earth. The hydrosphere is made up of all the earths oceans, seas, and surface waters, including all of lakes, rivers, oceans, streams, underground water, snow and ice. 70.8 percent of the Earth's surface is covered by the sphere (the total volume is about 1.39 billion km3). About 96.4 percent of the hydrosphere is made up od oceans and seas, and 1.68 percent is made up of underground waters. Snow and ice is made up 2% of the surface, mostly in the Arctic, Antarctic, and Greenland. Surface water, saline lakes, and inland seas make up the remaining 0.059 percent. Water is also present in the atmosphere and in insignificant amount in living organisms.

The Earth's freshwater ecosystems which contain lakes, ponds, rivers, springs, bogs, and wetlands are a subunit of the Earth's aquatic ecosystems. They can be compared to marine environments, which have higher content of salt (Carpenter *et al*., 2011). The distribution of freshwater on earth is uneven. The 21 largest lakes on Earth contain two thirds of the entire global freshwater sources and engaged various ecological and social environments (Sterner *et al*.,

2020). All fresh inland water bodies, such as rivers, streams, wetlands, surface waters, and estuaries, fall under the category of freshwater environments. The term ‘inland water ecosystems’ sometimes referred to as ‘freshwater ecosystems’ because they exclude saline ecosystems. (Driver *et al*., 2011).

Freshwater habitats are essential for maintaining global biodiversity because they offer critical services to the environment. Studies revealed that freshwater environments are vulnerable due to the impacts of environmental change (Pinceel *et al.*, 2018; Reid *et al.,* 2019), which contribute to irreversible changes in the regime, through which biodiversity and ecological services can be lost (Hossain *et al*., 2018; Jarić *et al.,* 2019).

The aquatic habitats have seen considerable changes as a result of increased human exploitation, changes that have an impact on their physical, chemical, and biological characteristics. Over time, freshwater environments have undergone significant transformations that have influenced their characteristics (Carpenter *et al.,* 2011).

For such a long time, the freshwater ecosystem has been mismanaged. There are several different types of ecosystem mismanagement, including altering human behavior and purposefully changing the freshwater ecosystem’s structure. The freshwater ecology is frequently contaminated by anthropogenic activities like industrial revolution and large-scale agriculture. Freshwater contamination is the degradation of non-coastal streams by substances that render them unfit for their intended or natural use. Freshwater pollution may involve fecal wastes, chemicals, pesticides, petroleum, precipitates, or even warmed trashes (Li *et al.,* 2016). The mismanagement of the freshwater ecosystem should be restrained. Although freshwater ecosystem takes a while to recover, it is essential to conserve it since it is a source of water

supply, source of economy, and biodiversity. Striving for solutions that could assist the conservation of freshwater habitats and at the same time providing important human necessities are significant (Matthews, 2016). The presence and absence of bankroot macroinverterbrate, such as the dipteran larva, the organism of emphasis in this thesis, can be used to identify changes in the condition or quality of freshwater.

1.2 Bankroot Macroinvertebrate

The use of bankroot macrophytes to ascertain the overall health status of aquatic environments remains and the most widely acclaimed method globally. Bank root macroinvertebrate are useful bio-indicators in understanding the ecological health of an aquatic ecosystem, rather than using chemical and microbiological data, which at least give short-term fluctuations (Ravera, 2000; Ikomi *et al.,* 2005; George *et al.,* 2009). Odiete (1999) discussed the use of bankroot macrophytes in the assessment of freshwater bodies. Bank root macro fauna were used as bio indicators for studies of impact of environmental perturbations on the aquatic ecosystems (Lenat *et al.,* 1981; Victor and Ogbeibu, 1985). They have minimal mobility (i.e., are sedentary or sessile or nearly so) and life cycles of several weeks or years, and are therefore essential because they reflex the cumulative impacts of the past and present conditions.

There has been extensive studies elsewhere of biomonitoring studies and the use of macrophytes to assess the health of water bodies that include both lotic and lentic types. (Ogbeibu and Oribhabor, 2002; Imoobe and Ohiozebau, 2009; Omoigberale and Ogbeibu, 2010; and Olomukoro and Dirisu, 2012). In aquatic pollution studies, Bankroot Macro fauna, which were utilized in aquatic pollution studies, included: true flies (Diptera) which is the focus of this research, Mayflies (Ephemeroptera), caddisflies (Trichoptera), stoneflies (Plecoptera), beetles

(Coleoptera), crayfish and amphipods (Crustaceans), aquatic snails (Mollusca), biting midges (Chironomids) and leeches (Hirudinea) in Nigeria, North America and Europe.

1.3 Dipteran larvae

Dipteran larvae are easily recognized through the complete absence of articulated thoracic appendages (legs).use Despite the fact that the majority of the order is terrestrial, there are more species of Dipteran than any other order. Dipteran that are regarded as aquatic have terrestrial adult along with aquatic larvae and pupae. Many other aquatic insects, (e.g. mayflies. dragonflies, stoneflies, caddisflies, alderflies, fishflies), are also referred to as flies, but these species are not true flies because they do not fall under the other dipteran order. The word "fly" is separate when referring to true flies or dipteran by their common names, (e.g. black fly, crane fly, moth fly. Dance fly, flower fly).). In contract, common names for non-dipteran taxa are one word. The true fly is extremely important in the aquatic food web and often is the most diverse and most abundant aquatic macro fauna taxon collected in many fresh water habitats. Dipteran inhabits a wide range of habitat and some taxa are extremely tolerant and occur in heavily polluted water bodies.

1.4 Justification of the Study

So far there has been paucity of information regarding the community structure of bank root macroinvertebrate of small rivers such as the Okhuaihe River, which are present all over the country as important habitats to the nation's aquatic diversity. This study was therefore, carried out to establish the diversity, relative abundance, species richness and composition of Dipteran

larva of bank root macro invertebrates of Okhuaihe River in Ikpe, Benin city, Edo state, Nigeria as an addition to the already existing knowledge of aquatic biodiversity.

1.5 Aims and Objectives

The aim of this study is to investigate the dipteran aquatic insect larvae community of Okhuaihe River in Benin City, Edo state, Nigeria.

The objectives of the study were to determine the:

1. spatio-temporal variation in the physico-chemical water quality in Okhuaihe River
2. spatio-temporal variation in the species composition, abundance, distribution and diversity of the dipteran aquatic insect larvae in Okhuaihe River.
3. relationship between the physico-chemical water quality and the dipteran aquatic insect larvae community structure.

CHAPTER TWO

LITERATURE REVIEW

2.0 Introduction

True flies (Dipteran) dominate the fresh water environment more than any other macro invertebrate group. Almost one-third of all flies (about 46,000 species) have some developmental relationship with the aquatic environment. They are important drivers of ecosystem processes and serve as a source of goods and biological inspiration to human society. Dipteran larvae are well known ecosystem engineers and important organisms that alters the biotic and abiotic environments through activities such as digging, grazing feeding, and predation. Since the early years of biological assessment, dipteran has been used as a water quality indicator. They act as marker for present and upcoming ecological and climatic changes. They act as biological pest control agents because they are both herbivores and predators. True fly relationships with aquatic environment carcasses offer further forensic capabilities, many dipteran species extremophiles offer a way for humans to adapt to harsh global and extraterrestrial environments. Many flies are beneficial to humans and the environment as aquatic immature, but a adults they are pests and disease carriers on land. Thus, as more species approach extinction, the scientific community is faced with the challenge of balancing the advantages and disadvantages of aquatic dipteran while maintaining sustainable population harsh global and extraterrestrial environments. Many flies provide valuable ecological and human services as aquatic immature, but are also pests and vectors of disease agents as terrestrial adults. The scientific community, thus, is challenged with balancing the benefits and costs of aquatic Dipteran, while maintaining sustainable populations as more species face extinction.

2.1 Dipteran as Bioindictor

Bioindicators are living organisms like plants, plankton, animals and microbes which are used to detect the health of the ecosystem. They are used to monitor the state of the environmental natural ecosystem. They are employed to evaluate the health of the environment and biogeographically changes that are occurring. Each organic component of a biological system gives a clue as to the state of its surrounding. The physiological and morphological adaptation of The *Chironomus* through its ability to slow metabolic rates allows it to survive in harsh and hostile environments (Hamburger et al. 1994). A larger body size, which helps with the ventilation of larval tubes, also allows Chironomids to tolerate low dissolved oxygen levels (Panis *et al*. 1996).

Chironomids shows different environmental response to stress induced by toxic agents. Overall Chironomids larvae has the good potential for providing early warnings of adverse long term effects of toxic agents at the individual, population and community level and can be used as cost effective tool for indicating environmental health of aquatic ecosystem (Deepak et al., 2019).

The impact of anthropogenic activities on streams and rivers of Ethiopia was assessed using the Dipteran family Chironomidae, by Mezgebu *et al.,* (2019). A variety of a portable square frame hand net with a mesh size of 500m and frame dimensions of25 × 25 cm was used to gather Chironomidae in severely contaminated areas were *Chironomus alluaudi* and *Chironomus imicola,* which were regarded as markers of highly polluted streams and river. However, because they were more prevalent in moderately contaminated sites, *Polypedium wittei, Polypedium bipustulatem,* and *Dicrotenipus septemmaculatus* were identified as indications of moderately polluted areas. The genus Conchapelopia was found in less polluted samples locations and is a sign of excellent water quality. Extremely polluted sites support low numbers of chironomid

taxa in general and, as such, larval Chironomidae assemblages are important tools in assessing human impact on rivers when identified to genes/species level. However, it should be noted that the method is deemed inadequate as a quick Bioindictor tool due to the time required to process the samples.

The aquatic ecosystem has seen profound change and degradation on several level as a result of anthropogenic activities. It is now essential to protect the aquatic environments' high standards, their proper operation, and the species that depend on them.

An investigation was conducted by Amira *et al*.,(2019) to determine whether the degree of water quality deterioration that is being experienced, degradation of water quality that are subjected to different ,is charges, in order to accomplished this, samples of water, sediment, and Chironomidae larvae were taken during the dry season. The deformities affecting the mentum and mandibles were examined together with heavy metals. The locations displayed more than 33% cadence deformities, which indicate the existence of toxic stress.

Francis *et al.,* (2014) investigated the link between mouthpart deformities in Chironomid larvae (diptera) and split contamination in the Shiroro Lake in Nigeria. The majority of the assemblage which Chironomus sp., Polypedilun sp., and Ablabesmyia sp., was discovered. At station 1, mouthpart deformities were far more prevalent that at station 3, and seasonally, the dry season saw a significant increase over the wet season. Chironomus spp, had a higher rate of deformity in their larvae compared to other genera. Designing measures to reduce pollution and biological effects is reguired However, over 40 years' worth of laboratory ecotoxicological experiments aiming to assess the causal relationship between contaminants and deformities (using the model genus *Chironomus*) have yielded inconsistent results (Vermeulen 1995; Janssens de Bisthoven and Gerhardt 2005; Arambourou *et al.,* 2014; Salmelin *et al*., 2015)..

The inconsistency of results may indicate that pollutants do not cause deformities or that the experimental setup utilized in various investigations differs too widely for an underlying connection. It may also suggest that chironomid deformities are primarily induced in the presence of mixed rather than single stressors (Milošević et al. 2016), of laboratory data do not tend to support this hypothesis (Arambourou et al. 2014; Gagliardi et al. 2016). These concerns have limited the application of this endpoint in ecotoxicology.

A high proportion of deformed larvae in a mortality-inducing exposure may simply indicate that deformed larvae can better survive the exposure: it does not unequivocally show that the chemical physiologically induced the observed deformities. Stressors such as s and pest malnutrition may induce deformities (de Haas et al. 2005; Janssens deiides in c Bisthoven and Gerhardt 2005).

Among the Dipteran, only the ubiquitous Chironomidae are routinely used in aquatic Bioindicators. They are a standard part of the Environmental Protection Agency's rapid bioassessment protocols (Barbour *et al.,* 1999). Chironomids also are used as standard organisms in laboratory toxicity tests (Weltje *et al.,* 2009). However, some taxa might be especially well-suited for identifying particular types of pollution. Dixid larvae, which are uniquely adapted for life in surface films, are sensitive to surfactants and oils (Fowler *et al*., 1997).

Water quality is affected by a range of natural and human activities. Rapid industrialization and urbanization increase in population, indiscriminate use of chemical fertilizers and pesticides in agriculture and large quantities of sewage and industrial waste are causing heavy and varied pollution in aquatic environment leading to deterioration of water quality and depletion of aquatic biota (Gorde *et al*., 2013).

Using the bankroot macrophytes, Emere and *Nasiru* (2004) conducted a survey on a fourth order perennial Northern Nigerian stream to assess the water quality. 1304 macrophytes species in all, including dipteran like the rattalk maggot (Eristalis), Culex Coatate pupa, and Chronomus species, were discovered. Low population of macrophytes groups that rate pollution, declining water quality, and the physical and chemical properties of the water during the dry season were indicators of organic pollution stress brought on by decaying household waste and inorganic fertilizer irrigation – related fertilizer washed into the stream.

In order to evaluate the macrophytes community and water quality on a rural river in South East Nigeria in connection to anthropogenic activities, Emeka et al., (2019) conducted a study, uncontrolled sand mining was a main human activity in the river. The community structure of the macrophytes indicated perturbation, and the results showed that pollution-tolerant species like Haliplus sp, larvae, and Chironomus sp. Larvae predominate. The water quality has not been negatively impacted by indiscriminate sand mining, but the macrophytes population was predominant.

Limited use of aquatic Dipteran in bioassessment, probably stems in part to identification difficulties. However, other elements are also at play, perhaps including taxon popularity and ease of identification. The Simuliidae, for example, are well known at the species level, with about 93% of the North American species known as pupae and about 98% as larvae (Adle *et al.*, 2004). Yet, they are rarely used in biotic assessment, even though metrics are available (Hilsenhoff *et al*., 1987).

2.2 Ecosystem Engineers

Ecosystem engineers are organisms that significantly alter their surroundings to fit their needs by constructing new habitants or altering old ones. By creating and preserving microhabitats that

would not otherwise exist, ecosystem engineers have a substantial impact on other species. They often but not always can be defined as keystone species, meaning that they play a critical role in their environment and affect many other species in the ecosystem (Houston Chandler 2018).

Few species have a significant impact on the overall habitat, despite the fact that all species have an impact on their environment, at least immediately around the individual. The impact is typically inversely correlated with population size. Certain aquatic dipteran that drastically modify their abiotic surroundings are considered to be "ecosystem engineers" "—those species that significantly alter their abiotic habitat and thereby affect the ecology of other organisms and related processes in the ecosystem by their feeding mechanism (Wotton *et al.,* 1998).

Suspension-feeding larval Diptera help retain organic matter in lentic and lotic environments (Wotton *et al*.,1998 and Wotton *et al*., 2001). Small particles, colloids and dissolved organic matter captured by suspension feeders, such as blackflies are packed into fecal pellets that are transported downstream. During transport or after sedimentation, the repackages organic matter becomes available as food for microbes and macroinvertebrate.

The daily transport of fecal pellets from larval simuliids past a line across some rivers can reach a stunning 429 tons of dry mass (Malmqvis *et al.,* 2001), roughly equivalent to 6000 elephants defecating (wet weight) into the river each day. These fecal pellets contain high amounts of carbon and nitrogen and provide substrate for bacteria and biofilms; thus, they contribute to the aquatic food web and fertilize riverbanks and floodplains (Malmqvis *et al.*, 2004).

The first few centimeters of the sediment are turned over as a result of the macro invertebrate's continuous burrowing and faecal pellet deposition, a process known as bioturbation. The importance of bioturbation is the reduction of bigger food molecules in the sediment to smaller forms that can be used by benthic species, especially the micro and meiobenthic components.

Bioturbators are organisms that can consume, urinate and borrow into sediment to turn and condition them. Bioturbators are well represented among aquatic Diptera. Chironomid larvae, which can reach densities of 150,000 per square meter, function much like earthworms, eating dead organic matter and defecating; these activities add significant aeration and nitrogen to the habitat, thereby transforming the plant and animal community (Wilke, C. 2018).

Scrapers (grazers) can clean substrates of periphyton and other adherent debris, opening up colonization areas for other organisms. Densities of up to 1000 larval blephariceridsper square meter (Courtney, G.W 2001) can clean a significant amount of rocky surface area. Diptera that break down plant material, for example by shredding Tipula, provide a critical service by supplying both coarse particulate organic matter (CPOM) and fine particulate organic matter (FPOM) that many organisms subsequently consume (Cummins *et al.*, 1989).

Predators can regulate populations and spatial distributions of other organisms and can structure Aquatic communities. Predatory larvae of Chaoborus, for instance, maintain the structure of Zooplankton communities in Canadian lakes (Yan *et al.*, 1991).

CHAPTER THREE

MATERIALS AND METHOD

3.1 DESCRIPTION OF THE STUDY AREA

Okhuaihe River passes through Ikpe community, along Benin Abraka road, Ikpoba-Okha Local Government Area of Edo State, Nigeria. The River is a chief tributary of Ossiomo river which empties into Benin River which terminates at the Atlantic ocean (Tawari-Fufeyin *et al*., 2008) Figure 3.1.

3.1.1 CLIMATE

The climate condition of the study area is characterized by rainy/wet seasons and dry seasons. The period of rainy season is usually from April to October, and dry season from November to March, with temperature ranging from 22℃ – 31℃ (Olomukoro 1983).

3.1.2 VEGETATION

The vegetation of the study area comprises mainly of Raffia palms (*Raphia farinifera*), Sensitive plants (*Mimosa pudica*), Bahama grasses (*Cynodon dactylon*), Stubborn grasses (*Sida acuta*), Ferns (or Polypodiophyta), Wild cocoyam plants (*Colocasia esculenta*), Plantain trees (*Musa sapientum*), Coconut trees (*Cocos nucifera*). There were floating and submerged macrophytes such as Water hyacinth (*Eichhornia crassipes*) observed in the river.

Especially after heavy rainfall while in the dry season; there is low or no flow rate and increased transparency (Ekhator *et al*., 2013).

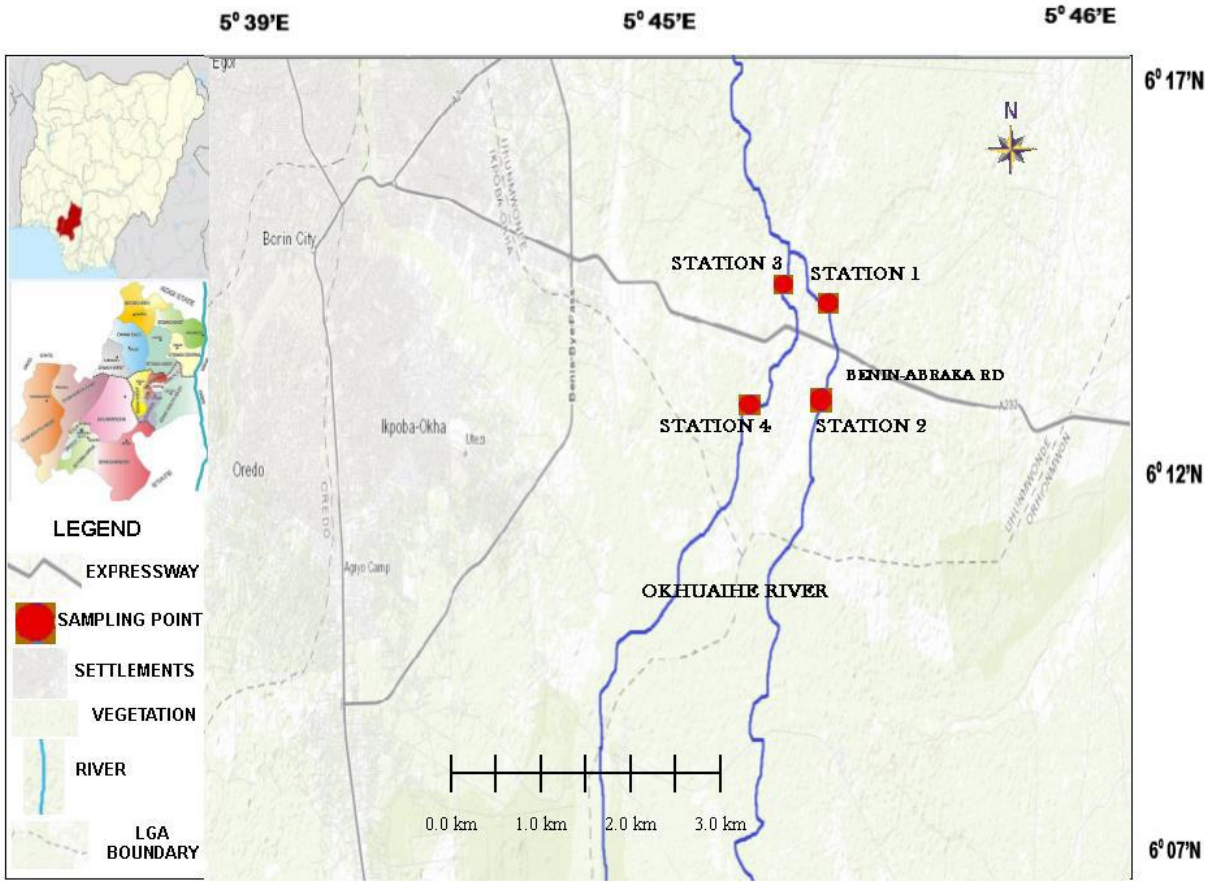

Fig 3.1: Map of Ikpe community showing the sampled areas.

