CLADOCERA COMMUNITY OF OKHUAIHE RIVER, IKPE, BENIN CITY, EDO STATE, NIGERIA.

By

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CERTIFICATION

We certify that this work was carried out by Miss **Precious Iziegbe OSAFONAMEN** in the Department of Animal and Environmental Biology, University of Benin, Benin City.

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DEDICATION

I dedicate this to God Almighty, the Author and Finisher of my faith, who have made it a success. I was without sweetness of tongue neither swiftness of feet nor strength of my own, but there was hope, Jesus is my Hope. A lot of challenges were met during the course of my project but by His grace I overcame.

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ABSTRACT

Cladocera is a crucial bio-indicator of water quality and trophic status of the aquatic environment they inhabit. This study was carried out from August 2021 to January 2022 using standard methods to investigate the species composition, abundance, distribution and diversity of Cladocera community of Okhuaihe River at Ikpe, Benin city, Edo state, Nigeria. A total of 22 physicochemical parameters were determined. Results show that flow rate, width and phosphate were significantly higher across the sampling stations, while temporally, air temperature, electrical conductivity, total dissolved solids, chloride, iron, zinc and manganese showed high significance difference. The physicochemical parameters measured were within the Federal Ministry of Environment and WHO permissible limits except electrical conductivity, ammonium, chloride, turbidity, iron, copper, manganese and chromium. A total of 6 families comprising 75 individuals were recorded. Abundance was highest in station 4 contributing 64 individuals and lowest at station 1 which accounted for 3 individuals of total individuals. The family Chydoridae (33.33%) dominated the samples followed by Sididae (26.67%), Moinidae (16.00%), Daphniidae (14.67%), Bosminidae (8.00%) and then Macrothricidae (1.33%). Species richness was highest in station 4 and lowest in station 2. Shannon wiener index indicated that station 4 had the highest diversity followed by station 3 while Cladocera species in station 2 were less diverse. Evenness was highest in station 1, closely followed by station 2 while station 4 had the least value. Dominance was measured with highest value in station 2 and least value in station 4. Daphniidae showed a positive significant correlation to turbidity while Macrothricidae exhibited positive significant correlations with sulphate and turbidity. The water quality index at stations 1 to 4 indicate that the sampled stations are safe for human consumption, support aquatic life and other domestic activities This study proved that Okhuaihe River is of good water quality and the Cladocera community encountered are typical of a tropical freshwater habitat but of low diversity. However, continuous monitoring should be carried out intermittently on the River so that a deviation in the quality of the water could be detected timely.

CHAPTER ONE

INTRODUCTION

1.1 BACKGROUND OF STUDY

Water is a basic component of life, a natural resource whose importance to the existence of mankind and other living things cannot be overemphasized. Water is life (Ondo and Addo, 2013; Lukubye and Andama, 2017). However, the standards and availability of water for various uses depends on the biological, radiological and physico-chemical parameters of water (Mirribasi *et al*, 2008). Water as a resource is distributed naturally as surface and ground water in various forms and sources which are oceans, seas, springs, streams, boreholes, ponds, wells, lakes and rivers. Rivers are among the oldest water bodies in the world (Higler, 2012; Igwe *et al*, 2017). With a combined total volume of 332 cubic miles, the water sources are one of the most abundant natural resources in the world but ironically, of that massive volume of water, only 2.8% is salt-free (freshwater), and only one-third of that 2.8% is available for human use (the rest are trapped in glaciers) (Curry, 2010; Iskandar, 2010). This information counters the belief that water is an infinite resource. Freshwater is a finite resource, essential for the well-being of people, aquatic and terrestrial plants and animals. Without freshwater of appropriate quantity and quality, sustainable development for long period of time will not be possible (Kumar, 2007; Gaddis *et al*, 2019). Marshes, swamps, wetlands forest, peatlands, rivers, ponds, lakes and headwaters are examples of freshwater ecosystems (or inland wetlands). These freshwater ecosystems provide a large range of sustenance which includes water and food supply, provender and building materials, carbon and nutrient sequestration, habitats for endangered species (including migratory birds), flood- and drought-minimizing capacity, ecotourism and cultural services, they are the ecosystems most affected by changes in land structure, particularly increasing urbanization and

agricultural expansion (Gaddis *et al*, 2019). Changes in the condition/quality of freshwater can be detected by the presence or absence of aquatic organisms like the plankton; phytoplankton and zooplankton.