3.1.3 SAMPLING STATIONS

Station 1

It is located about 500m before Orhionmwon bridge, at latitude 6° 12' 25.19" N and longitude 5° 45' 17.12" E. The marginal vegetation is made up of raffia palm trees, sensitive plants, stubborn grasses, Bahama grasses, fern, water hyacinth and wild cocoyam plants. The river at this point is transparent, but the bed of the river is muddy. Fingerlings could be seen swimming. Anthropogenic activities include timber and lumber production, fishing, swiming palm wine and local gin (ogogoro) production and spiritual activities.

Station 2:

It is located about 500 m before Orhionmwon bridge, at latitude, at latitude 6° 12' 24.18" N and longitude 5° 45' 15.99" E. I 6° 12' 25.19" N. This site is directly opposite station 1 It is surrounded by canopy trees, raffia palm trees, sensitive plants, ferns, plantain trees, wild cocoyam plants and water hyacinth. A bathroom and a hut was seen sitting on top this site made from bamboo and pam froot.

Station 3:

This sampling site is located 200 m to station 4 at latitude 6° 12' 28.76" N and longitude 5° 45' 8.55" E. The water is transparent and has high flow velocity compared to other stations. The vegetation at this station includes plantain trees, raffia palm trees, coconut trees, and wild cocoyam plants, submerged and floating macrophytes. A shrine was seen in the middle of the water. Activities such as timber and lumber production, cooking, fishing and spiritual activities are carried out.

Station 4:

It is located 100 m to station 1 at latitude 6° 12' 29.93" N and longitude 5° 45' 3.84" E. The water is highly turbid and has the lowest flow velocity compared to the other stations. The marginal vegetation surrounding this station include raffia palm trees, palm kernel trees, plantain trees, wild cocoyam plants, ferns and floating macrophytes. Human activities include lumber and timber production, spiritual activities and broom making.

Plate 1: Station 1

Plate 2: Station 2

Plate 3: Station 3

Plate 4: Station 4

3.1.4 SAMPLE COLLECTION

Samples were collected monthly for a period of six months, August 2021 to January 2022. Sampling was carried out between 0800 hours and 1200 hours each sampling day. The first three months sampling duration was at rainy season while the last three was at the dry season.

3.1.4.1 Collection of water samples

Water samples for the analysis of the following parameters: Dissolved Oxygen (DO), Biological Oxygen Demand (BOD5), Total Dissolved Solids (TDS), Total Suspended Solids (TSS), Total Solids (TS), Chemical Oxygen Demand (COD), Electrical Conductivity, Chlorinity, Calcium, Ammonium, Sulphate, Nitrate, Phosphate, Magnesium, Sodium, Potassium and Bicarbonate were collected and taken to University of Benin/ Benin Owena Joint Analytical Laboratory for analysis. In-situ measurement (on site) was however done for such parameters as air temperature, water temperature, water depth/width, flow velocity, turbidity and transparency.

The sample bottle is immersed into the water body at each sampling station, filled with water and covered with its appropriate lid. Note that the sample bottles were first rinsed with the water

Samples for Dissolved Oxygen (DO) at the four stations were collected by rinsing 250 ml and carefully corked while still in the water in order to avoid air bubbles and that no atmospheric oxygen enters the sample. The DO is then fixed in the field with winklers solutions A and B to produce a white precipitate.

Chemistry of Oxygen fixation

Winkler's solution A = $MnSO_4$

Winkler's solution B = KOH + KI

Eqn. 1: $MnSO_4 + 2KOH \rightarrow Mn(OH)_2 + K_2SO_4$ *(white ppt)*

Eqn. 2: In the presence of DO2 in water:

4Mn (OH)2 + 2H2O + O2 4Mn(OH)3 (manganic hydroxide)

Flocculent brown ppt which is insoluble in the alkaline medium provided by the presence of KOH or Mn(OH)2.

Water samples for Biological Oxygen Demand (BOD) were collected by rinsing the 250 ml amber bottle with the river's water, immersed into the water and corked while still in the water in order to avoid trapping air. Unlike the Dissolved Oxygen samples, that of Biological Oxygen Demand are not fixed with Winkler's solution A and B but rather wrapped with black polythene bags to prevent the peation of sunlight, hence preventing photosynthetic activities from occurring.

3.1.4.2 Collection of Bankroot Macroinvertebrate samples

Macroinvertebrate samples were collected from the 4 different stations using the modified kick sampling technique described by Keçi *et al.* (2012). The sediment upstream was disturbed by kicking with foot for about 5 minutes and the macroinvertebrate dislodged were washed into the net placed downstream of the disturbed point. Aquatic macrophytes along the banks and the macroinvertebrate dislodged were washed into the net. All the samples were preserved with 10% formalin in a plastic container and well labeled then taken to the Benin Owena laboratory for proper identification. The isolated macroinvertebrates were identified to the lowest possible taxonomic level.

LABORATORY ANALYSES

3.2 DETERMINATION OF PHYSICO-CHEMICAL PARAMETERS

3.2.1 Atmospheric temperature:

The atmospheric temperature was measured in-situ using mercury-in-glass thermometer graduated in ℃. The thermometer was held in the air for at the sampling site to adust to the outdoor temperature several minutes until it was stable, the red line on the thermometer was read at eye level to avoid parallax error and then recorded.

3.2.2 Water temperature:

The water temperature can affect the metabolic rates and biological activity of aqatic organisms, this was determined in-situ using mercury-in-glass thermometer. Part of the thermometer was submerged into the water at the station for a while until it stabilized and then recorded.

3.2.3 Water depth:

Water depth refers to how deep a water body is. This was measured using a secchi-disk. The secchi-disk was submerged using a calibrated rope in to the water at the station until it hits the river bottom; at this point the measurement is noted on the rope and then recorded.

3.2.4 Flow rate:

The current velocity was determined using the surface floatation technique, Here, a floatable material (cork) was dropped on the water surface and allowed to flow un-interrupted through a known distance, and the time taken to cover such a distance was recorded using a stopwatch. From the recordings obtained, the velocity was calculated from the formula- distance/time which gives an estimate of the velocity in cm/s.

3.2.5 Transparency

This was determined using a secchi-disk. The secchi-disk was submerged slowly in to the water at the sample station using a calibrated rope, the depth which it disappeared was recorded, the disc was gradually drawn up and the depth at which it reappears was recorded too. The average of the two depths was taken as the transparency reading.

3.2.6 Turbidity:

Turbidity is the cloudiness of water. It is a measure of the ability of light to pass through water. Visible spectrophometer Vs721G was used to determine the turbidity. The cuvettes were washed and rinsed with distilled water. One cuvette was filed to mark with distilled water which was used to standardize the spectrophotometer. The sample was then read at 420nm wavelength.

3.2.7 Colour:

Colour is affected by dissolved materials, especially organics, phytoplankton blooms, suspended iron hydroxide or a dinoflagallete bloom, and run-offs from surrounding environment into the water when it rains. Colour was determined using the visible spectrophotometer VS721g at 455nm. Distilled water of 50ml was poured through a filter paper to rinse it. Another 50ml distilled water was poured through the filter into a clean 50ml flask. Water sample of 50ml was added through the filter paper into a 50ml flask. These were read and the colour of water in mg/Pt-Co sample was recorded.

3.2.8 Total solids (TS):

Total solids were determined using gravimetric method. 10ml of the sample was measured into a pre-weighted evaporating dish. This was oven dried at a temperature between 103℃ and 105℃ for 2 and a half hour. The dish was cooled in a desiccator at room temperature and then weighted. The total solid was represented by the increase in the weight of the evaporating dish.

The formula is represented below.

Mg/l of total solid = (W2-W1) mg x 1000

ml of sample used

Where:

W_1= initial weight of evaporating dish

W_2= final weight of the dish (evaporating dish + residue)

3.2.9 Total Dissolved Solids (TDS):

Total dissolved solids were determined using the HACH 44600-00 conductivity/TDS meter. The probe was dipped into the sample container, a stable reading was obtained and recorded in mg/l.

3.2.10 Total Suspended Solids (TSS):

This was obtained by extrapolation, by subtracting the amount calculated from the Total Dissolved Solids from the Total Solid, i.e. TSS (mg/l) – TDS (mg/l).

3.3 CHEMICAL PARAMETERS

3.3.1 Hydrogen Ion Concentration

The pH of the water at the different sampling stations was measured by electronic movable pH meter (electrometric system). The probe of the pH was dipped into the water samples, held still till the values on the probe stabilized before the readings were recorded.

3.3.2 Dissolved Oxygen (Mg/ L)

Dissolved Oxygen (DO) is an important parameter that was determined using the Winkler system, which is else known as trimetric system. After the collection of water samples using 250 ml reagent bottles, they were fixed in- situ by adding 1 ml each of Winkler A result Manganese(II) sulphate(MnSO4) and Winkler B result Alkali- iodate azide(KI) independently, incontinently forming a precipitate indicating the oxygen had been trapped.

In the laboratory, the effects were dissolved adding 2 ml of concentrated Sulphuric acid (H_2SO4). Also, 100 ml of the aliquot was measured into a 250 ml conical beaker, later, two drops of lately prepared bounce index was added and mixed completely. Titration was done on the result against 0.025 M sodium thiosulphate result (NaSO5HO) till it came colorless. The volume of sodium thiosulphate used till the result came colorless is equal to the dissolved oxygen in mg/ l in the water sample.

3.3.3 Biochemical Oxygen Demand (Mg/ L)

Water samples for this parameter was collected like that of Dissolved Oxygen except that 250 ml amber reagent bottles were used and they were not fixed with Winkler result but rather wrapped in polythene bags in- situ to exclude photosynthesis from taken place.

In the laboratory, the water samples were incubated at 20 ℃ for 5 days. later, the same procedure for Dissolved Oxygen was used, the samples were analyzed and recorded. BOD5 was determined from the equation

BOD5 = DO1- DO5.

Where BOD5 = natural oxygen demand at day five

DO5 = dissolved oxygen at day five

DO1 = dissolved oxygen at day

3.3.4 Chemical Oxygen Demand (Mg/ L)

Chemical Oxygen Demand of the water samples was determined using the Dichromate system. 25 ml of the water sample being anatomized was pipette into a conical beaker, 10 ml of0.000833 Potassium dichromate (K2Cr2O7) result was added, and a pinch of Mercury(II) sulphate(HgSO4) and 10 ml of tableware sulphate(AgSO4.H2SO4) were also added to the sample and brought to boil gently on a hot plate for exactly 10minutes with plastic channel on

the mouth of the conical beaker. The mixture was left to cool down for 30minutes. later, 2 drops of ferroin index was added and titrated against0.025 M Ammonium Iron(II) sulphate hexahydrate(Fe(NH4) 2(SO4)2.6 H2O) until there was a color change, that is, from blue-green to red- brown.

The value of Chemical Oxygen Demand is determined by abating the Chemical Oxygen Demand of a pre-determined blank is abated from that of the water sample.

3.3.5 Alkalinity (Hco3-)

To assay the water samples for alkalinity, originally, 50 ml of the sample was pipetted into a clean 250 ml conical beaker. Later, two drops of methyl orange index were added and the result Was Titrated Against A Standard0.01 M Sodium Hydroxide (Noah) Result Till It Turned Pink(Andersen, 2002).

Total alkalinity (mg/ l) = V x M x,100

ml of sample used

Where V = volume of acid used

M = Molarity of acid used.

3.3.6 Chlorinity (Mg/ L)

This parameter was determined in the laboratory using a multiple parameter turbidimeter. The inquiry of the cadence was dipped into the water samples, held still till a stable reading was attained and also recorded (Beauchemin and Berman, 1989).

3.3.7 Nitrates (Mg/ L)

Nitrate was determined using the colorimetric system. Then, 5 ml of the water sample was measured and pipetted into a 50 ml beaker, 1 ml of Brucine was added, 5 ml of Sulphuric acid (H2SO4) was added fleetly and precisely and 14 ml of distilled water was added to the result to

make it up to 25 ml, the result was mixed completely. The result was also read at 470nm in the visible spectrophotometer VS721G(Beauchemin and Berman, 1989).

NO3(mg/ l) = instrument reading × pitch complementary ×col.vol.

Aliquot taken

Aliquot is the portion of the sample prepared.

3.3.8 Phosphates (Mg/ L)

Phosphate was determined in the water samples using ascorbic acid system. 5 ml of the water sample was measured into a 50 ml beaker, also 1 ml of Ascorbic acid was added and 19 ml of distilled water was added to make the result up to 25 ml. After 30 twinkles, the result, which is in blue colour, was read using visible spectrophotometer VS721G at a wavelength of 660nm(Beauchemin and Berman, 1989).

PO4(mg/ l) = instrument reading × pitch complementary ×col.vol.

Aliquot taken

Aliquot is the portion of the sample prepared.

3.3.9 Sulphates (Mg/ L)

This parameter was determined in the laboratory by the colorimetric system. 5 ml of the water ml of sample used

sample was pipetted into a 50 ml beaker, later, 1 ml of Gelatin- $BaCl_2$- reagent was added, 19 ml of distilled water was also added to make the result up to 25 ml. The sample was left to rest for 30 mins and later read at 420nm using the visible spectrophotometer VS721G(Beauchemin and Berman, 1989).

SO42-(mg/ l) = instrument reading × pitch complementary ×col.vol.

Aliquot taken

Aliquot is the portion of the sample prepared.

Interchangeable ANIONS(Sodium, Potassium)

(mg/ l)

3.3.10 Exchangeable Anions(Sodium, Potassium, Calcium And Magnesium)

The exchangeable bases(Sodium, Potassium, Calcium and Magnesium) attention in the water samples were determined using honey photometric system. This involved the use of Technicon bus analyzer honey photometer IV, which was precalibrated using known attention of Na, K, Ca2 and Mg2 with lithium as internal norms. The water samples were placed in small mugs in the sample charger module and automatically aspirated into the mixing module where the mixing of lithium and the samples passed, and the Teflon tube was checked regularly for good bubbles pattern. The mixed samples were also passed to the honey chamber where they were comminuted and burned with the aid of propane gas. The attention of each anion were measured by the colour intensity of the honey and the values were attained from an attached archivist(Philips and Greenway, 2008).

3.4 SORTING AND IDENTIFICATION OF BANKROOT MACROPHYTES

Sorting consists of picking up from the sieved material all the animals that were alive at the moment of the sampling. Large samples can be subdivided into sub-samples of roughly equal sized ins that can be sorted more comfortably. The sub-samples should be placed in different jars with preserving solution and labeled. A small quantity of the unsorted material is placed on a tray for an initial general sorting for large organisms with the aid of a magnifying lens. Large organism is placed immediately in appropriate containers making sure that no other smaller animals are attached to their bodies. Fine sorting is performed under a dissection microscope, during this phase a small quantity of the sample is spread onto a Petri-dish and carefully

examined to identify the organism. Organism are picked up and placed in different containers according to the main taxonomic groups, containers are labeled inside and outside. The organisms collected were stored in small sizes preservation specimen bottles, labeled and containing 4% formalin for later examination and identification

After sorting, organisms were identified to the taxonomic level required, which was carried out with the help of an identification key. The key are structured with a series of two choices to be made about the anatomy of the sorted organisms ("dichotomous", two branches), and the answers progressively reduce possible identification choices until a single name is left. For correct identification, accurate analytical keys for the geographical region from which the samples correctly. To catalogue species correctly it is strongly recommended that the international checklist of species e.g. the European Register of Marine Species (ERMS) or integrated Taxonomic Information System (ITIS), or national checklists are consulted.

CHAPTER FOUR

RESULTS

Along with the dipteran larvae macroinvertebrate that was gathered throughout the study period, August 2021 – January 2022, the values of the physical and chemical parameters for the study stations of the Okhuaihe River in Edo State are presented.

4.1 PHYSICAL AND CHEMICAL PARMETERS OF OKHUAIHE RIVER

The summary of the physio-chemical parameters of Okhuaihe River are provided in table 4.1 for spatial comparison and Table 4.2 for seasonal comparison respectively, Graphics for that comparison also are provided in Figure 4.1-4.1.1.

4.1.1 AIR TEMPERATURE

The spatial and seasonal variation of air temperature of the 4 different stations in the course of the study is given in Table 4.1 and 4.2 respectively and shown in Figure 4.1. The air temperature ranged from 25.00 – 30.00°C at station 1, with a mean value of 28.33°C, 26.00 -30.00°C at station 2 with a mean value of 27.67°C, 24.00 – 30.00°C at station 3, and 25.00 – 31.00°C at station 4, with a mean value of 28.33°C. Station 4 reported the maximum temperature of 31.00°C in December 2021 and January 2022, while station 3 recorded the minimum temperature of 24.00 °C in October 2021. Analysis of variance (ANOVA) results indicate d that the mean values at the study stations did not differ significantly from one another ($p>0.05$) (Table 4.1). According to Table 4.2, the dry season mean air temperature ($29.50\pm1.17^{o}C$) was higher than the wet season value of ($26.83\pm1.75^{o}C$) between the wet and dry season values, there was a highly significant difference ($p>0.1$) (Table 4.2).

Table 4.1: Spatial Variation of Physical and Chemical Parameters for Water Samples of Okhuaihe River.

Parameters	STATION 1 $\bar{X}$±SD (Min-Max)	STATION 2 $\bar{X}$± SD (Min-Max)	STATION 3 $\bar{X}$± SD (Min-Max)	STATION 4 $\bar{X}$± SD (Min-Max)	*p*-Value
Air temperature (^{0}C)	28.33±1.86 (25.00-30.00)	28.33±1.97 (26.00-30.00)	27.67±2.07 (24.00-30.00)	28.33±2.50 (25.00-31.00)	$p > 0.05$
Water temperature (^{0}C)	25.50±0.55 (25.00-26.00)	24.83±0.98 (24.00-26.00)	25.83±0.75 (25.00-27.00)	26.67±1.75 (25.00-30.00)	$p > 0.05$
Depth (cm)	0.48±0.35 (0.15-1.00)	0.36±0.17 (0.13-0.60)	0.36±0.25 (0.11-0.81)	0.28±0.09 (0.14-0.40)	$p > 0.05$
Ph	6.08±0.14 (5.90-6.30)	5.90±0.23 (5.58-6.30)	5.70±0.34 (5.30-6.30)	5.92±0.25 (5.70-6.30)	$p > 0.05$
Electrical Conductivity (µS/cm)	95.17±42.46 (52.50-161.30)	92.52±44.71 (40.70-155.50)	109.00±219.80 (39.30-219.80)	106.67±52.86 (40.80-181.60)	$p > 0.05$
Flow rate (m/s)	0.09 ± 0.09^{A} (0.00-0.20)	1.51 ± 1.63^{B} (0.01-3.00)	1.01 ± 1.08^{AB} (0.00-2.00)	0.01 ± 0.00^{A} (0.00-0.01)	$p < 0.05$
Total Dissolved Solids (mg/L)	46.78±21.17 (24.20-80.60)	45.67±21.64 (21.40-77.50)	54.25±30.08 (19.50-108.40)	52.97±26.16 (20.50-90.70)	$p > 0.05$
Transparency (m)	0.95±0.22 (0.70-1.20)	0.67±0.23 (0.40-1.00)	0.82±0.74 (0.20-2.00)	0.50±0.50 (0.20-1.50)	$p > 0.05$
Width (m)	16.58 ± 2.33^{C} (14.00-20.00)	11.50 ± 1.84^{B} (10.00-15.00)	10.58 ± 1.36^{B} (9.00-13.00)	3.17 ± 1.33^{A} (2.00-5.00)	$p < 0.01$
Dissolved Oxygen (mg/L)	1.15±0.70 (0.20-2.00)	1.00±0.66 (0.60-2.30)	1.75±1.52 (0.50-4.60)	1.97±2.42 (0.50-6.80)	$p > 0.05$
Biochemical Oxygen Demand (mg/L)	3.60±1.65 (0.05-5.40)	3.37±1.18 (1.10-4.30)	3.55±0065 (2.80-4.60)	3.82±0.54 (3.20-4.60)	$p > 0.05$
Sulphate (mg/L)	13.17±15.26 (3.00-43.00)	4.67±2.73 (3.00-10.00)	6.00±7.51 (2.00-21.00)	7.67±4.84 (3.00-17.00)	$p > 0.05$
Nitrate (mg/L)	0.86±0.69 (0.25-2.12)	0.85±0.54 (0.25-1.61)	0.72±0.43 (0.21-1.47)	1.16±1.58 (0.22-4.36)	$p > 0.05$
Ammonium-N (mg/L)	0.26±0.23 (0.12-0.72)	0.19±0.09 (0.09-0.31)	0.15±0.11 (0.01-0.31)	0.49±0.76 (0.09-2.04)	$p > 0.05$
Phosphate (mg/L)	0.12 ± 0.04^{A} (0.04-0.14)	0.08 ± 0.06^{A} (0.02-0.18)	0.09 ± 0.07^{A} (0.02-0.20)	0.23 ± 0.14^{B} (0.03-0.40)	$p < 0.05$

	10.59±3.87	10.59±3.87	11.77±3.65	10.59±3.87	$p > 0.05$
Chloride (mg/L)	(7.06-14.12)	(7.06-14.12)	(7.06-14.12)	(7.06-14.12)	
	42.33±61.26	9.50±5.99	12.50±6.98	17.33±6.15	$p > 0.05$
Turbidity (NTU)	(5.00-165.00)	(0.00-18.00)	(5.00-25.00)	(10.00-25.00)	
	0.59±0.36	0.53±0.11	0.52±0.17	0.89±0.64	$p > 0.05$
Iron (mg/L)	(0.37-1.32)	(0.43-0.75)	(0.39-0.87)	(0.41-2.14)	
	0.42±0.19	0.34±0.04	0.39±0.14	0.43±0.22	$p > 0.05$
Zinc (mg/L)	(0.25-0.74)	(0.28-0.38)	(0.24-0.65)	(0.25-0.84)	
	0.33±0.03	0.32±0.03	0.33±0.04	0.32±0.06	$p > 0.05$
Copper (mg/L)	(0.29-0.38)	(0.29-0.36)	(0.28-0.37)	(0.21-0.38)	
	0.05±0.01	0.04±0.01	0.04±0.01	0.05±0.01	$p > 0.05$
Manganese (mg/L)	(0.04-0.06)	(0.03-0.05)	(0.03-0.06)	(0.04-0.07)	
	0.07±0.02	0.06±0.02	0.06±0.02	0.07±0.01	$p > 0.05$
Chromium (mg/L)	(0.05-0.09)	(0.04-0.10)	(0.04-0.09)	(0.05-0.10)	

NOTE: $p < 0.01$ – Highly Significant Difference; $p > 0.05$ – No Significant Difference; Similar Superscripts Row-wise – No Significant Difference using Duncan Multiple Range Tests (DMRT). Where X = Mean, SD = Standard Deviation, Min. = Minimum value and Max. = Maximum value.

Table 4.2: Seasonal Variation of Physical and Chemical Parameters for Water Samples of Okhuaihe River

Parameter	Rainy Season			Dry Season			*p*-Value
	Min	Max	$\bar{X}$±SD	Min	Max	$\bar{X}$±SD	
Air temperature (^{0}C)	24.00	30.00	26.83±1.75	27.00	31.00	29.50±1.17	$p < 0.01$
Water temperature (^{0}C)	24.00	27.00	25.83±0.83	24.00	30.00	25.58±1.56	$p > 0.05$
Depth (m)	0.11	1.00	0.41±0.28	0.15	0.81	0.33±0.17	$p > 0.05$
Ph	5.30	6.30	5.93±0.33	5.58	6.16	5.88±0.20	$p > 0.05$
Electrical Conductivity (µS/cm)	68.50	219.80	128.73±46.48	39.30	122.50	72.95±31.04	$p < 0.01$
Flow rate (m/s)	0.01	3.00	0.87±1.24	0.00	3.00	0.44±0.99	$p > 0.05$
Total Dissolved Solids (mg/)	33.60	108.40	63.86±23.24	19.50	57.80	35.98±14.33	$p < 0.01$
Transparency (m)	0.20	1.50	0.68±0.42	0.20	2.00	0.79±0.54	$p > 0.05$
Width (m)	2.00	20.00	11.46±5.72	2.00	15.00	9.46±4.56	$p > 0.05$
Dissolved Oxygen (mg/L)	0.50	1.90	1.03±0.55	0.20	6.80	1.90±1.94	$p > 0.05$
Biochemical Oxygen Demand (mg/L)	3.10	4.60	3.83±0.43	0.50	5.40	3.34±1.39	$p > 0.05$
Sulphate (mg/L)	2.00	43.00	8.08±11.58	3.00	21.00	7.67±5.85	$p > 0.05$
Phosphate (mg/L)	0.02	0.40	0.16±0.12	0.02	0.26	0.10±0.07	$p > 0.05$
Nitrate (mg/L)	0.21	1.61	0.69±0.42	0.385	4.36	1.11±1.16	$p > 0.05$
Ammonium-N (mg/L)	0.12	0.72	0.27±0.15	0.009	2.04	0.27±0.56	$p > 0.05$

Chloride (mg/L)	7.06	14.12	12.36±3.19	7.06	14.12	9.41±3.48	$p < 0.05$
Turbidity (NTU)	7.00	165.00	27.67±43.89	0.00	32.00	13.17±9.33	$p > 0.05$
Iron (mg/L)	0.43	2.14	0.80±0.49	0.37	0.56	0.46±0.07	$p < 0.05$
Zinc (mg/L)	0.32	0.84	0.50±0.17	0.24	0.35	0.29±0.03	$p < 0.01$
Copper (mg/L)	0.29	0.38	0.34±0.03	0.21	0.36	0.32±0.04	$p > 0.05$
Manganese (mg/L)	0.03	0.07	0.05±0.01	0.03	0.05	0.04±0.00	$p < 0.01$
Chromium (mg/L)	0.04	0.10	0.07±0.02	0.04	0.07	0.06±0.01	$p > 0.05$

NOTE: $p < 0.01$ – Highly Significant Difference; $p > 0.05$ – No Significant Difference; Similar Superscripts Row-wise – No Significant Difference using Duncan Multiple Range Tests (DMRT). Where X = Mean, SD = Standard Deviation, Min. = Minimum value and Max. = Maximum.

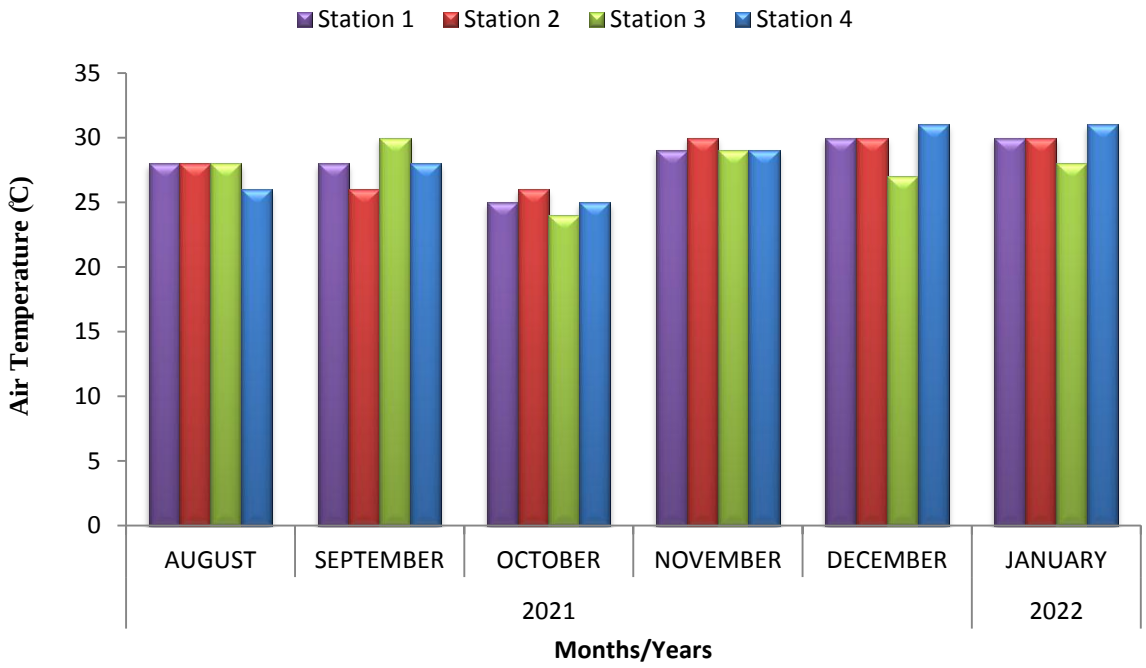

Fig. 4.1: Spatial and temporal variation of Air temperature

4.1.2 WATER TEMPERATURE (°C)

The spatial and seasonal variation of water temperature of the 4 different stations recorded in the course of this research as shown in Table 4.1- 4.2 respectively and represented in Fig 4.2, with the mean temperature at station 1 ranging from 24.00 – 26.00 °C, the mean value at station from 25.00 – 27.00 °C, and the mean value at station 4 from 25.00 – 30.00 °C. Station 4 reported the maximum temperature of 30.00 °C in November 2021, while station 2 recorded the minimum temperature of 24.00 °C on October 2021. There was no difference, according to analysis of variance (ANOVA) in the research stations mean values that was significant ($p>0.05$) (Table 4.1). In Table 4.2, the mean and standard deviation for the water temperature during the wet season (25.83±0.83 °C) were higher than the values during the dry season (25.58±1.56 °C). There was no discernible difference between the wet and dry season values ($p > 0.05$) (Table 4.2)**.**

4.1.3 DEPTH (cm)

The spatial and temporal variation in the depth of the sample stations are represented in Table 4.1 – 4.2 respectively and represented in Fig 4.3. The depth of the various samples stations measured throughout the investigation period ranged from 0.38 – 1.00 cm in station 1, 0.13 – 0.60 cm in station 2, 0.36 – 0.36 cm in station 3, and 0.11 – 0.81 cm in station 3. Station 4 depth ranged from 0.14 – 0.40 cm, with a mean value of 0.28 cm in September 2021, station 1 reported the deepest depth of 1.00 cm, while station 3 recorded the shallowest depth of 0.11 cm. analysis of variance (ANOVA) results indicated that the mean values of the study and did not differ significantly ($p>0.05$) (Table 4.2) than the dry season in Table 4.2, the rainy season mean value

and standard deviation for depth (0.41±0.28 cm) was larger than the dry season ((0.33±0.17 cm) value. There was no discernible difference between the wet and dry season data ($p > 0.05$). (Table 4.2).

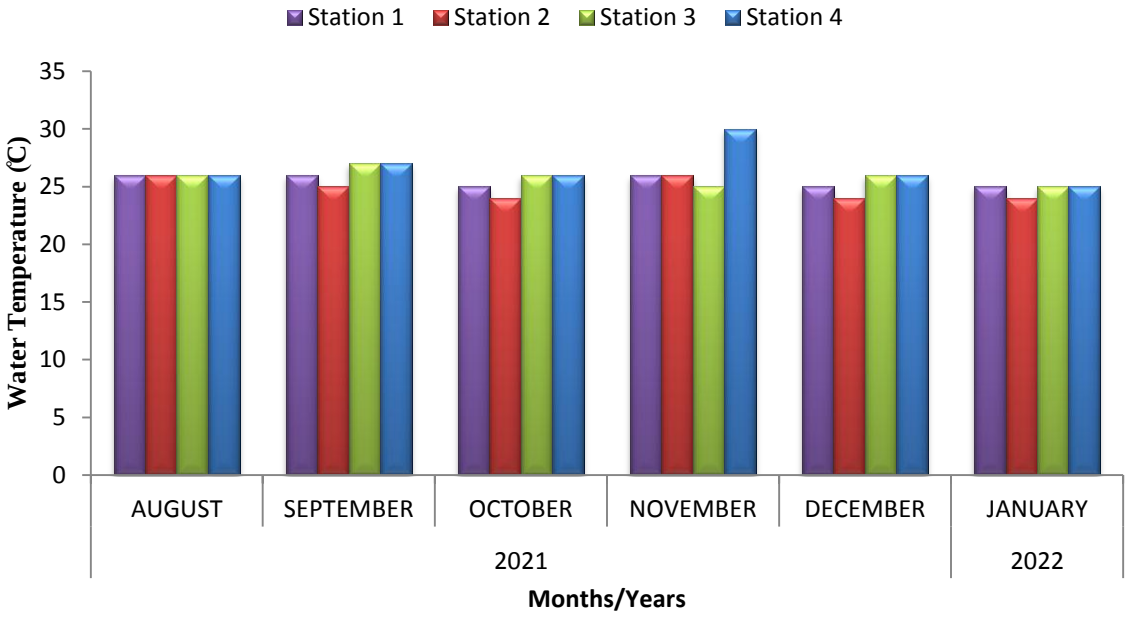

Fig. 4.2: Spatial and temporal variation of Water temperature

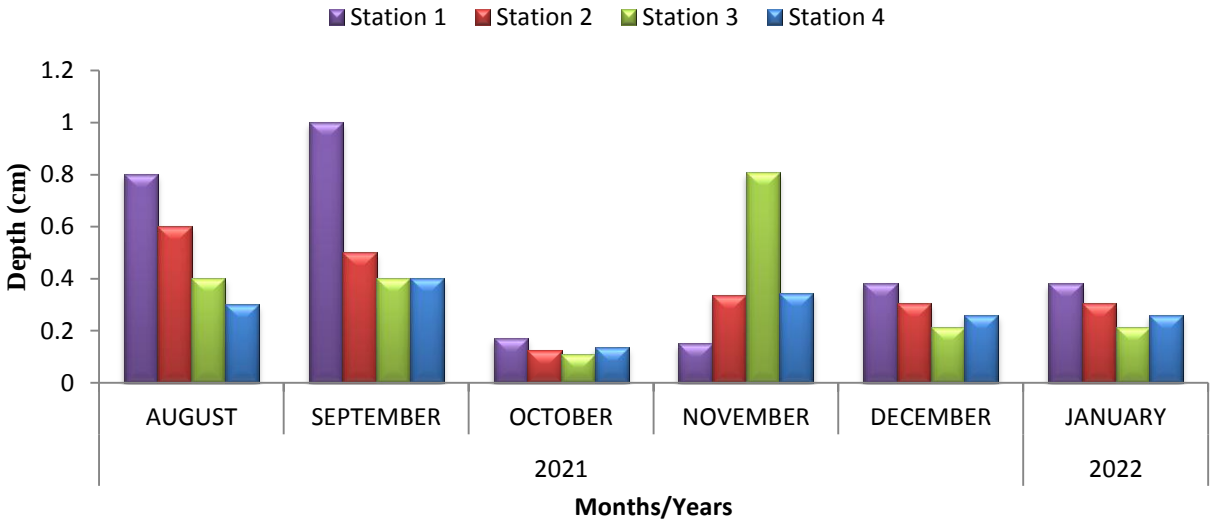

Fig. 4.3: Spatial and temporal variation of Depth

4.1.4 HYDROGEN CONCENTRATION (pH)

The spatial and seasonal comparison in the value of pH for the water are proven in Table 4.1 – 4.2 respectively and represented in Fig 4.4. the pH values measured during the research period for the 4 sample stations varied from 5.90 – 6.30 in station 1 with a mean value of 6.08, 5.590 – 6.30 in station 2, 5.90 – 6.30 in station 3, and 5.70 – 6.30 with a mean value of 5.92 in station 4. The stations 1, 2, 3 and 4 recorded the maximum pH of 6.30 in October 2021, and station 3 recorded the lowest pH of 5.30 in September 2021. Analysis of variance (ANOVA) results indicated that the study stations mean values did not differ significantly ($p > 0.05$). (Table 4.1). In Table 4.2, the dry season mean pH value and standard deviation (5.88±0.20) was lower than the rainy season 5.93±0.33 (). There was no discernible difference between the wet and dry season data ($p > 0.05$). (Table 4.2).

4.1.5 ELECTRICAL CONDUCTIVITY (µS/cm)

The spatial and temporal variations in electrical conductivity values for water are proven in Table 4.1 and 4.2 respectively and represented in Fig 4.5. The electrical conductivity values ranged from 52.50 – 161.30 µS/cm in station 1 with a mean value of 95. 17 µS/cm, 40.70 – 155.50 µS/cm in station 2 with a mean value of 92.52 µS/cm, 39.30 – 219.80 µS/cm in station 3 with a mean value of 109.00 µS/cm and 40.80 – 181.60 µS/cm in station 4 with a mean value of 106.67 µS/cm. station 3 recorded the lowest electrical conductivity value of 39.30 µS/cm in December 2021, and the greatest electrical conductivity value of 219.80 µS/cm in September 2021. Analysis of variance (ANOVA) results indicated that the study stations mean values did not differ significantly ($p > 0.05$). Electrical conductivity mean value and standard deviation during dry season (72.95±31.04 µS/cm) were lower than those during the wet season

(72.95±31.04 µS/cm). The wet and dry season had a significant difference (p 0.01) in the value (Table 4.2).

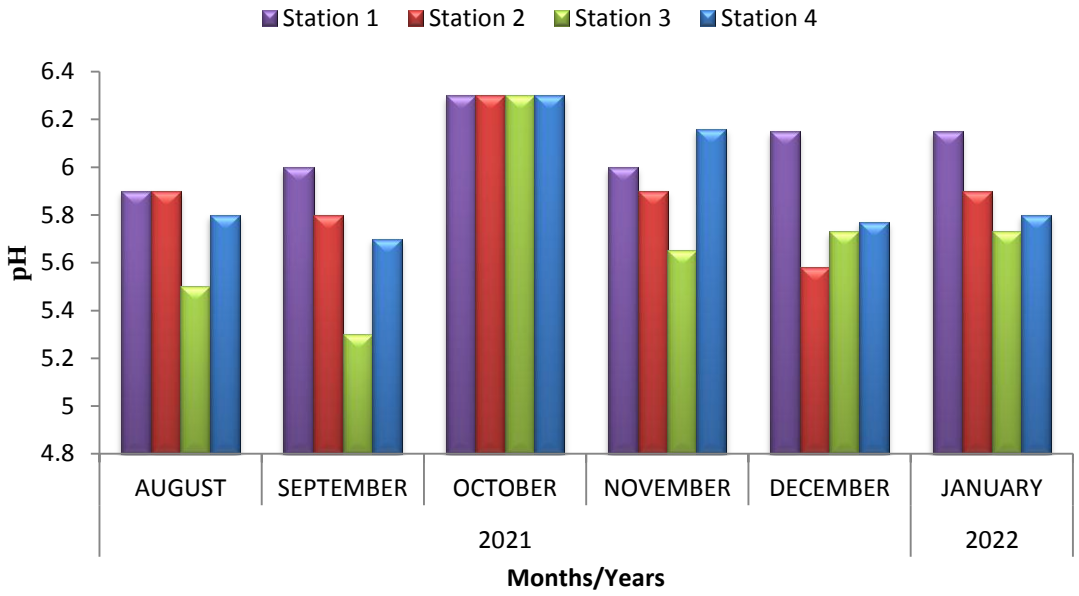

Fig. 4.4: Spatial and temporal variation of pH

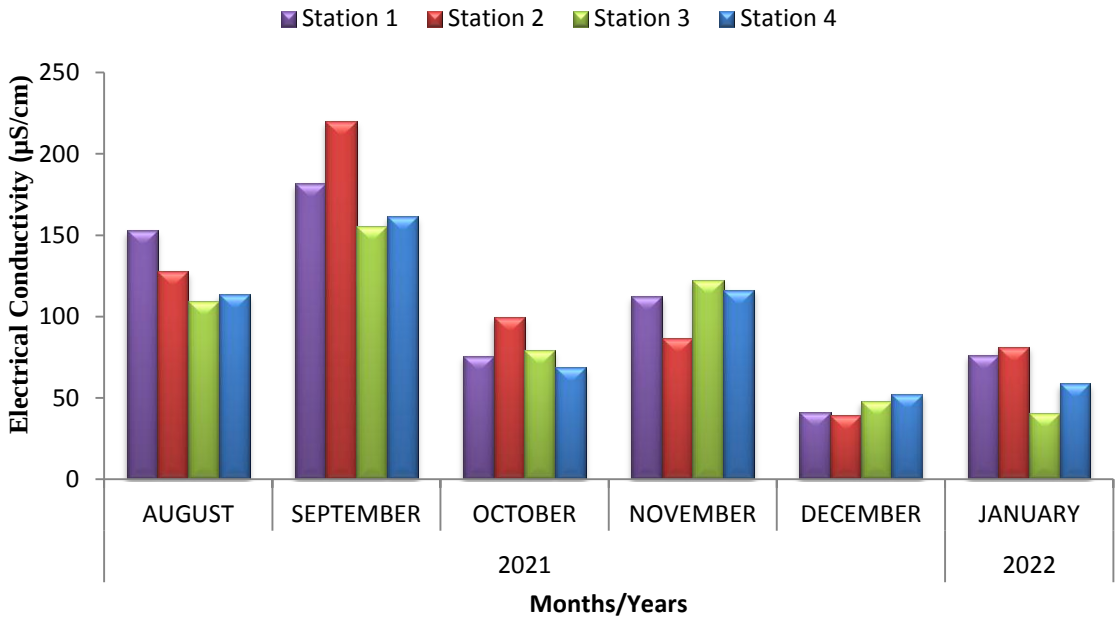

Fig. 4.5: Spatial and temporal variation Electrical conductivity

4.1.6 FLOW RATE (cm/s)

The flow rate of the four distinct stations recorded during the course of the research as represented in Table 4.1 – 4.2 respectively and represented in Fig 4.6 ranged from 0.00 – 0.20cm/s in station 1 with a mean value of 0.09cm/s, 0.01 – 3.00cm/s in station 2 with a mean value of 1.51cm/s, 0.00 – 2.00cm/s in station 3 with a mean value of 1.01cm/s and 0.00 – 0.1cm/s with a mean value of 0.01cm/s in station 4. In august, September, and January 2022, station 2 recorded the greatest flow rate of 3.00 cm/s, while station 1, 3, and 4 reported the lowest figure of 0.00 cm/s .the results of the Duncan Multiple Range test revealed that station 2 differed significantly from station 1, 3, and 4. (Table 4.1) in Table 4.2, the mean value and standard deviation for flow rate during the dry season were lower (0.44±0.99 cm/s) than the wet season (0.87±1.24 cm/s). There was no discernible difference between the wet and dry season data ($p > 0.05$). (Table 4.2).