Zooplankton have of recent times being used as bio indicators of the condition of their ecosystem, that is the aquatic ecosystem, and they respond swiftly to changes in their immediate environment (Basu *et al*., 2010; Omoigberale and Oronsaye, 2011). The diversity of zooplankton communities are highly extreme, in spite of this, the predominant zooplankton include cladocerans, rotifers, ostracods and copepods. The abundance and diversity of the zooplankton are determined by temporal variations of physico-chemical characteristics, biotic factors such as prey-predation pressure (Edmonson, 1965; Egborge, 1994; Imoobe, 2011). In the aquatic food chain, zooplankton are the first feeders (predator), feeding on phytoplankton (converting plant constituents into animal tissues), bacterioplankton, nektonic and detritus organisms and they also feed on other zooplankton (cannibalism), they also help in controlling algal production by grazing on them (Jude *et al.,* 2005; Omoigberale and Oronsaye, 2011; Imoobe, 2011; Brraich and Kaur, 2015). Several researches carried out have helped clarify that zooplankton are very crucial in aquatic food chain due to their nutritional composition (Bhatnagar and Devi, 2013; Napior kowskwa-krzebietke, 2017). Zooplankton are also the preferred meal for fish larva, and the larva of some aquatic organisms, they are the bridge between the primary production (phytoplankton) and higher trophic levels (Davies and Otene, 2009; Dutta *et al*., 2017). This mediating role of bridging the gap between the aquatic macrophytes and higher aquatic animals helps the zooplankton in detecting changes initiated by polluting and non-polluting bodies (Baloch *et al*., 2010; Khalifa *et al*., 2015; Dhanasekaran *et al*., 2017). The dominance of zooplankton fluctuates in different water bodies, this is influenced by several ecological factors ranging from physicochemical parameters, age, form, to the geographical location of the water body (Basu *et al*., 2010;

Amanu, 2015; Iloba *et al*., 2016, Rai *et al*., 2016; Untoo *et al*., 2016). As earlier stated, the zooplankton are unique organisms used as bio indicators in bio monitoring studies because of their intermediary role in the aquatic food chain and because they are highly sensitive in alteration of their environmental condition (Omoregie, 2017). Zooplankton have being used as bio indicators for as early as the Birge-Juday era, 1879-1910 (Frey, 1963). Ever since then researches have being done using zooplankton to investigate alteration in aquatic ecosystem because they can be identified easily and their body sizes determines the extent to which the pollution have affected the water and its dwellers (Pace, 1986; Zorka *et al*., 2006). Zooplankton directly influence the production of fishes positively, and also in regulating good water quality by grazing on the phytoplankton, resulting into a "clear water condition" (Lampert *et al*., 1986). Nevertheless, the most crucial impacts on phytoplankton take place when the zooplankton communities present are predominated by large Cladocera, specifically, larger species of *Daphnia* (Gulati, 1990; Theiss *et al*., 1990).

Cladocera are considered important bio indicators in freshwater for various ecological variables due to their taxa specificity to such changes in their ambient environment. They show rapid response to changes in the pH of the water indicating their sensitivity to acidity and alkalinity (Zawiska *et al*., 2013; Zawisza *et al*., 2016). Cladocera have an important duty in the freshwater ecosystem, as they are the intermediate organism between phytoplankton and higher organisms. The structure of cladocera community is determined by the aquatic food web and not basically the water, unlike other aquatic organisms such as benthos and nekton (Berta *et al*., 2019). Increase in plant nutrient (eutrophication) leads to an increase in the cladocera communities, that is, they are more abundant in phytoplankton rich waters. However, this increment result to high predation pressure, most nekton that are planktivorous are size-specific; feeding on large sized cladocerans, living behind the small-sized cladocera such as *Bosmina longirostris* which eventually leads to an increase in their population (Hunt

and Matveev, 2005). Whereas, in waters having poor nutrient (Oligotrophic waters), the population of cladocerans are reduced, excluding *Leptodora*, *Bythotrephes* and *Polyphemus*, these species of cladocera compete with filter feeders/microfiltrators for smaller particles (Brooks and Dodson, 1965). Nektons are not the only predators of cladocerans but there are invertebrate predators as well, such as adult cyclopoid copepods, carnivorous cladocera and insects (de Bernardi *et al*, 1987).

Information on the scientific study, diversity and distribution of different species of Cladocera in Nigeria is limited; even as they carry out an essential role (alongside other zooplankton) in conveying primary production into fish production (Jeje, 1989). Cladocera and Copepod were first recorded in Africa by Blanchard and Richard (1890) from lakes in Algeria. The largest checklist of cladocera was listed by Green (1962) in his work on River Sokoto, he was able to establish the taxonomic classification of 29 species, identifying one new species, *Alona holdeni*. The new species was also recorded by Egborge in 1981 from Lake Asejire.

1.2 JUSTIFICATION

Even though the Zooplankton including the Cladocera fauna of Okhuaihe River has been widely studied at some sections of the river particularly along the Benin-Agbor road (Ogbeibu and Ogiesoba-Eguakun, 2019), no report on the diversity or the taxonomy of Cladocera at Ikpe section of the river along Benin-Abraka road has been made. Okhuaihe River at Ikpe is under the influence of many environmental stresses. Due to these stresses, a wide fluctuation can be expected in the diversity of Cladoceran communities here. It is therefore for this reason that this study was carried out to establish the diversity, relative abundance and composition of the Cladocera community.

1.3 AIMS AND OBJECTIVES

The aim of this study is to investigate Cladocera community of Okhuaihe River at Ikpe, Benin City, Edo state, Nigeria.

The objectives for which the study was carried out 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 Cladocera zooplankton in Okhuaihe River.
3. Relationship between the physico-chemical water quality and Cladocera zooplankton community structure.

CHAPTER TWO

LITERATURE REVIEW

Zooplankton have in recent times be used as bio indicators of the condition of the aquatic ecosystem because they respond swiftly to changes in their immediate environment (Basu *et al*., 2010; Omoigberale and Oronsaye, 2011). The diversity of zooplankton communities are highly extreme, in spite of this, the predominant zooplankton include cladocerans, rotifers, ostracods and copepods. According to Imoobe (2011), the nature of the species abundance, occurrence and diversity of zooplankton in Okhuo River varies temporally, with higher number of species found during wet season and a decline in species number and density during dry season. It is however argued that overflow during rainy season may also contribute to the increase in zooplankton population.

2.1 CLADOCERAN AS BIOMONITORS

Cladocera are considered important bio indicators in freshwater for various ecological variables due to their taxa specificity to such changes in their ambient environment. They show rapid response to changes in the pH of the water indicating their sensitivity to acidity and alkalinity (Zawisza *et al*., 2016).

Suhett *et al*., (2015) considered cladocerans as important bio indicators for estimating the toxicity of pesticides and other environmental pollution in freshwater. Special attention has been given to the Cladoceran across ecological studies, particularly to those dealing with environmentally-influenced stress from its many factors like biochemical, molecular, physiological, toxicological, etc.

Ferrao-Filho *et al*., (2009) assessed the possibility of using cladocerans as biomonitors of cyanobacterial toxins in the Funil and Lajes reservoirs of Brazil. *Daphnia gessneri* and *Moina micrura* were cultivated in the laboratory for toxicity testing; acute and chronic toxicity

testing specifically. Water samples collected from the two reservoirs were diluted in mineral at four concentrations. Analysis of the phytoplankton present in the water samples revealed cyanobacteria represented by the genera *Anabaena*, *Cylindrospermopsi*s, and *Microcystis* as the dominant species in one of the reservoirs. Survival in the acute bioassays was used to determine the median lethal concentration while the survival rate and fecundity in the chronic bioassays were used to determine the population growth rate and median effective concentration of the cladocerans. The results of the bioassays revealed adverse effects including death, paralysis, reduced fecundity, and these maybe due to the presence of cyanobacteria toxins (microcystins or saxitoxins) in the water.