4.1.7 TOTAL DISSOLVED SOLIDS (mg/l)

The spatial and temporal variations in the total dissolved solids value are shown in Table 4.1 – 4.2 respectively and represented in Fig 4.7. the total dissolved solids value ranged between 24.20 – 80.60 mg/l in station 1 with a mean value of 46.78 mg/l, 21.40 – 77.50 mg/l in station 2 with a mean value of 45.67 mg/l, 19.50 – 108.40 mg/l in station 3 with a mean value of 54.25mg/l and 20.50 – 90.70mg/l in station 4 with a mean value of 52.97mg/l. In September 2021, station 3 recorded a maximum value of 108.40 mg/l, while in December 2021, station 3 recorded the minimum value of 19.50 mg/l. analysis of variance (ANOVA) results indicated that the study stations mean values did not differ significantly ($p >0.05$). (Table 4.1). as shown in Table 4.2, the mean value and standard deviation during the dry season(35.98±14.33 mg/l) were lower than

those during the wet season (63.86±23.24 mg/l) . The wet and dry seasons had a significant difference (p 0.01) in the values (Table 4.2).

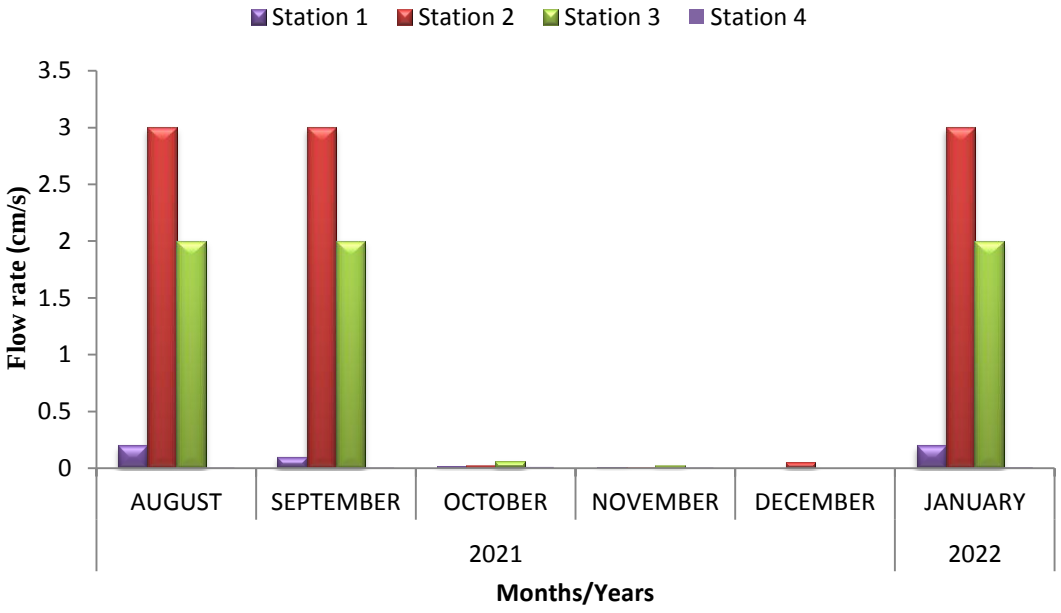

Fig. 4.6: Spatial and temporal variation of Flow rate

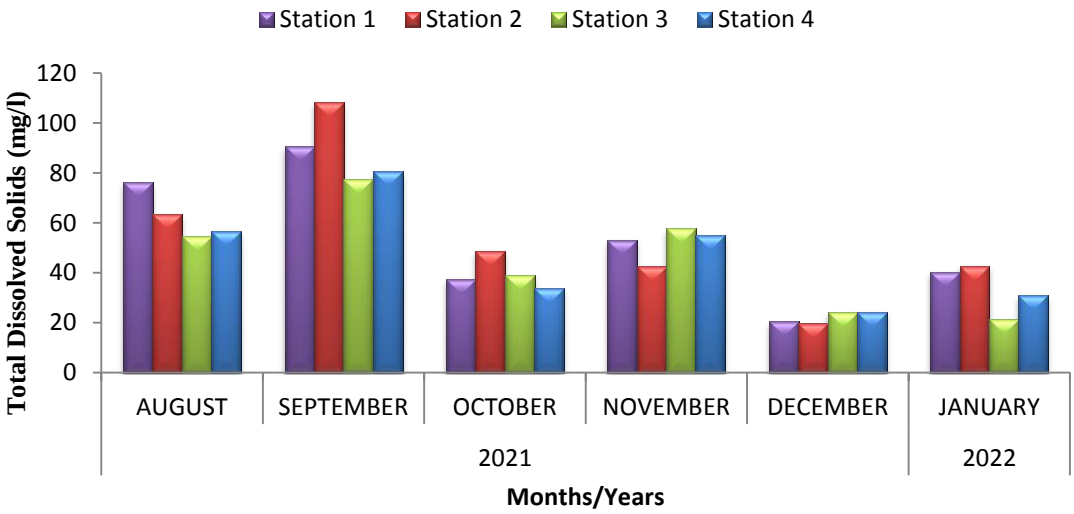

Fig. 4.7: Spatial and temporal variation of Total dissolved solids

4.1.8 TRANSPARENCY

The transparency across the sampled stations recorded throughout the duration of research as in seen in Table 4.1 – 4.2 respectively and represented in Fig 4.8 ranged between 0.70 – 1.20 in station 1 with a mean value of 0.90, 0.40 – 1.00 in station 2 with a mean value of 0.67, 0.20 – 2.00 in station 3 with a mean value of 0.82 and 0.20 – 1.50 in station 4 with a mean value of 0.50. The lowest value of 0.20 was recorded at station 3 in October 2021, station 4 in September 2021, and station 3 in November 2021, station 4 in September 2021, and station 3 in November 2021. The highest clarity of 2.00 was recorded at station 3 in November 2021. Analysis in variance (ANOVA) results indicated that the study stations mean values did not differ significantly ($p > 0.05$). (Table 4.1). In Table 4.2, the mean value and standard deviation for transparency during the dry season (0.79 ± 0.54) were higher than the value during the rainy season (0.68 ± 0.42). There was no discernible difference between the wet and dry season data. ($p > 0.05$). (Table 4.2).

4.1.9 WIDTH (cm)

The spatial and temporal variation in the width of the sampled station during the period of investigations are shown in Table 4.1 – 4.2 respectively and represented in Fig 4.9. The width of the 4 different stations recorded throughout the duration of research ranged from 14.00 – 20.00cm in station 1 with a mean value of 16. 58cm, 10.00 -15.00cm in station 2 with a mean value of 11.50cm, 9.00 – 13.00 in a station 3 with a mean value of 10.58cm and 2.00 – 5.00cm in station 4 with a mean value of 3.17cm in station 4. In august 2021, station 1 recorded the narrowest width of 20 cm, and station recorded the narrowest width of 2 cm in August 2021, November 2021, and January 2022. Analysis of variance (ANOVA) results indicated a highly significant difference between the study stations mean values 9p 0.01). (Table 4.1). In Table 4.2,

the mean and standard deviation for the width during the dry season (9.46±4.56 cm) were lower than those during the wet season (11.46±5.72 cm). There was no discernible difference between the wet and dry season data. ($p > 0.05$). (Table 4.2).

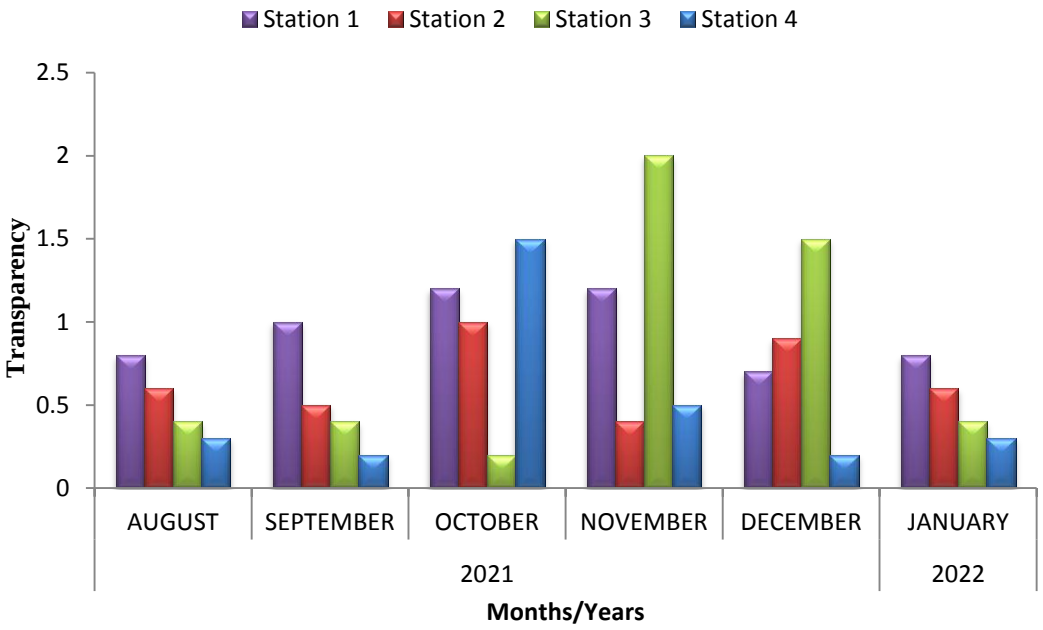

Fig. 4.8: Spatial and temporal variation of Transparency

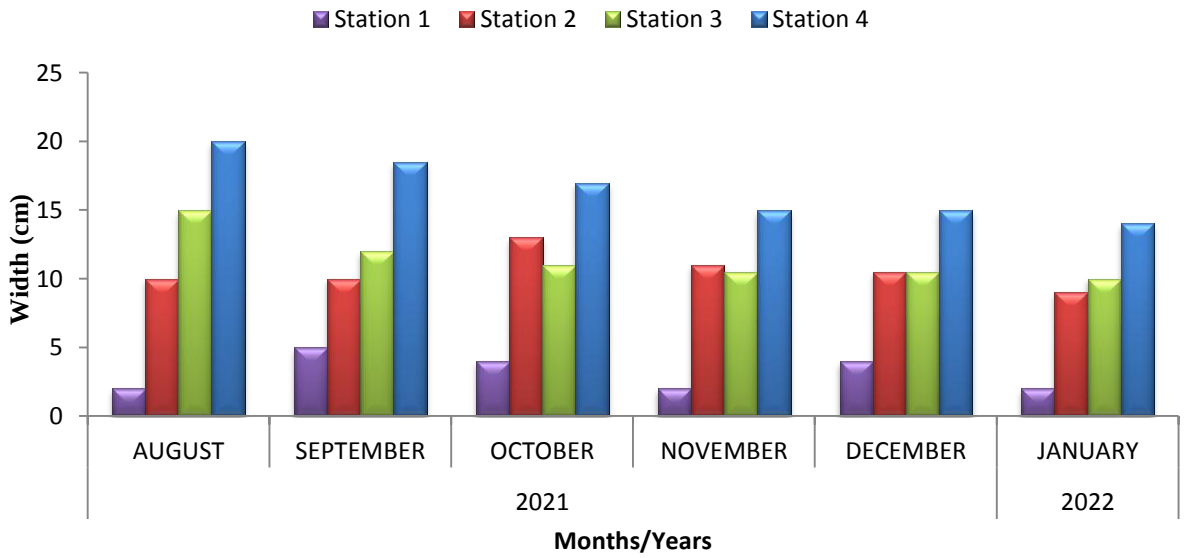

Fig. 4.9: Spatial and temporal variation of Width

4.1.10 DISSOLVED OXYGEN (mg/l)

The dissolved oxygen recorded in the course of the duration of this research for the 4 stations as shown in Table 4.1 – 4.2 respectively and represented in Fig 4.10 ranged between 0 200 – 2.00mg/l in station with a mean value of 1.15mg/l, 0.60 – 2.00mg/l in station 2 with a mean value of 1.00mg/l, 0.50 – 4.60mg/l in station 3 with a mean value of 1.75mg/l and 0.50 – 6.80mg/l with a mean value of 1.97mg/l in station 4. Station 4 recorded the maximum dissolved oxygen value of 6.8o mg/l in January 2022, while station 1 recorded the lowest value of 0.20 mg/l in November 2021. Analysis of variance (ANOVA) results indicated that the study stations mean values did not differ significantly ($p > 0.05$). (Table 4.1). According to Table 4.2, the mean and standard deviation for dissolved oxygen during the dry season (1.03±0.55 mg/l) were higher than those during the wet season (1.90±1.94 mg/l). There was no discernible difference between the wet and the dry season data ($p > 0.05$). (Table 4.2).

4.1.11 BIOCHEMICAL OXYGEN DEMAND (mg/l)

The biochemical oxygen demand for the four station recorded during the course of this research as shown in Table 4.1 – 4.2 respectively and represented in Fig 4.11 ranged among 0.50 – 5.40mg/l in station 1 with a mean value of 3.60mg/l, 1.10 – 4.30mg/l in station 2 with a mean value of 3.37mg/l, 2.8 – 4.60mg/l in station 3 with a mean value of 3.55mg/l and 3.20 – 4.60mg/l with a mean value of 3.82mg/l in station 4. In November 2021, station 1recorded the greasiest biochemical oxygen demand of 5.40 mg/l, while in January 2021, station 1 recorded the lowest biochemical oxygen demand of 0.50 mg/l. analysis of variance (ANOVA) results indicated that the study stations mean values did not differ significantly ($p > 0.05$). (Table 4.1). in table 4.2, the mean and standard deviation for the biochemical oxygen demand during the dry season were

lower (3.34±1.39 mg/l) than those during the rainy season (3.83±0.43 mg/l). Here was no discernible difference between the wet and dry season data. (P > 0.05). (Table 4.2).

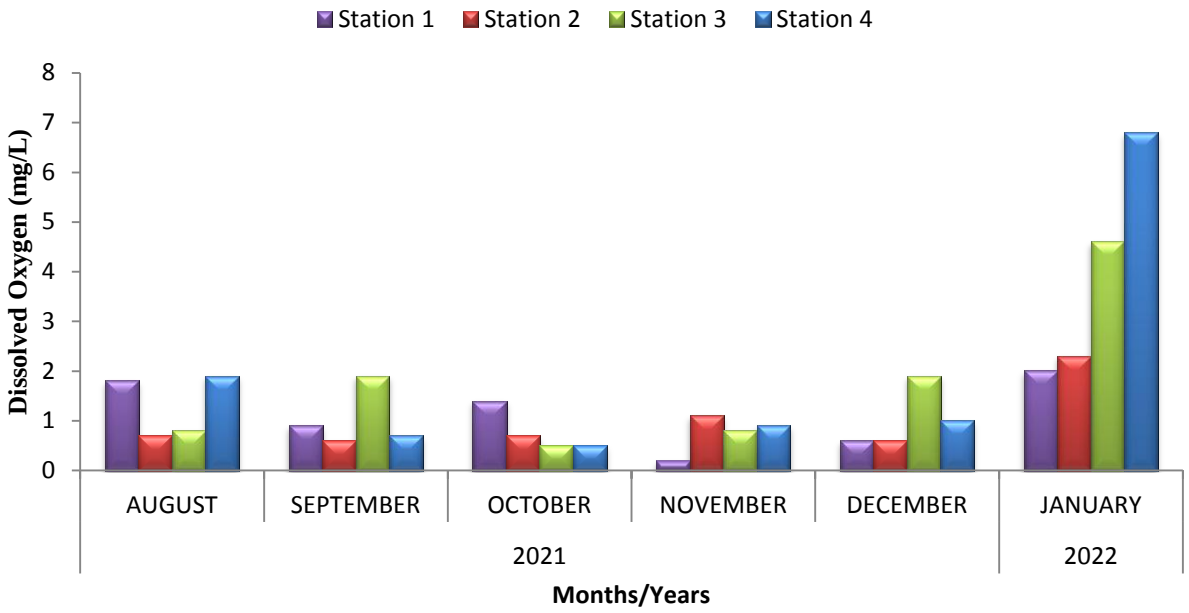

Fig. 4.10: Spatial and temporal variation of Dissolved oxygen

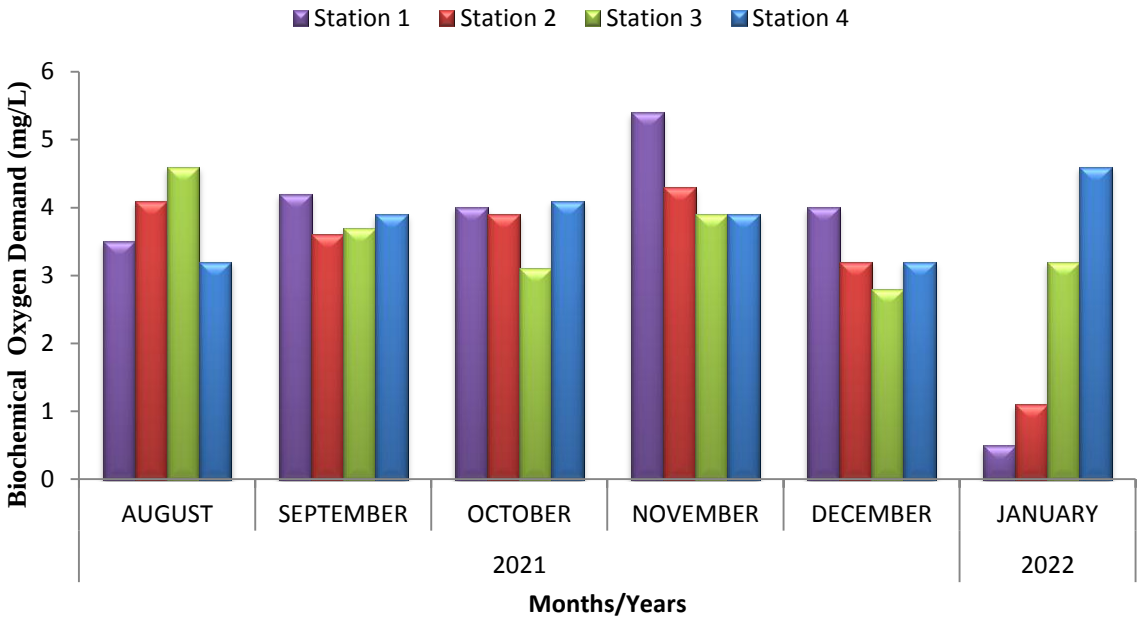

Fig. 4.11: Spatial and temporal variation of Biochemical oxygen demand

4.1.12 SULPHATE

The nutrient value primarily based on Sulphates for the 4 stations recorded throughout the length of the research as shown in Table 4.1 – 4.2 respectively and represented in Fig 12 ranged among 3.00 – 43.oomg/l in station 1 with am mean value of 13.17mg/l, 3.00 – 10.00mg/l in station 2 with a mean value of 4.67mg/l, 2.00 – 21.00mg/l in station 3 with a mean value of 6.00mg/l and 3.00 – 17 00mg/l with a mean value of 7.67mg/l in station 4. The lowest value of 2.00 mg/l was recorded at station 3 in August, September, and October 2021, while station 1 recorded the highest sulphate value of 43.00 mg/l on October 2021. Analysis of variance (ANOVA) results indicated that the study stations mean values did not differ significantly ($p > 0.05$). (Table 4.1). in Table 4.2, the mean and standard deviation for sulphate during the dry season (7.67±5.85 mg/l) were lower than those during the wet season (8.08±11.58 mg/l). There was no discernible difference between the wet and dry season data. ($p > 0.05$). (Table 4.2).

4.1.13 NITRATES (mg/l)

The nitrates content during the length of research as shown in Table 4.1 -4.2 respectively and represented in Fig 4.13 ranged among 0.25 2.12mg/l in station 1 with a mean value of 0.86mg/l, 0.25 – 1.61mg/l in station 2 with a mean value of 0.85mg/l, 0.21 – 1.47mg/l in station 3 with a mean value of 0.72mg/l and 0.22 – 4.36mg/l in station 4 with a mean value of 1.16mg/l. The highest nitrate value of 4.36 mg/l was recorded at station 4 in January, 2022 and lowest value of 0.21 mg/l was recorded at station 3 in September, 2021. Analysis of Variance (ANOVA) results indicated that the study stations mean values did not differ significantly ($p > 0.05$). (Table 4.1). in Table 4.2, the mean and standard deviation for nitrate during the dry season (1.11±1.16 mg/l)

were higher than those during the rainy season (0.69±0.42 mg/l). There was no discernible difference between the wet and dry season data ($p > 0.05$). (Table 4.2).

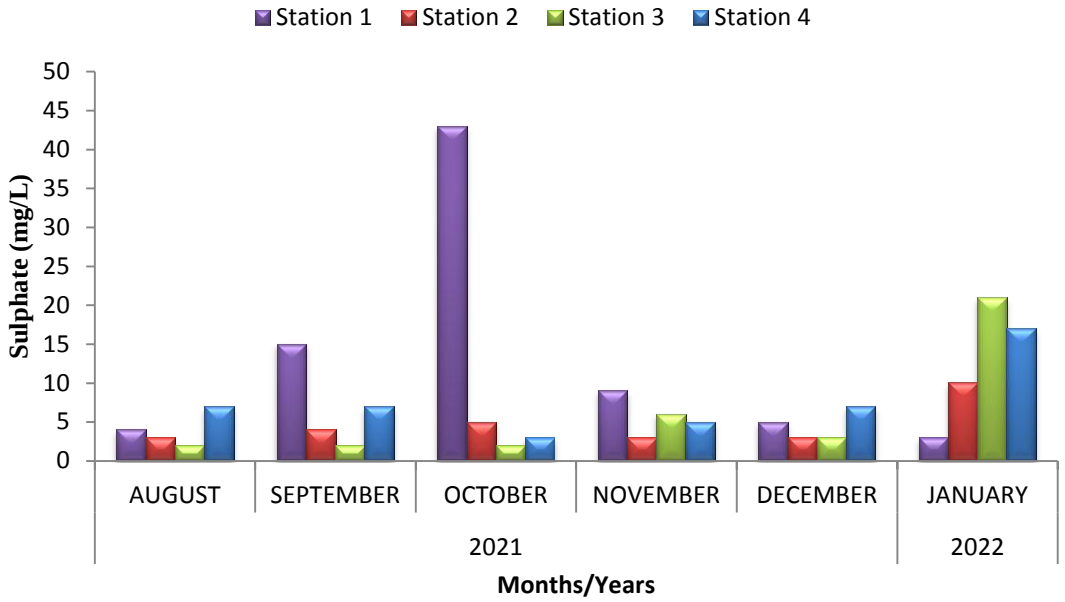

Fig. 4.12: Spatial and temporal variation of Sulphate

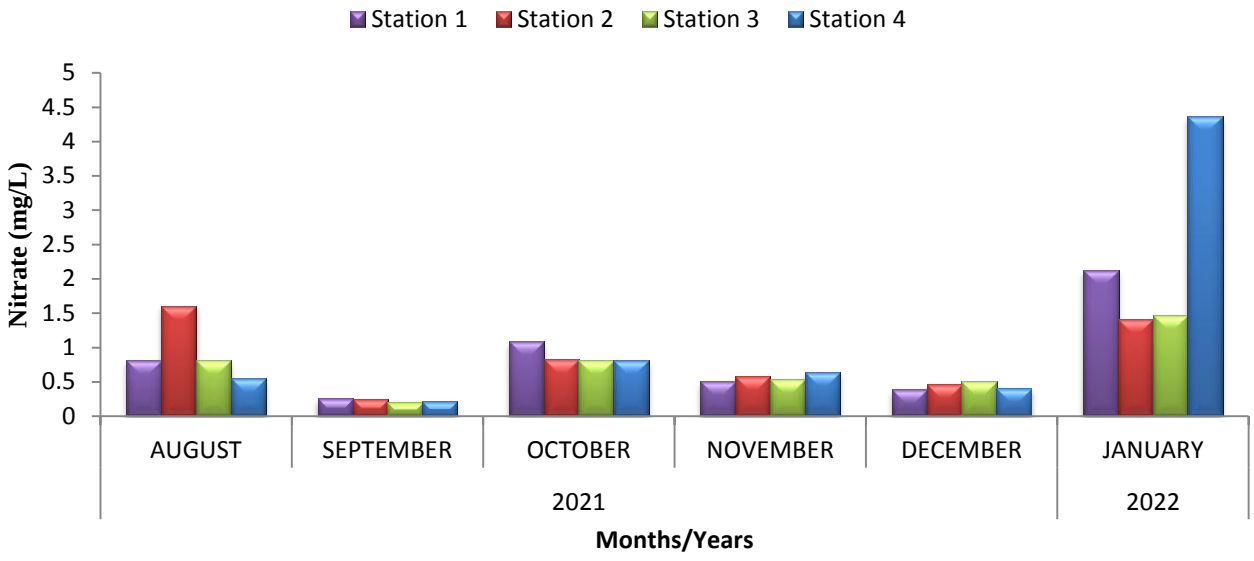

Fig. 4.13: Spatial and temporal variation of Nitrate

4.1.14 AMMONIUM-N (mg/l)

The nutrient values based on Ammonium-N for the 4 sample stations recorded during the period of investigation as seen in Table 4.1 – 4.2 respectively and represented in Fig. 4.14 ranged between 0.12 – 0.72 mg/l in station 1 with a mean value of 0.26 mg/l, 0.09 – 0.31 mg/l in station 2 with a mean value of 0.19 mg/l, 0.01 – 0.31 mg/l in station 3 with a mean value of 0.15 mg/l and 0.09 – 2.04 mg/l in station 4 with a mean value of 0.49 mg/l. In January 2022, station 4 recorded the highest ammonium value of 2.04 mg/l while station 3 recorded the lowest value of 0.01 mg/l. Analysis variance (ANOVA) results indicated that the study stations mean values did not differ significantly ($p > 0.05$). (Table 4.1). In Table 4.2, the mean and standard deviation for ammonium during the dry season (0.27±0.56 mg/l) were higher than those during the wet season (0.27±0.15 mg/l). No difference was fond that was significant ($p > 0.05$). (Table 4.2).

4.1.15 PHOSPHATE (mg/l)

The nutrient values based on phosphate for the 4 sample stations recorded during the period of investigation as seen in Table 4.1 – 4.2 respectively and represented in Fig. 4.15 ranged between 0.04 – 0.14 mg/l in station 1 with a mean value of 0.12 mg/l, 0.02 – 0.18 mg/l in station 2 with a mean value of 0.08 mg/l, 0.02 – 0.20 mg/l in station 3 with a mean value of 0.09 mg/l and 0.03 – 0.40 mg/l in station 4 with a mean value of 0.23 mg/l. The highest phosphate value of 0.40 mg/l was recorded at station 4 in August, 2021 and lowest value of 0.02 mg/l was recorded at station 2 and 3 in October, 2021 and November, 2021 respectively. Analysis of Variance (ANOVA) result indicated that the study stations mean values did not differ significantly ($p >0.05$). (Table 4.1). in Table 4.2, the mean and standard deviation for phosphate during the dry season (0.10±0.07 mg/l) were lower than those during the wet season (0.16±0.12 mg/l). There was no discernible difference between the wet and dry season data ($p >0.05$). (Table 4.2).

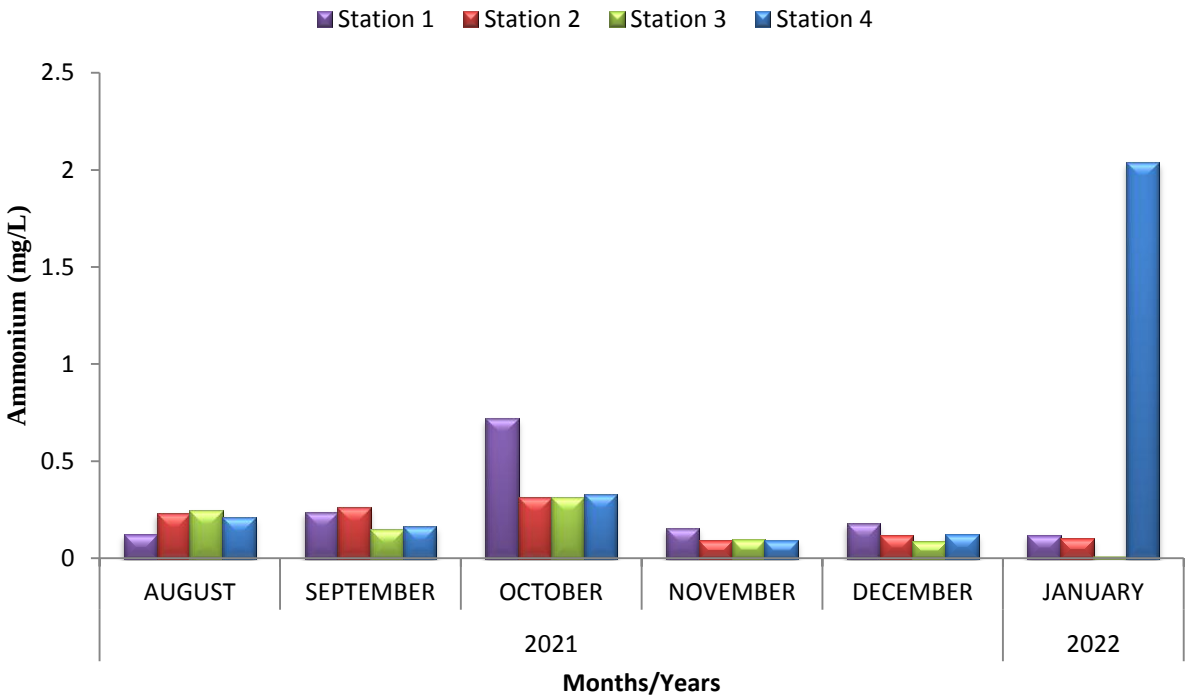

Fig. 4.14: Spatial and temporal variation of Ammonium

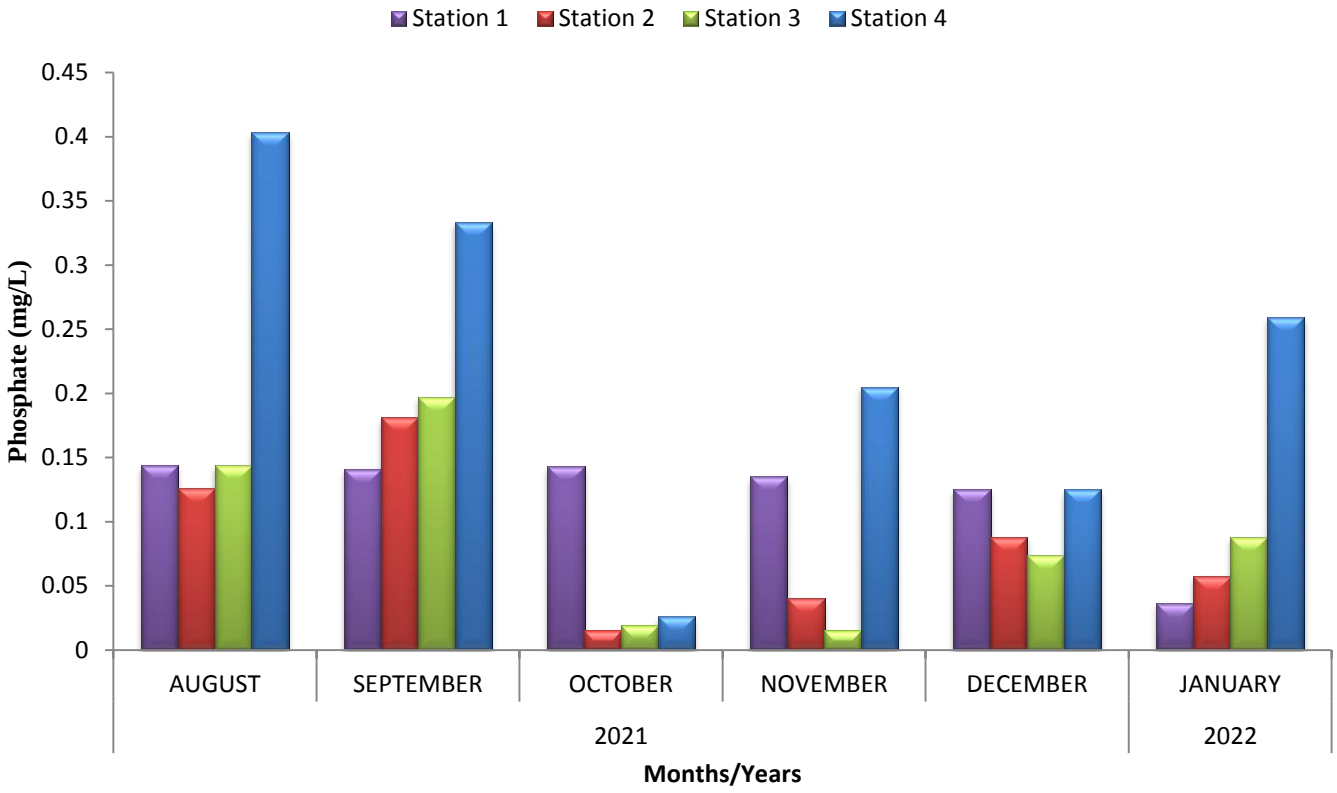

Fig. 4.15: Spatial and temporal variation of Phosphate

4.1.16 CHLORIDE (mg/l)

The nutrient values based on chloride for the 4 sample stations recorded during the period of investigation as seen in Table 4.1 – 4.2 respectively and represented in Fig. 4.16 ranged between 7.06 – 14.12 mg/l in station 1 with a mean value of 10.59 mg/l, 7.06 – 14.12 mg/l in station 2 with a mean value of 10.59 mg/l, 7.06 – 14.12 mg/l in station 3 with a mean value of 11.77 mg/l and 7.06 – 14.12 mg/l in station 4 with a mean value of 10.59 mg/l. In total, 14.12 mg/l and 7.06 mg/l of chloride were measured at the highest and lowest sampling locations respectively. Analysis of variance (ANOVA) results indicated that the study stations mean values did not differ significantly ($p > 0.05$). (Tablen4.1). in Table 4.2, the mean values and standard deviation for chloride during the dry season (9.41±3.48 mg/l) were lower than those during the dry season (12.36±3.19 mg/l). The wet season and dry season value differed significantly ($p > 0.05$). (Table 4.2).

4.1.17 TURBIDITY (NTU)

The turbidity values recorded for the 4 sample stations during the period of investigation as seen in Table 4.1 – 4.2 respectively and represented in Fig. 4.17 ranged between 5.00 – 165.00 NTU in station 1 with a mean value of 42.33 NTU, 0.00 – 18.00 NTU in station 2 with a mean value of 9.50 NTU, 5.00 – 25.00 NTU in station 3 with a mean value of 12.50 NTU and 10.00 – 25.00 NTU in station 4 with a mean value of 17.33 NTU. The lowest value of 0.00 NTU was recorded at station 2 in January 2022, and the highest turbidity value of 165.00 NTU was reported at station 1 in October 2021. Analysis of variance (ANOVA) results indicated that the study stations mean values did not differ significantly ($p > 0.05$). (Table 4.1). In Table 4.2, the mean and standard deviation for turbidity during the dry season (13.17±9.33 NTU) were lower than

those during the wet season (27.67±43.89 NTU). There was no discernible difference between the wet and dry season data ($p > 0.05$). (Table 4.2).

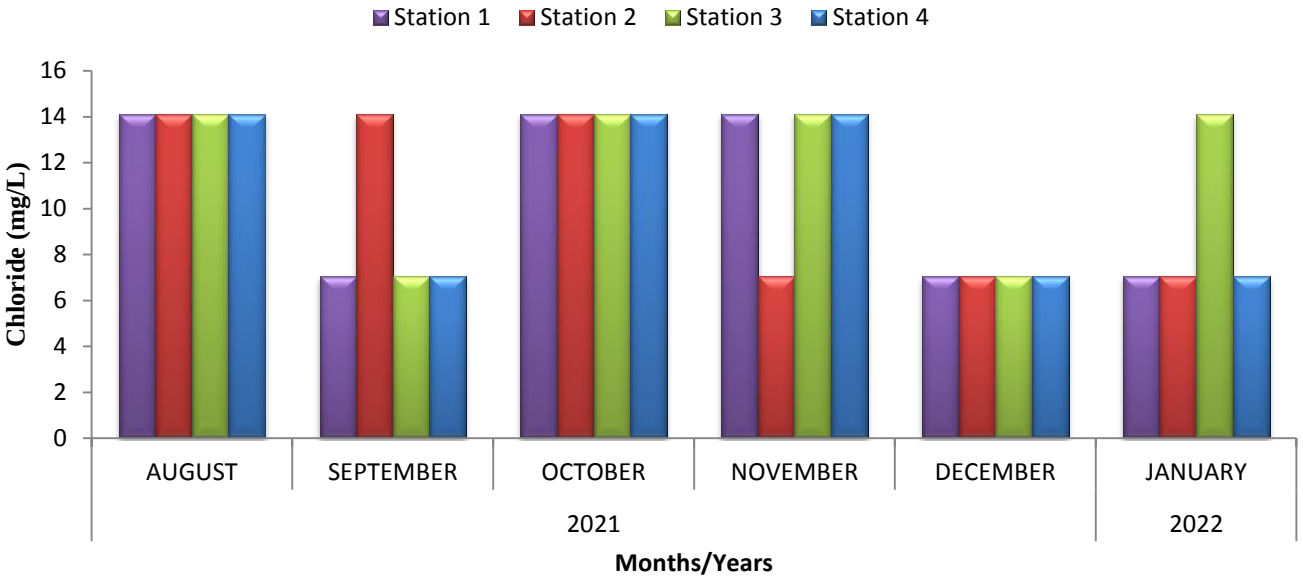

Fig. 4.16: Spatial and temporal variation of Chloride

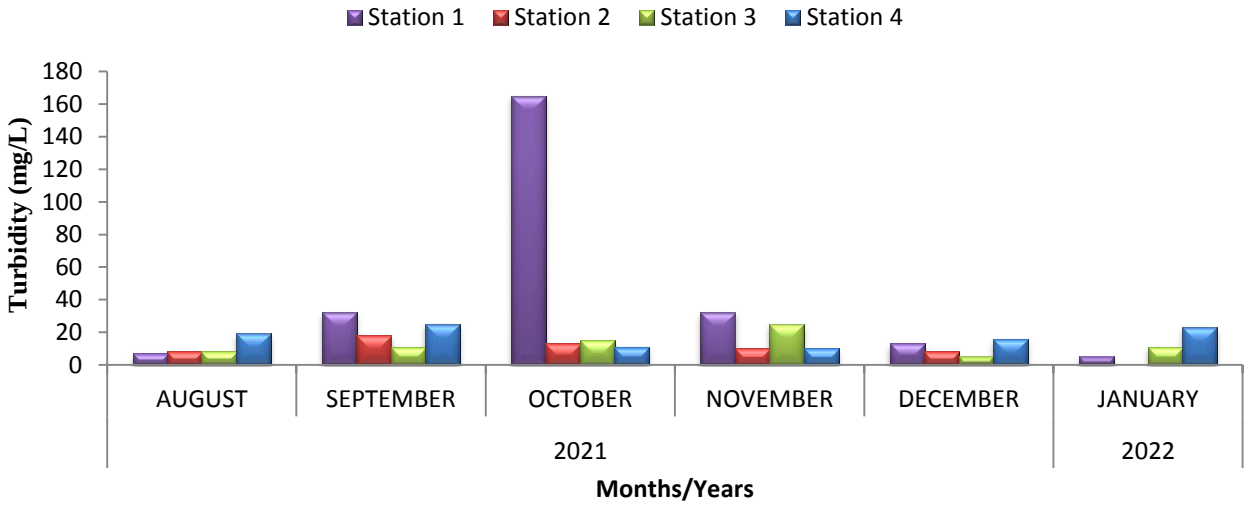

Fig. 4.17: Spatial and temporal variation of Turbidity

4.1.18 IRON (mg/l)

The nutrient values based on iron for the 4 sample stations recorded during the period of investigation as seen in Table 4.1 – 4.2 respectively and represented in Fig. 4.18 ranged between 0.37 – 1.32 mg/l in station 1 with a mean value of 0.59 mg/l, 0.43 – 0.75 mg/l in station 2 with a mean value of 0.53 mg/l, 0.39 – 0.87 mg/l in station 3 with a mean value of 0.52 mg/l and 0.41 – 2.14 mg/l in station 4 with a mean value of 0.89 mg/l. in September 2021, station 4 reported the highest iron value 2.14 mg/l, while station 1 recorded the lowest value of 0.37 mg/l. analysis of variance (ANOVA) results indicated that the study stations mean values did not differ significantly ($p > 0.05$). (Table 4.1). In table 4.2, the mean and standard deviation for iron during the dry season (0.46±0.07 mg/l) were lower than those during the wet season (0.80±0.49 mg/l). The wet season and dry season values differed significantly ($p > 0.05$. (Table 4.2).