Adamczuk (2016), studied a small Cladoceran (*Bosmina longirostris*) which is a cosmopolitan species thriving in all kinds of inland water regardless of their trophy, acidification or salinity. This species is used as indicators in ecological, neolimnological and paleolimnological researches. According to Hart (2004), *Bosmina longirostris* are 'disturbance-tolerant' species; it has the ability to rapidly adapt to environmental fluctuations. Its wide distribution causes this species to be the most taxonomically identified Cladocera species globally. However, its abundance does not cause it to play an important role in the aquatic food web because it is assumed that the body sizes of zooplankton determine their grazing range on phytoplankton and planktivorous fishes feed on larger Cladocera like *Daphnia* sp. than smaller ones like *Bosmina longirostris*.

Sweetman *et* al., (2008) carried out a study on evaluating the response of Cladocera to recent environmental changes in Lakes from the Central Canadian Arctic treeline region. They agree Cladocerans (Crustacea: Branchiopoda) are important organisms present in many high-latitude lakes and ponds, and are oftentimes considered to be key species in both pelagic environments (i.e. the Daphniidae and Bosminidae families) and benthic habitats (i.e. the

Chydoridae family). This is so because of their essential roles in the aquatic food webs, and their abilities to respond rapidly to changing environmental conditions.

Cladocerans are regarded as excellent indicators of changes in lakes. Lakes are known to recover from pollution more slowly than other water bodies, so Leppanen (2018) carried out a study on impacts of mine water on lakes in North America, Central Europe and Brazil. *Daphnia* is one of the frequently used organisms in ecotoxicology but the most tolerant taxa to pollution caused by mining are *Bosmina* sp. and *Chydorus sphaericus*. These species has potential as community level bioindicator/biomonitors in studies carried out on mining pollution but the lack of data concerning the most responsive taxa has proven to be a challenge when indicator values of any single species is estimated.

2.2 SPATIAL DISTRIBUTION

In a study by Lauridsen *et al*., (1996), Cladoceran composition and diel horizontal migration were studied in 2, 10 and 25 m diameter macrophyte exclosures formed at the shore of shallow Lake Stigsholm, Denmark. The exclosures were protected from wildfowls that graze on them but open to fishes. The density of cladocerans like *Ceriodaphnia* sp., *Bosmina* sp., *Eurycercus lamellatus* sp., and *Simocephalus vetulus* sp. varied in the macrophyte exclosures. This led to the conclusion that the composition of Cladoceran community differs with macrophyte bed size, and that the edge zone between the river bed and pelagic zone is a crucial daytime shelter for migrating pelagic cladocerans.

The study by Burks *et al*., (2002) in shallow lakes further confirms that Cladoceran like *Daphnia* and other important pelagic consumers of phytoplankton undertake diel horizontal migration in macrophytes or other anchorages in the littoral zone. This act of migration by *Daphnia* and other cladocerans helps serve as an escape from planktivorous fishes and predacious invertebrates thus resulting in a lower phytoplankton biomass in such lakes.

CHAPTER THREE

MATERIALS AND METHOD

3.1 DESCRIPTION OF STUDY AREA

The study was carried out at four stations along the Okhuaihe River in Ikpe village, Ikpoba-Okha Local Government Area of Edo State, Nigeria. The section of the river studied runs across the Benin-Abraka express road, 30 kilometers from Benin City, with an average elevation of -8.48 m below sea level to 1.87 m above sea level. Okhuaihe River is one of the major Rivers that flows into Ossiomo River which empties into the Atlantic Ocean. It is situated in the tropical rainforest of Southern Nigeria. The Okhuaihe community today has a human population of over 500 inhabitants, mainly the Ijaws and Urhobos. The major activities of the population include farming, fishing, local gin production, palm wine production, timber and lumber production.