4.1.19 ZINC (mg/l)

The nutrient values based on zinc for the 4 sample stations recorded during the period of investigation as seen in Table 4.1 – 4.2 respectively and represented in Fig. 4.19 ranged between 0.25 – 0.74 mg/l in station 1 with a mean value of 0.42 mg/l, 0.28 – 0.38 mg/l in station 2 with a mean value of 0.34 mg/l, 0.24 – 0.65 mg/l in station 3 with a mean value of 0.39 mg/l and 0.25 – 0.84 mg/l in station 4 with a mean value of 0.43 mg/l. A mean value of 0.43 mg/l and a range of 0.43 mg/l and a range ofo.25 mg/l to o.80 mg/l in station 4. In September 2021, station 4 reported the highest zinc value of 0.84 mg/l, while station 3 recorded the lowest value of 0.24 mg/l. analysis of variance (ANOVA) results indicated that the study stations mean values did not differ significantly ($p > 0.05$). (Table 4.1). in Table 4.2, the mean and standard deviation for zinc during the dry season 0.50±0.17 mg/l () were lower than the value during the wet season

(0.29±0.03 mg/l). Between the wet and dry season values, there was a highly significant difference ($p > 0.05$). (Table 4.2).

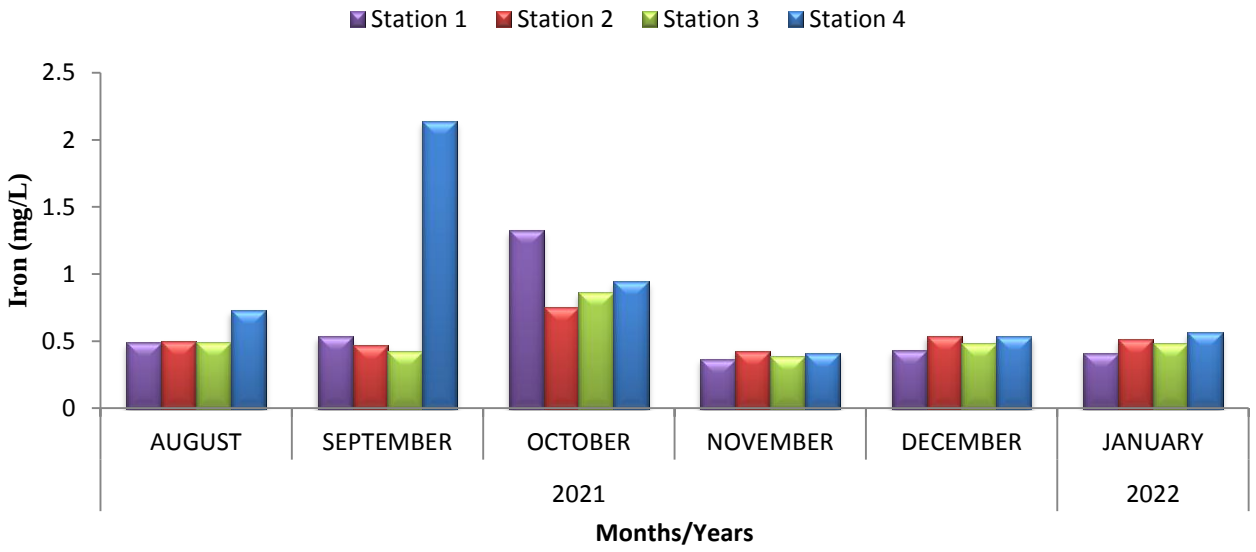

Fig. 4.18: Spatial and temporal variation of Iron

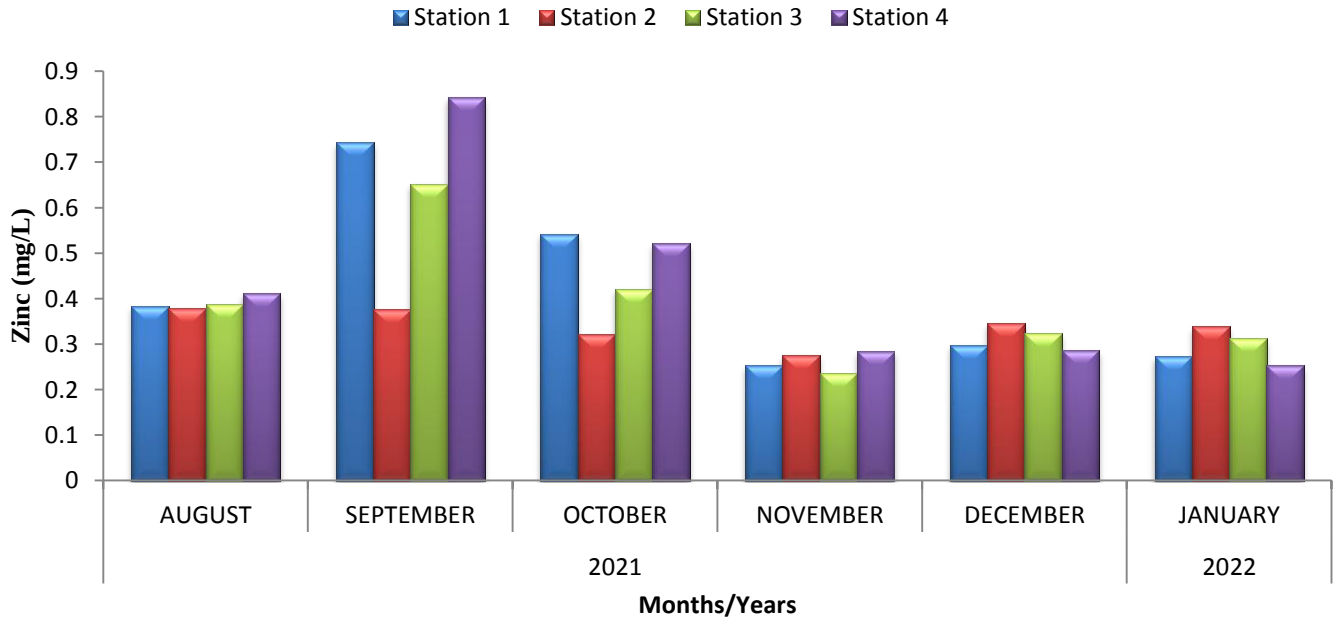

Fig. 4.19: Spatial and temporal variation of Zinc

4.1.20 COPPER (mg/l)

The nutrient values based on copper for the 4 sample stations recorded during the period of investigation as seen in Table 4.1 – 4.2 respectively and represented in Fig. 4.20 ranged between 0.29 – 0.38 mg/l in station 1 with a mean value of 0.33 mg/l, 0.29 – 0.36 mg/l in station 2 with a mean value of 0.32 mg/l, 0.28 – 0.37 mg/l in station 3 with a mean value of 0.33 mg/l and 0.21 – 0.38 mg/l in station 4 with a mean value of 0.32 mg/l. In September 2021, station 4 reported the highest zinc value of 0.84 mg/l, while station 3 recorded the lowes**t** value of 0.24 mg/l. analysis of variance (ANOVA) results indicated that the study stations mean values did not differ significantly ($p > 0.05$). (Table 4.1). In Table 4.2, the mean and standard deviation for zinc during the dry season (0.32±0.04 mg/l) were lower than the value during the wet season (0.34±0.03 mg/l). Between the wet and dry season values, there was a highly significant difference ($p > 0.01$). (Table 4.2).

4.1.21 MANGANESE (mg/l)

The nutrient values based on manganese for the 4 sample stations recorded during the period of investigation as seen in Table 4.1 – 4.2 respectively and represented in Fig. 4.21 ranged between 0.04 – 0.06 mg/l in station 1 with a mean value of 0.05 mg/l, 0.03 – 0.05 mg/l in station 2 with a mean value of 0.04 mg/l, 0.03 – 0.06 mg/l in station 3 with a mean value of 0.04 mg/l and 0.04 – 0.07 mg/l in station 4 with a mean value of 0.05 mg/l. Station 4 reported the highest manganese value of 0.07 mg/l in September 2021, while stations 2 and 3 recorded the lowest value of 0.03 mg/l in August 2021 and January 2022, respectively. Analysis of variance (ANOVA) results indicated that the study stations mean values did not differ significantly ($p > 0.05$). (Table 4.1). In Table 4.2, the mean and standard deviation for manganese during the dry season (0.04±0.00

mg/l) were lower than those during the wet and dry season values(0.05±0.01 mg/l), there was a highly significant difference (p> 0.01). (Table 4.2).

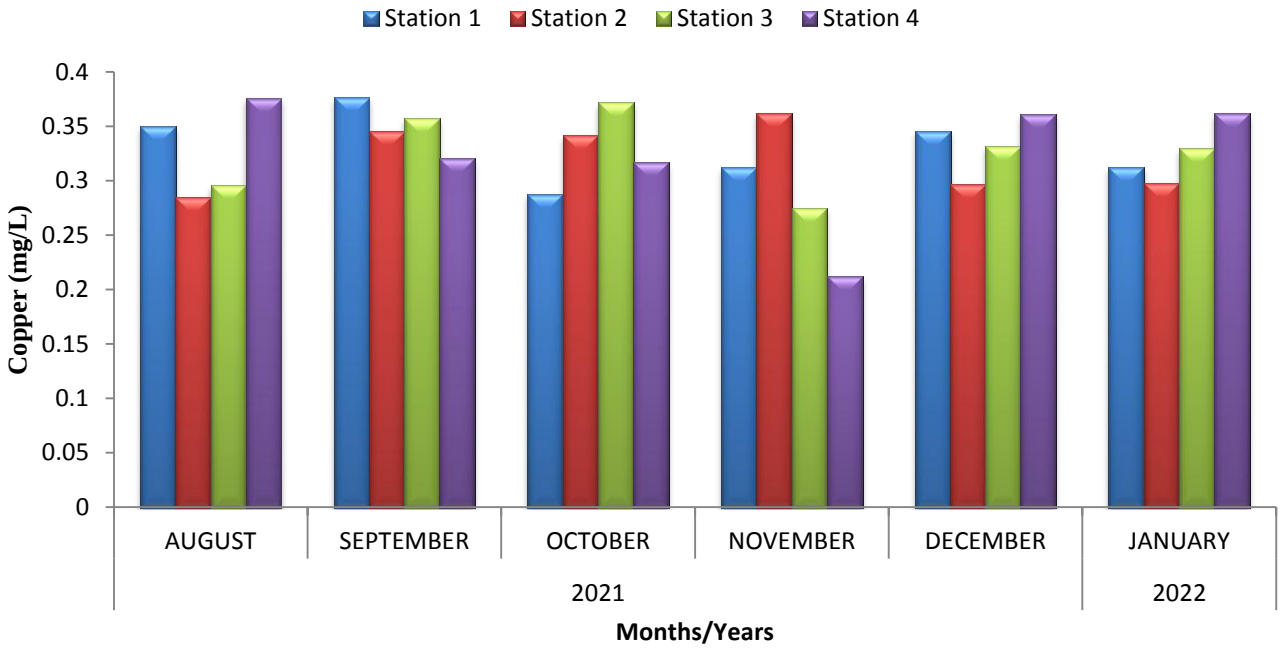

Fig. 4.20: Spatial and temporal variation of Copper

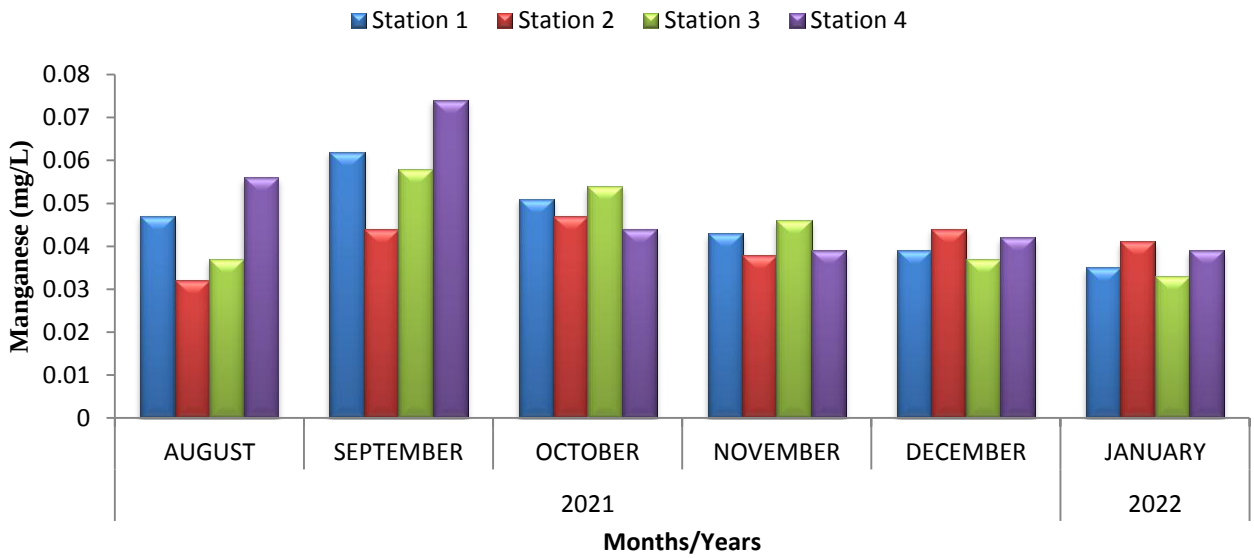

Fig. 4.21: Spatial and temporal variation Manganese

4.1.22 CHROMIUM (mg/l)

The nutrient values based on chromium for the 4 sample stations recorded during the period of investigation as seen in Table 4.1 – 4.2 respectively and represented in Fig. 4.22 ranged between 0.05 – 0.09 mg/l in station 1 with a mean value of 0.07 mg/l, 0.04 – 0.10 mg/l in station 2 with a mean value of 0.06 mg/l, 0.04 – 0.09 mg/l in station 3 with a mean value of 0.06 mg/l and 0.05 – 0.10 mg/l in station 4 with a mean value of 0.07 mg/l. the stations 2 and 4 recorded the highest chromium value of0.10 mg/l in September 2021. Whereas the station 2 and 3 recorded the lowest value of 0.04 mg/l in August 2021. Analysis of variance (ANOVA) results indicated that te study stations mean values did not differ significantly ($p > 0.05$). (Table 4.1). In table 4.2, the mean and standard deviation for chromium during the dry season (0.06±0.01 mg/l) were lower than the value during the wet season (0.07±0.02 mg/l). There was no discernible difference between the wet and dry season data ($p > 0.05$). (Table 4.2).

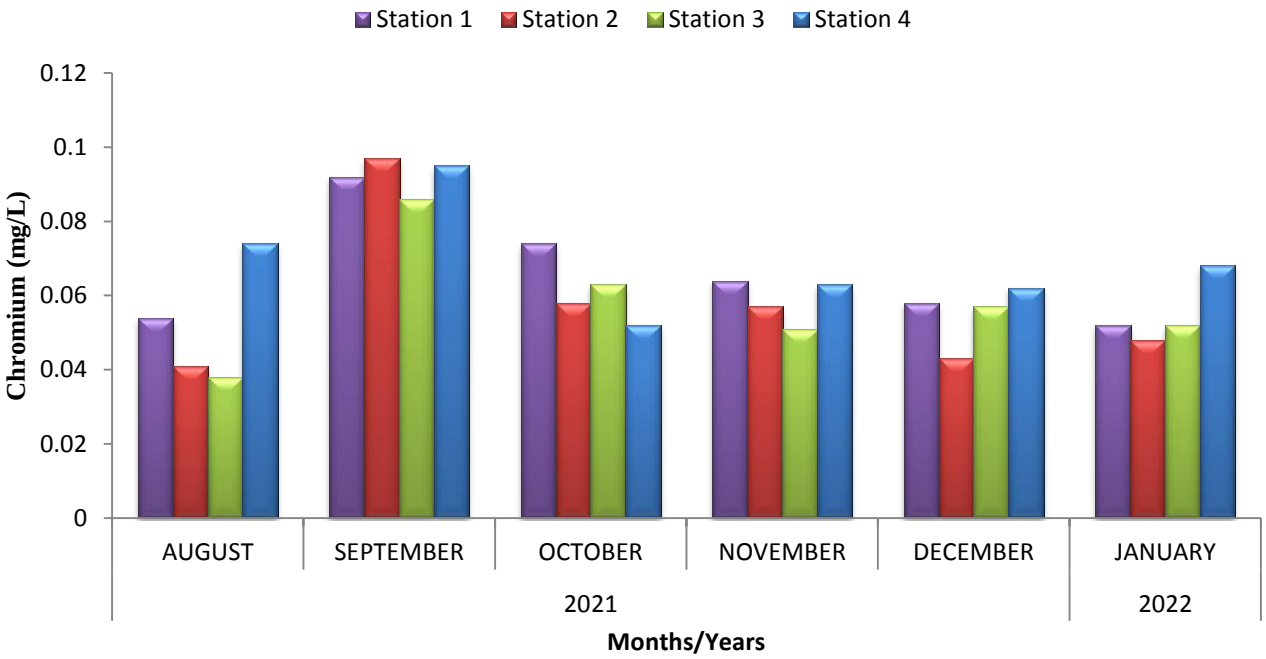

Fig. 4.22: Spatial and temporal variation of Chromium

4.1.23 WATER QUALITY INDEX (WQI)

Table 4.3 shows the study stations water quality computations. The values of some of the physiochemical parameters collected in 4 sampling stations were compared with the Federal ministry of Environment (FMEnv) permissible limits for certain of the parameters as shown in Appendices 4.1 – 4.2.

12.50, 10.25, 11.94, and 11.92 are the values recorded at the study stations, which are stations, 1, 2, 3, and 4, respectively (Table 4. 3). According to the water quality results at stations I and 4, the sampled stations area suitable for human consumption and can sustain aquatic life as well as other domestic activities (< 50).

Table 4.3: Water Quality of the Study Stations

Station	Water Quality Index (WQI)
Station 1	12.50
Station 2	10.25
Station 3	11.94
Station 4	11.92

< 50 = Excellent,

50 – 100 = Good

100 – 200 = Poor

200 – 300 = Very poor (bad) water

> 300 = Unsuitable (unfit) for drinking (Ramakrishniah *et al.*, 2009).

APPENDIX 4.1: Water Quality Index for Station 1

Parameter	Test Result	FME Limits (Si)	1/Si	K	Weightage (Wi)	Quality Rating (Qi)	[(Wi)(Qi)]
Transparency (mg/L)	0.95	0.5	2	0.013113	0.006557	190	1.245779
Conductivity (µS/cm)	95.17	1000	0.001	0.013113	13.113	9.517	124.7964
Turbidity (mg/L)	42.33	5	0.2	0.013113	0.065565	846.6	55.50733
pH	6.08	6.5-8.5	0.153846	0.013113	0.085235	184	15.68315
TDS (mg/L)	46.78	500	0.002	0.013113	6.5565	9.356	61.34261
Chloride (mg/L)	10.59	250	0.004	0.013113	3.27825	4.236	13.88667
Phosphate (mg/L)	0.12	5	0.2	0.013113	0.065565	2.4	0.157356
Sulphate (mg/L)	13.17	100	0.01	0.013113	1.3113	13.17	17.26982
Nitrate (mg/L)	0.86	50	0.02	0.013113	0.65565	1.72	1.127718
DO (mg/L)	1.15	7.5	0.133333	0.013113	0.098348	189.4366	18.63062
BOD_5 (mg/L)	3.6	0.05	20	0.013113	0.000656	7200	4.72068
Iron (mg/L)	0.59	0.3	3.333333	0.013113	0.003934	196.6667	0.773667
Zinc	0.42	5	0.2	0.013113	0.065565	8.4	0.550746
Copper	0.33	0.1	10	0.013113	0.001311	330	0.432729
Manganese	0.046	0.05	20	0.013113	0.000656	92	0.06032
Chromium	0.066	0.05	20	0.013113	0.000656	132	0.086546
Total			**76.25751**		**25.30875**		**316.2722**
WQ1 = 12.49656							

APPENDIX 4.2: Water Quality Index for Station 2

Parameter	Test Result	FME Limits (Si)	1/Si	K	Weightage (Wi)	Quality Rating (Qi)	[(Wi)(Qi)]
Transparency (mg/L)	0.67	0.5	2	0.013113	0.006557	134	0.878602
Conductivity (µS/cm)	92.52	1000	0.001	0.013113	13.113	9.252	121.3215
Turbidity (mg/L)	9.5	5	0.2	0.013113	0.065565	190	12.45735
pH	5.9	6.5-8.5	0.153846	0.013113	0.085235	220	18.75159
TDS (mg/L)	45.67	500	0.002	0.013113	6.5565	9.134	59.88707
Chloride (mg/L)	10.59	250	0.004	0.013113	3.27825	4.236	13.88667
Phosphate (mg/L)	0.085	5	0.2	0.013113	0.065565	1.7	0.111461
Sulphate (mg/L)	4.67	100	0.01	0.013113	1.3113	4.67	6.123771
Nitrate (mg/L)	0.85	50	0.02	0.013113	0.65565	1.7	1.114605
DO (mg/L)	1	7.5	0.133333	0.013113	0.098348	191.5493	18.83839
BOD_5 (mg/L)	3.37	0.05	20	0.013113	0.000656	6740	4.419081
Iron (mg/L)	0.5	0.3	3.333333	0.013113	0.003934	166.6667	0.65565
Zinc	0.34	5	0.2	0.013113	0.065565	6.8	0.445842
Copper	0.32	0.1	10	0.013113	0.001311	320	0.419616
Manganese	0.041	0.05	20	0.013113	0.000656	82	0.053763
Chromium	0.057	0.05	20	0.013113	0.000656	114	0.074744
Total			**76.25751**		**25.30875**		**259.4397**
WQ2 = 10.25099							

APPENDIX 4.3: Water Quality Index for Station 3

Parameter	Test Result	FME Limits (Si)	1/Si	K	Weightage (Wi)	Quality Rating (Qi)	[(Wi)(Qi)]
Transparency (mg/L)	0.82	0.5	2	0.013113	0.006557	164	1.075304
Conductivity (µS/cm)	109	1000	0.001	0.013113	13.113	10.9	142.9317
Turbidity (mg/L)	12.5	5	0.2	0.013113	0.065565	250	16.39125
pH	5.7	6.5-8.5	0.153846	0.013113	0.085235	260	22.16097
TDS (mg/L)	54.25	500	0.002	0.013113	6.5565	10.85	71.13803
Chloride (mg/L)	11.77	250	0.004	0.013113	3.27825	4.708	15.434
Phosphate (mg/L)	0.09	5	0.2	0.013113	0.065565	1.8	0.118017
Sulphate (mg/L)	6	100	0.01	0.013113	1.3113	6	7.8678
Nitrate (mg/L)	0.72	50	0.02	0.013113	0.65565	1.44	0.944136
DO (mg/L)	1.75	7.5	0.133333	0.013113	0.098348	180.9859	17.79951
BOD_5 (mg/L)	3.55	0.05	20	0.013113	0.000656	7100	4.655115
Iron (mg/L)	0.52	0.3	3.333333	0.013113	0.003934	173.3333	0.681876
Zinc	0.39	5	0.2	0.013113	0.065565	7.8	0.511407
Copper	0.33	0.1	10	0.013113	0.001311	330	0.432729
Manganese	0.044	0.05	20	0.013113	0.000656	88	0.057697
Chromium	0.058	0.05	20	0.013113	0.000656	116	0.076055
Total			**76.25751**		**25.30875**		**302.2756**
WQ3 = 11.94352							

APPENDIX 4.4: Water Quality Index for Station 4

Parameter	Test Result	FME Limits (Si)	1/Si	K	Weightage (Wi)	Quality Rating (Qi)	[(Wi)(Qi)]
Transparency (mg/L)	0.5	0.5	2	0.013113	0.006557	100	0.655673
Conductivity (µS/cm)	106.67	1000	0.001	0.013113	13.113	10.667	139.8764
Turbidity (mg/L)	17.34	5	0.2	0.013113	0.065565	346.8	22.73794
pH	5.92	6.5-8.5	0.153846	0.013113	0.085235	216	18.41065
TDS (mg/L)	52.97	500	0.002	0.013113	6.5565	10.594	69.45956
Chloride (mg/L)	10.59	250	0.004	0.013113	3.27825	4.236	13.88667
Phosphate (mg/L)	0.23	5	0.2	0.013113	0.065565	4.6	0.301599
Sulphate (mg/L)	7.67	100	0.01	0.013113	1.3113	7.67	10.05767
Nitrate (mg/L)	1.16	50	0.02	0.013113	0.65565	2.32	1.521108
DO (mg/L)	1.97	7.5	0.133333	0.013113	0.098348	177.8873	17.49477
BOD_5 (mg/L)	3.82	0.05	20	0.013113	0.000656	7640	5.009166
Iron (mg/L)	0.89	0.3	3.333333	0.013113	0.003934	296.6667	1.167057
Zinc	0.43	5	0.2	0.013113	0.065565	8.6	0.563859
Copper	0.33	0.1	10	0.013113	0.001311	330	0.432729
Manganese	0.05	0.05	20	0.013113	0.000656	100	0.065565
Chromium	0.06	0.05	20	0.013113	0.000656	120	0.078678
Total			**76.25751**		**25.30875**		**301.7191**
WQ4 = 11.92153							

4.2 DIPTERAN LARVAE BANKROOT MACROINVERTEBRATE FAUNA OF OKHUAIHE RIVER

CHECKLIST OF DIPTERANS IN OKHUAIHE RIVER

Phylum: Arthropoda

Class: Insecta

Order: Diptera

Family: Chironomidae

Ablabesmyia sp.	Johannsen, 1905.	Plate
Chironomus fractilobus	Kieffer, 1923.	Plate
Chironomus transvalensis	Kieffer, 1923.	Plate
Pentaneura sp.	Johannsen, 1905.	Plate
Polypedilum sp.	Kieffer, 1912.	Plate

Family: Culicidae

Culex sp. (larvae)	Linnaeus, 1758.	Plate

Family: Tanyderidae

Protoplasa sp.	Osten-Sacken, 1859.	Plate

Family: Chironomidae

Plate 5: ***Ablabesmyia spp***

Plate 6: *Polypedilum sp*.

Plate 7A: *Chironomus fractilobus*
(Posterior region)

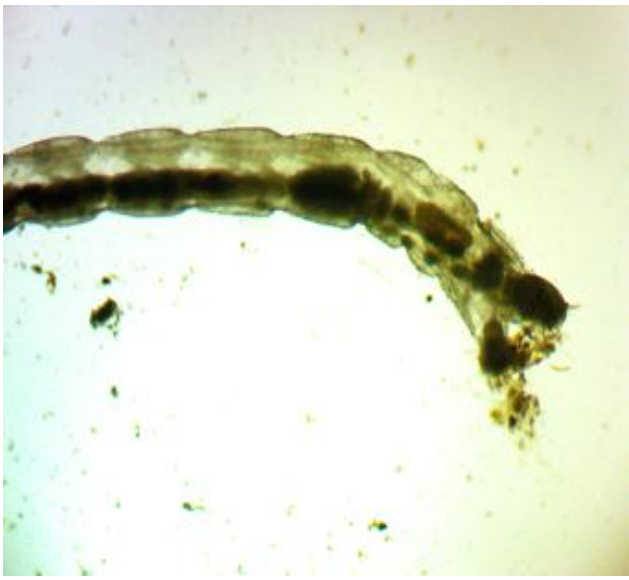

Plate 7B: *Chironomus fractilobus*
(Anterior region)

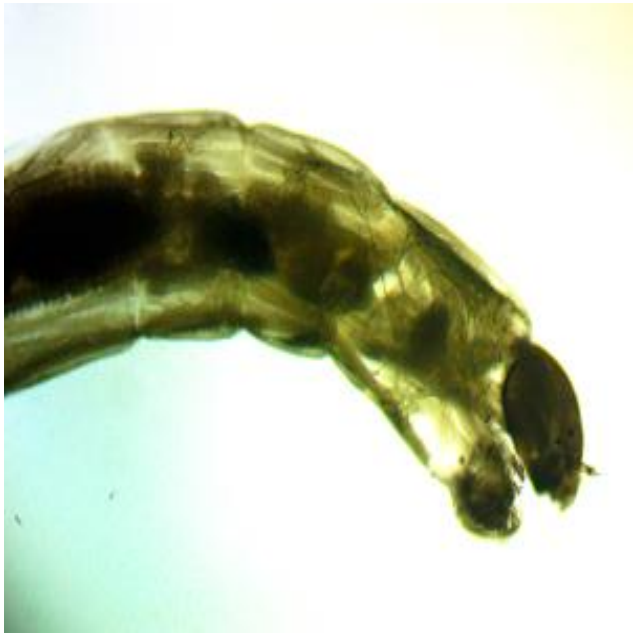

Plate 8A: *Chironomus transvalensis* (Anterior region)

Plate 8B: *Chironomus transvalensis* (posterior region)

Plate 9A: *Pentaneura sp*. (anterior region)

Plate 9B: *Pentaneura sp*. (posterior region)

Family: Culicidae

Figure 10: *Culex sp*

Family: Tanyderidae

Plate 11: *Protoplasa* sp.

4.2.2 COMMUNITY STRUCTURES

In order to determine the taxonomy composition, distribution, abundance, diversity, and dominance of the species, the dipteran samples taken from the study locations were examined. The collected information is utilized to assess the dipteran spatial distribution along the Okhuaihe River. Members of the families *Ablabesmyia* sp. *Chironomus fractilobus, Culex* sp. (larvae), and *Protoplasa* sp. Are among the dipteran macroinvertebrate that were recorded in this study.

COMPOSITION, DISTRIBUTION, ABUNDANCE AND DOMINANCE OF dipteran COMMUNITY

In Table 4.9 and visually in Fig 4.16, the overall taxa composition, abundance, and distribution of the Dipteran community are shown. Of the total number of individuals, *Chironomus fractilobus40.35, Chironomus transvaalensis 51.31, Culex* sp 1.09, *Polypedilum* sp 1.53, *Pentaneura* sp 4.60, *Protoplasa* sp. *0.56, and Ablabesmyia* sp *0.43.* When the spatial distribution of the various dipteran families was examined using the chi- square goodness of fit test, the family Chironomidae, Culicidae, Tanyderidae show no significant difference in density ($p > 0.05$)

Table 4.4: Abundance and Distribution of Dipterans at the Four Stations in Okhuaihe River, August, 2021 - January, 2022

	Taxa	Station 1	Station 2	Station 3	Station 4
Diptera	*Chironomus*				
	fractilobus	46	30	68	40
	Chironomus				
	transvaalensis	62	37	65	70
	Culex sp. (larva)	0	5	0	0
	Polypedilum sp.	0	2	4	1
	Pentaneura sp.	5	3	7	6
	Protoplasa sp.	0	2	1	0
	Ablabesmyia sp.	0	0	2	0
Number of Species		**3**	**6**	**6**	**4**
Number of Individuals		**113**	**79**	**147**	**117**

Table 4.5: Relative Abundance of Dipterans across the Study Stations

Taxa	Number of Species	Relative Abundance (%)
Chironomus fractilobus	184	40.35088
Chironomus transvaalensis	234	51.31579
Culex sp. (larva)	5	1.096491
Polypedilum sp.	7	1.535088
Pentaneura sp.	21	4.605263
Protoplasa sp.	3	0.657895
Ablabesmyia sp.	2	0.438596
Total	**456**	**100**

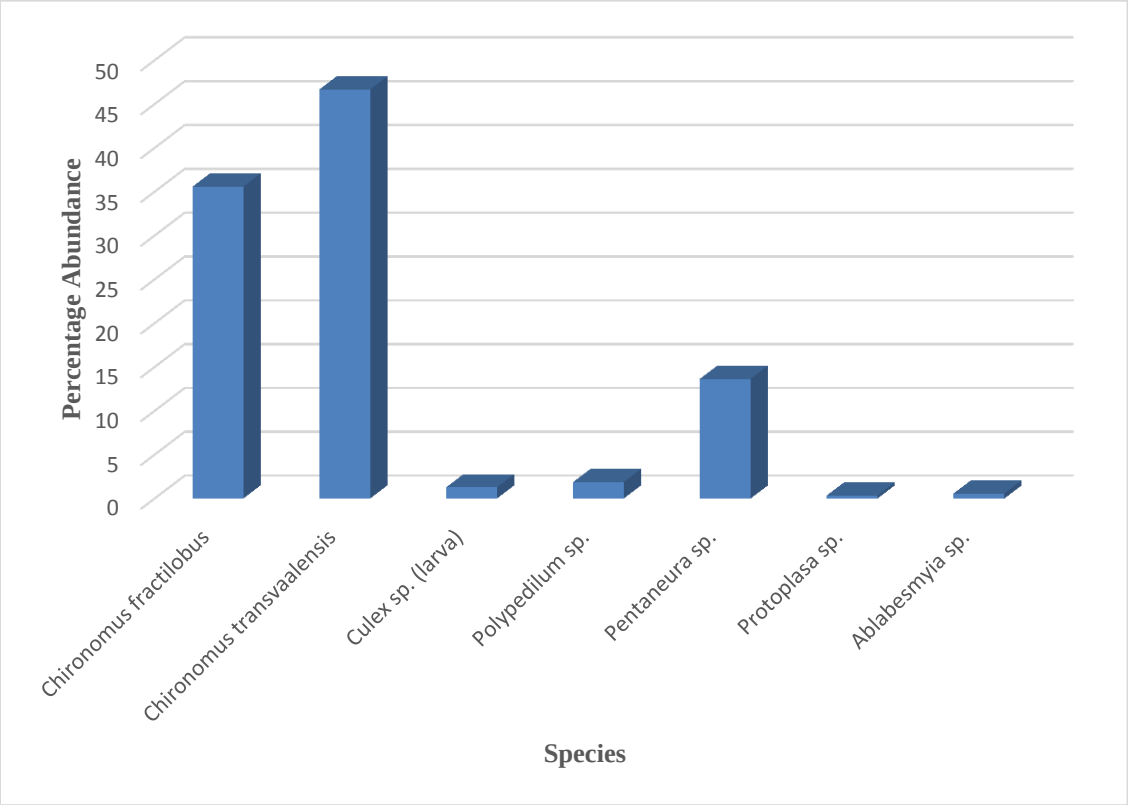

Figure 23: Relative Abundance of Dipterans across the Study Stations.

4.2.3 DIVERSITY INDICES

Margalef's index, Dominance, Shannon Wiener, Evenness, and Dipteran prevalence were all considered (Table 4.11). The Margalef's index, which measures species richness, showed the highest value at station 2 with an index of 1.144 and the lowest value at station 1 with an index of 0.4231. Station 2 had the highest diversity among the study stations , according to the general diversity calculation (Shannon Weiner Index), with an index of 1.208. Station 3 came next with a reading of 1.053,followed by station 4 with a reading of 0.8673 station 1 had the low with a reading of 0.8332.

Station 1 (0.7669) had the highest evenness, closely followed by station 4 (0.5951). Station 3 got the lowest value of 0.4777 and was closely behind station 2 with an evenness of 0.5578 .station 4 (0.4775) had the most dominance, closely followed by station 1 (0.4687). Station 3 reported a value of (0.4127), while station 2 reported the lowest value of 0.3703 station.

Table 4.6: Spatial Distribution of Dipterans Composition across the Stations

Family	Station 1	Station 2	Station 3	Station 4	P - Value
Chironomidae	113	72	146	117	$p > 0.05$
Culicidae	0	5	0	0	$p > 0.05$
Tanyderidae	0	2	1	0	$p > 0.05$
Total	**113**	**79**	**147**	**117**	

Note: P > 0.05 = No Significant difference.

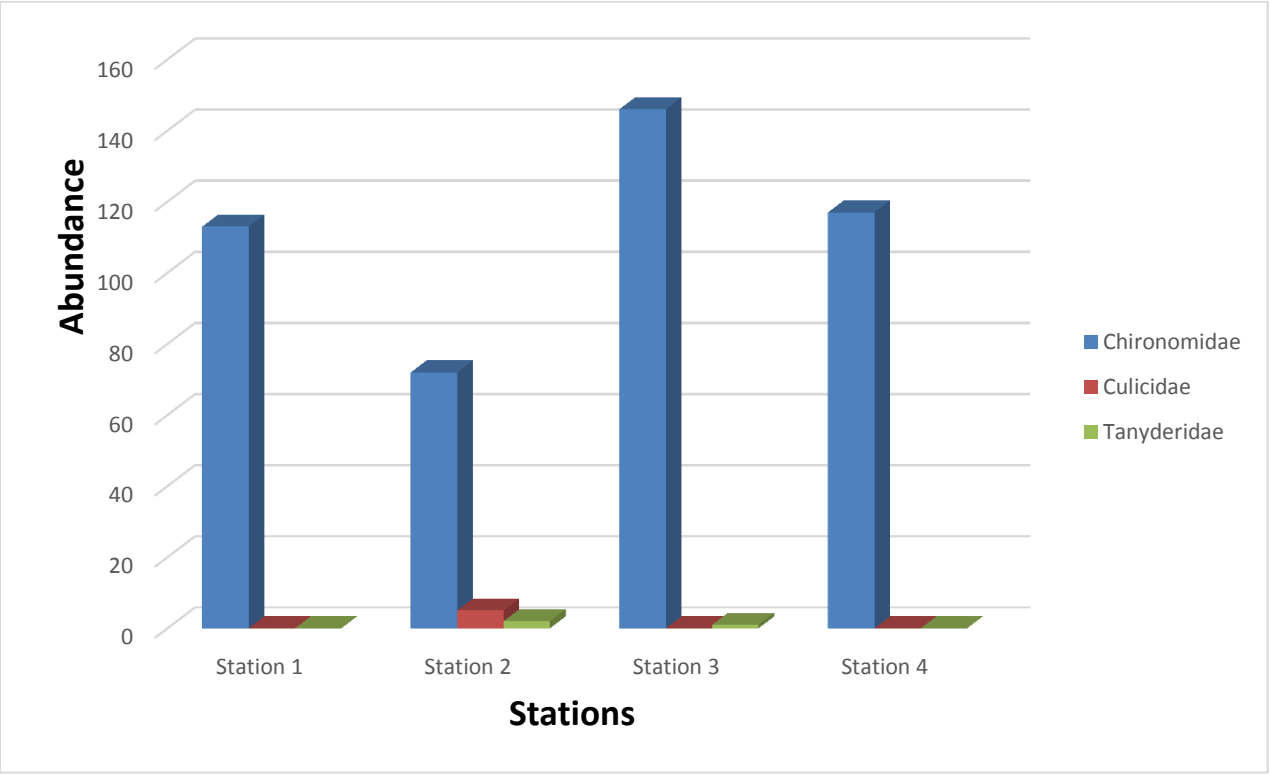

Figure 24: Spatial Distribution of Dipterans across the Stations.

Table 4.7: Diversity Indices of Dipterans in the Study Area.

DIVERSITY INDICES	Station 1	Station 2	Station 3	Station 4
Taxa_S	3	6	6	4
Individuals	113	79	147	117
Dominance_D	0.4687	0.3703	0.4127	0.4775
Shannon_H	0.8332	1.208	1.053	0.8673
Simpson_1-D	0.5313	0.6297	0.5873	0.5225
Evenness_eˆH/S	0.7669	0.5578	0.4777	0.5951
Margalef	0.4231	1.144	1.002	0.63
Equitability_J	0.7584	0.6742	0.5876	0.6256

Table 4.8: Correlation matrix between Physiochemical Parameters and Dipterans of the Study Stations.

	D.O	B.O.D	SULPHATE	NITRATE	AMMONI	PHOSP	CHLOR	TURBI
D.O	1							
B.O.D	-0.13658	1						
SULPHATE	0.366981	0.119036	1					
NITRATE	**0.806112**	-0.12555	0.277996	1				
AMMONI	**0.657599**	0.280423	0.403038	**0.791304**	1			
PHOSP	0.22848	0.240162	0.135854	0.0347	0.270044	1		
CHLOR	-0.21395	0.323028	0.110646	-0.09634	-0.09147	-0.03931	1	
TURBI	-0.02362	0.233397	**0.863364**	0.01757	0.297101	0.12029	0.205074	1
IRON	-0.12617	0.089779	0.308957	-0.10651	0.121111	0.35446	-0.00519	0.426026
ZINC	-0.20259	0.134528	0.169591	-0.33445	-0.05962	0.381301	-0.15854	0.267506
COPPER	0.210193	0.022069	-0.07642	-0.00166	0.182762	0.138784	-0.30147	-0.13346
MANG	-0.24104	0.145732	0.103367	-0.40149	-0.02828	**0.458899**	-0.11235	0.258296
CHROM	-0.01645	0.186274	0.224232	-0.24417	0.148981	**0.558726**	-0.16035	0.297291
pH	-0.2144	-0.05397	0.234527	0.107331	0.093942	-0.32985	0.293491	0.303799
EC	-0.15106	0.37691	-0.15485	-0.32474	-0.09525	**0.551766**	0.120105	-0.03248
TDS	-0.11467	0.351826	-0.14207	-0.29496	-0.07643	**0.563079**	0.111193	-0.03691
TRANS.	-0.25784	0.08053	0.106841	-0.16115	-0.12827	**-0.48316**	0.191385	0.230641
Chironomidae	-0.10863	0.293974	**0.586943**	-0.08528	0.080639	**0.048741**	0.258661	**0.674214**
Culicidae	-0.08245	0.126817	0.169096	-0.15678	-0.01701	0.023811	-0.22668	0.077342
Tanyderidae	-0.07948	0.154459	**0.533405**	-0.12285	0.092874	0.03448	-0.11906	**0.509853**

IRON	ZINC	COPPER	MANG	CHROM	pH	EC
1						
0.681193	1					
0.011622	0.207873	1				
0.677644	**0.826945**	0.31922	1			
0.414639	**0.63209**	0.390921	**0.727244**	1		
0.162238	-0.10307	-0.07966	-0.07437	-0.05624	1	
0.213045	**0.62196**	0.225666	**0.61029**	**0.648336**	-0.36273	1
0.222234	**0.634013**	0.239948	**0.614065**	**0.652743**	-0.38093	**0.998234**
-0.12832	-0.12351	-0.3227	-0.10527	-0.22629	0.19698	-0.32583
0.117698	0.182112	-0.02157	0.203951	0.181805	0.280864	0.059282
-0.05503	**0.469399**	0.275876	0.362232	0.381531	0.078104	0.268205
0.122903	**0.518157**	0.157051	0.387446	0.415198	0.214213	0.178877

TDS	TRANS.	Chironomidae	Culicidae	Tanyderidae
1				
-0.33871	1			
0.048163	0.309985868	1		
0.276356	0.119303364	0.257986	1	
0.184698	0.203650924	0.515247	**0.890609055**	1

BOLD FACE = SHOW SIGNIFICANT CORRELATION

df = 2 r 0.05. Any value > 0.367 is Significant

Critical level of correlation coefficient (p<0.05; df_{18}) 0.444

CHAPTER FIVE

DISCUSSION

5.0 PHYSICAL AND CHEMICAL PARAMETERS OF WATER

An essential tool in defending the environment from menacing anthropogenic activities is the routine assessment of the physiochemical parameters of water. In every sampling month across all stations, the air temperature was apparently high (24.00 – 31.00), while the water temperature was slightly lower and cooler (24.00 – 30.00) than the air temperature. Analysis of variance (ANOVA) was used to examine the seasonal variation in air and water temperatures. The results revealed a highly significant difference (p 0.01) in the mean air temperature values and no significant difference (p> 0.05) in the mean water temperature values in the study stations. According to Mohseni and Stefan (1999) and Webb *et al.* (2003), air temperatures influence water temperatures; the lowest water temperature was recorded in station 1 in July, which is one of the peaks of wet season while the highest value was recorded in station 2 in May before the onset of the wet season. Akpe *et al*. (2018) recorded 23.0–30.5ºC in Ikpoba River, Benin City and Anyanwu and Mbekee (2020) recorded 21.0–28.0ºC in Ossah River, Umuahia, Nigeria, which is quite comparable to this study.

In comparison to the approved range of 6.50 to 8.50 (FME, 2001; WHO, 2011) for tropical water bodies, the pH value range (5.30 to 6.30) measured was marginally acidic. This may be attributable to the human activities such as local brewing (making of ogogoro) and logging activities that were detected during the sampling period. Anyanwu *et al.* (2019) recorded a range of 4.6–6.3 in Ossah River, Umuahia and Anyanwu and Umeham (2020) recorded a range of 4.9–6.3 in Eme River, Umuahia, Nigeria; attributed to the geogenic, seasonal and anthropogenic influences.

Electrical conductivity's average values ranged from 92.52 to 109.00 S/cm. The quantity and concentration of calcium, magnesium, and sodium ions in water determine its conductivity. These ions contribute to the stabilization of the action of carbonate and bicarbonate ions, hence preserving the pH level (Raymont, 1983). The seasonal variation of electrical conductivity was significantly different (p 0.01).

The flow rate value across the sampled stations ranged from 0.01 to 1.51 m/s. Station 4 had the lowest flow velocity and Station 2 had the highest flow velocity, which may be related to the

The amount of suspended particles at station 4 and the growth of plants in the river paths. The flow rate of the four stations that were sampled, a significant difference was seen (p 0.05). The flow velocities were higher than 1.48–1.83 ms-1 recorded in selected river in Ebonyi State, South- East Nigeria by Ani *et al.* (2016) but lower than 0.05–0.13 ms-1 recorded by Anyanwu and Mbekee (2020) in Ossah River, Umuahia, Nigeria.

The total dissolved solids' mean values ranged from 45.67 to 54.25 mg/l. The data collected showed a substantial pronounced seasonal change (p 0.01); values dropped from the rainy season to the dry season. This may be because there are higher run-offs during the rainy season, which is unusual for the majority of Nigeria's interior lakes.

All of the sampled locations had different river widths, with station 4 having the. Narrowest river and station 1 having the widest river. All variables showed a significant difference (p 0.01). Across all stations, a significant difference (p 0.01) was seen.

The mean phosphate concentrations ranged from 0.08 to 0.23 mg/l, and all examined sites showed a significant difference (p 0.05). These low levels were brought on by microbial activity, water movement's removal, and sediment's absorption (Anyanwu, 2012). The soaps and

detergents used in activities like washing motorcycles, bathing, and other laundry that are frequently done in the river are likely a significant source of phosphate in the Okhuaihe River.

The range of chloride readings is 10.59 to 11.77 mg/l. A significant difference (p 0.05) was found between the high chloride values recorded during the rainy season months and the low chloride values recorded during the dry season.

The range of chloride readings is 10.59 to 11.77 mg/l. A significant difference (p 0.05) across seasons was noticed due to the high chloride values reported during the rainy season months and the lower chloride values obtained during the dry season. The concentrations of chloride are quite low when compared to the WHO standard, which is 200 mg/l; this may be because there are no companies in the research region that discharge effluents with high chloride levels. This is comparable to the study done by Edori et al. in 2021, which found concentrations of chloride ranging from 11.50 to 18.65 mg/l.

The values of iron element ranged from 0.37 – 2.14 mg/l. The values of zinc ranged from 0.24 – 0.84 mg/l across the sampled stations. Iron and zinc showed a clear trend in their season variations, hence there were significant differences ($p < 0.05$) ($p < 0.01$) observed respectively across the two seasons.

Manganese ranged from 0.03 – 0.07 mg/l across the sampled stations. The mean values of manganese in rainy season were slightly higher than that of dry season, there was a significant difference ($p < 0.01$) observed across the two stations.

5.2 WATER QUALITY INDEX

The Water Quality Index (WQI) at the sampled stations distinctively showed that the water body of Okhuaihe River is suitable for man’s consumption, supports aquatic life and can be used for

other domestic activities. Water quality, immediate substrates of occupation and food availability are important factors governing the abundance and distribution of benthos Dance and Hynes (1980) Similarly, Ishaku *et al*., (2012) reported WQI values of 15 to 43 in Jada North-Eastern, Nigeria, Asuquo and Etim (2012) reported 33.01 to 40.32 in Uyo Metropolis, Oko *et al*., (2014) reported 26 to 38 in Wukari town and Etim *et al*., (2013) reported WQI values of 38.52 to 48.67 for some chosen boreholes and 55.05 to 84.94 for stream water across the Niger Delta region in Nigeria.

5.3 DIPTERAN BANKROOT MACROPHYTE COMMUNITY OF OKHUAIHE RIVER

A total of 456 species of Dipteran macrophytes were counted, consisting of 3 taxonomic groups and 7 taxa was recorded. Percentage composition of the taxa showed Chironomid had the highest abundance (98%), followed by Culex (1.2%) while the least was Tanyderidae (0.3%). The total number of dipteran taxa reported in the study is low when compared with earlier reseaech carried out on ponds in Okomu Forest Reserve by Ogbeibu (1988), which recorded 5% of Chironomid, and 11% of Culex The total number of dipteran taxa reported here is lows when compared with earlier studies by Victor & Ogbeibu (1985), Ogbeibu & Victor (1989), and Victor & Onomivbori (1996), which reported 10, 19 and 14 taxa respectively from a southern Nigeria fourth order stream.

Chironomid were abundance and diversified than Culex and Tanyderidae respectively. This is similar to the study done by Victor & Ogbeibu (1985) Mezgebu *et al*., (2019) were 6 chironomid taxa was recorded. This could be attributed to the fact that Most stream in the world are dominated by Chironomidae (Towns 1979). This could also be attributed to the fact that Chironomid are pollution tolerant. Tolerant species can survive in unstable environment because

of their ability to cope with perturbation Mariantika and Retnaningdyah (2014) and become more abundant Kucuk (2008).

Also the dipterans, notably the family Chironomidae, have been found to dominate aquatic invertebrate communities Hynes(1975) and show no habitat restriction.

The Abundance and Distribution of Dipterans at the Four Stations in Okhuaihe River, August, 2021 - January, 2022, varies from station 1 to station 4. Station 3 recorded the highest number of individuals of 146, followed by station 4 (134), station 1(113) and station 2(77) respectively. This may be due to reduced anthropogenic activities and increased productivity.

The Abundance and Distribution of Dipterans across the Four Stations in Okhuaihe River, August, 2021 - January, 2022, varies from station 1 to station 4. Station 3 recorded the highest number of individuals of 147, followed by station 4 (117), station 1(113) and station 2 (79 respectively.

The calculated Diversity Indices of Dipterans in the Study Area, using Shannon's index revealed that station 2(1.208) had the highest diversity followed by station 3 (1.053), station 4 (0.8673). and station 1(0.8332) diversity was the lowest. Margalef's richness index which take into consideration the relationship between the number of species 'S' and the total number of individuals observed 'N', indicated that station 3 (1.144) had the highest number of species and the lowest was recorded in station 1 (0.4231).). Simpson's index which considers both richness and diversity showed that station 2 (0.6297), followed by station 3 (0.5873), then station 1 (0.5313) while station 4 (0.5225) had the lowest value.

The calculated Diversity Indices of Dipterans in the Study Area, using Shannon's diversity index, the highest diversity is at station 2 (1.118), followed by station 3 (0.9503), station 1 (0.8332) and station 4 (0.8251) in that order. Evenness was greater in station 1 which indicates that the Dipteran larvae associated with macrophytes are more evenly distributed in this station than the other stations.

In conclusion, more study should be undertaken in Okhuaihe River. I recommend that people of Okhuaihe community should be educated on the adverse effect of brewing, wood logging on the abiotic community of the River.

REFERENCES

Adler, P.H.; Currie, D.C.; Wood, D.M. The Black Flies (Simuliidae) of North America; Cornell University Press: Akpe A. R., Femi I. J., Okwu G. I., Obiazi H. 2018. *Seasonal variations in the physicochemical parameters of Ikpoba River Water Samples*. Int. J. Life. Sci. Scienti. Res., 4(3): 1810–1821.

Ani C., Okogwu O.I., Nwonumara G.N., Nwani C.D., Nwiniyimagu A.J. 2016. *Evaluation of physicochemical parameters of selected rivers in Ebonyi State, Southeast, Nigeria*. Greener J. Biol. Sci., 6(2):34–41.

Anyanwu E.D., Mbekee F. 2020. *Water quality and plankton assessment of Ossah River, Umuahia, Southeast Nigeria*. Taiwan Water Conserv., 68(4): 34–46, doi: 10.6937/TWC.202012/ PP_68(4).0004.

Anyanwu E.D., Okorie M.C., Odo S.N. 2019. *Macroinvertebrates as bioindicators of water quality of effluent-receiving Ossah River, Umuahia, Southeast Nigeria*. Zanco J. Pure Appl. Sci., 31(5): 9–17, doi: http://dx.doi.org/10.21271/ZJPAS.31.5.2.

Anyanwu E.D., Umeham S.N. 2020. *Identification of waterbody status in Nigeria using predictive index assessment tools: a case study of Eme River, Umuahia, Nigeria*. Int. J. Energ. Water Res., March 2020, https://doi.org/10.1007/s42108-020-00066-5.

Arambourou H, Beisel J-N, Branchu P, Debat V. 2014. Exposure to sediments from polluted rivers has limited phenotypic effects on larvae and adults of *Chironomus riparius*. *Sci. Total Environ.* 484:92-101.

Barbour, M.T.; Gerritsen, J.; Snyder, B.D.; Stribling, J.B. Benthic macroinvertebrate protocols. In Rapid Bioassessment Protocols for Use in Streams and Wadeable Rivers: Periphyton,

Benthic Macroinvertebrates, and Fish, 2nd ed.; EPA 841-B-99-002; U.S. Environmental Protection Agency, Office ofWater: Washington, DC, USA, 1999; Chapter 7; pp. 1–34.

BioScience **1989**, 39, 24–30. [CrossRef] Courtney, G.W. Biology of Blephariceridae. 2001. Available online: https://www.ent.iastate.edu/dept/

Cummins, K.W.; Wilzbach, M.A.; Gates, D.M.; Perry, J.B.; Taliaferro, W.B. Shredders and riparian vegetation.

Dance KW, Hynes HBN. Some effects of agricultural land use on stream insect communities. Environ Pollut Ser A 1980;22:19–28.

De Haas EM, Van Haaren R, Koelmans AA, Kraak MH, Admiraal W. 2005. Analyzing the causes for the persistence of chironomids in floodplain lake sediments. *Arch. Hydrobiol.* 162:211-228.

Fowler, J.A.; Withers, I.D.; Dewhurst, F. Meniscus midges (Diptera: Dixidae) as indicators of surfactant Gagliardi BS, Pettigrove VJ, Long SM, Hoffmann AA. 2016. A meta-analysis evaluating the relationship between aquatic contaminants and chironomid larval deformities in laboratory studies. *Environ. Sci. Technol.*

Goddeeris B, Verheyen R. 1996. The relationship between vertical micro distribution and adaptations to oxygen stress in littoral Chironomidae (Diptera). *Hydrobiologia* 318: 61–67.

Hamburger K, Dall PC, Lindegaard C. 1994. Energy metabolism of *Chironomus anthracinus* (Diptera: Chironomidae) from the profundal zone of Lake Esrom, Denmark, as a function of body size, temperature and oxygen concentration. *Hydrobiologia* 294: 43–50. Panis LI,

Hilsenhoff, W.L. An improved biotic index of organic stream pollution. Great Lakes Entomol. **1987**, 20, 31–39..

Hynes JD. Downstream drift of invertebrates in a river in Southern Ghana. Freshwater Biol 1975;5:515–32. Ithaca, NY, USA, 2004; xv + 941 pp. + 24 color plates.

Janssens de Bisthoven L, Gerhardt A. 2005. A critical appraisal of morphological deformities in midge larvae (Insecta, Nematocera: Chironomidae): Clues for biomonitoring the sediment quality of freshwater ecosystems. *Comp. Biochem. Physiol.*:27-36.

Kucuk S. 2008. *The effect of organic pollution on Benthic macroinvertebrate fauna in the Kirmir Creek in the Sakarya Basin*. ADÜ Ziraat Fak. Derg., 5: 5–12.

Mariantika L., Retnaningdyah C. 2014. *The change of benthic macroinvertebrate community structure due to human activity in the spring channel of the source of clouds of Singosari subdistrict, Malang Regency*. Journal Biotropika, 2: 254–259.

Milošević D, Čerba D, Szekeres J, Csányi B, Tubić B, Simić V, Paunović M. 2016. Artificial neural networks as an indicator search engine: The visualization of natural and man-caused taxa variability. *Ecol. Indic.* 61:777-789.

Mohseni O., Stefan H.G. 1999. *Stream temperature/air temperature relationship: A physical interpretation.* J. Hydrol., 218: 128–141.northern rivers. Oikos **2001**, 92, 35–41. [CrossRef

Ogbeibu, A.E. & A.B.M. Egborge. 1995. Hydrobiological studies of water bodies in the Okomu Forest Reserve (Sanctuary) in southern Nigeria. 1. Distribution and diversity of the invertebrate fauna.

Ogbeibu, A.E. & R. Victor. 1989. The effects of road and bridge construction on the bankroot macrobenthic invertebrates of a southern Nigerian stream. *Environmental Pollution* **56:** 85-100. organisms in both terrestrial and aquatic environments: A review. *É*coscience

2004, 11, 187–200. [CrossRef] pollutants. Entomologiste **1997**, 116, 24–27 research/systematics/bleph/biology.html (accessed on 28 January 2019).

Salmelin J, Vuori KM, Hämäläinen H. 2015. Inconsistency in the analysis of morphological deformities in Chironomidae (insecta: Diptera) larvae. *Environ. Toxicol. Chem.* 34:1891-1898.

Servia MJ, Cobo F, Gonzalez MA. 2000. Incidence and causes of deformities in recently hatched larvae of *Chironomus riparius* meigen, 1804 (diptera, chironomidae). *Arch. Hydrobiol.* 149:387-401. suspension-feeders in a stream: An example of ecosystem engineering. Limnol. Oceanogr. **1998**, 43, 719–725.

Towns, D. R. (1979). Composition and zonation of benthic invertebrate community in a New Zealand Kauri Forest stream. *Freshwat. Biol., 9,* 251-62. toxicity test: Development of a new test system. Integr. Environ. Assess. Manag. **2009**, 6, 301–307. [CrossRef]

Vermeulen AC. 1995. Elaborating chironomid deformities as bioindicators of toxic sediment stress: The potential application of mixture toxicity concepts. *Ann. Zool. Fennici* 32:265-285.

Victor, R. & O. Onomivbori. 1996. The effects of urban perturbations on the benthic macroinvertebrates of a southern Nigerian stream. pp. 223-238. *In*: F. Schiomer & K.T. Biland. (eds). *Perspectives in Tropical Limnology*. SPB Academic Publishing bv, Amsterdam, The Netherlands.

Victor, R. & Ogbeibu, A.E. 1985. Macrobenthic invertebrates of a stream flowing through farmlands in southern Nigeria. *Environmental Pollution Series A* **39:** 337-349.

Webb B.W., Clack P.D., WallingD.E. 2003. *Water-air temperature relationships in a Devon River system and the role of flow*. Hydrol. Process., 17: 3069–3084.

Weltje, L.; Rufli, H.; Heimbach, F.; Wheeler, J.; Vervliet-Scheebaum, M.; Hame, M. The chironomid acute Wilke, C. An invasive midge could wreak havoc on Antarctica. The Scientist, 19 December 2018.