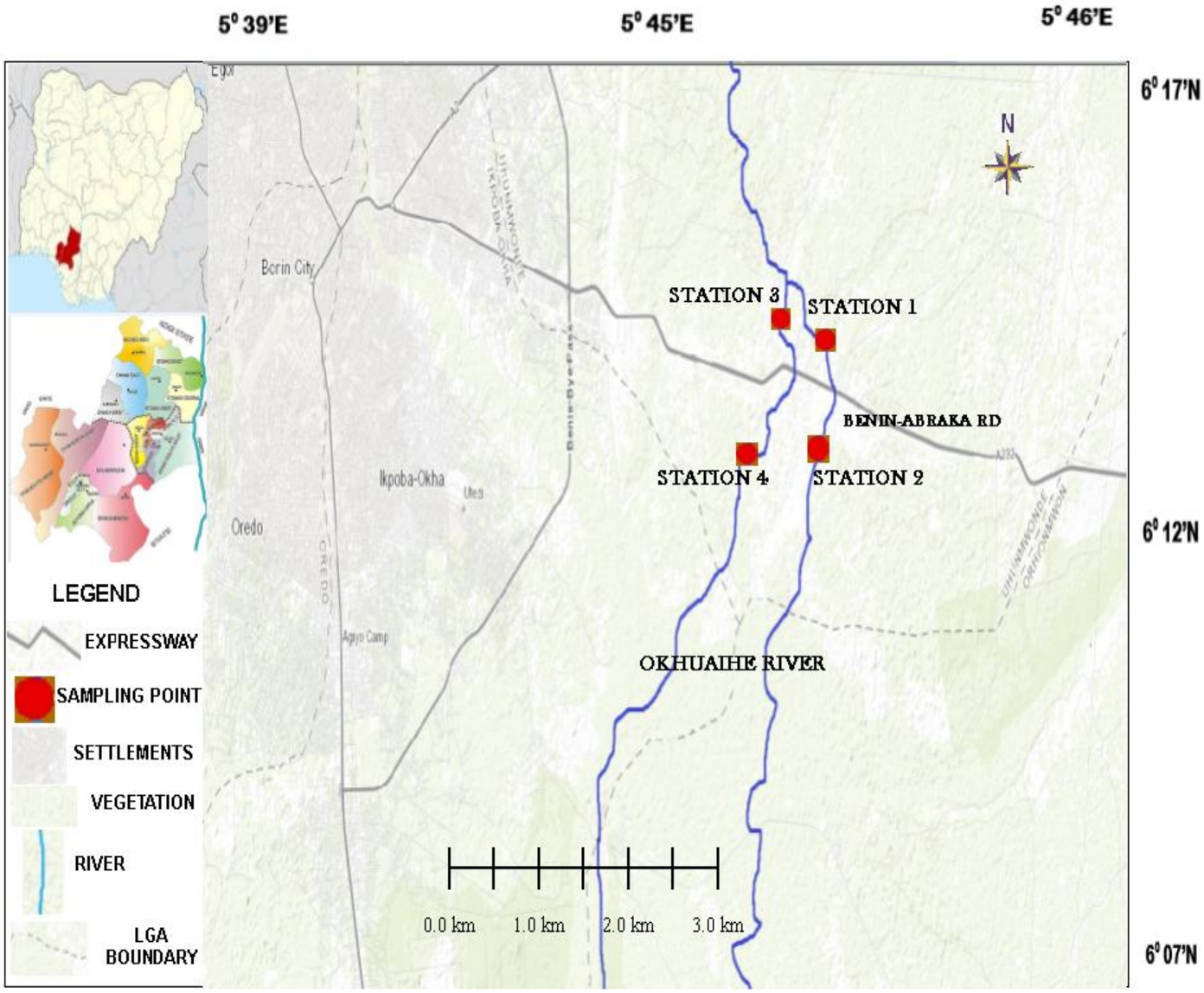

Fig. 3.1: Map of Okhuaihe River showing the sampled areas.

3.1.1 CLIMATE

The climate condition of the study area is characterized by rainy/wet seasons and dry seasons. The physico-chemical properties of the river changes with season. In the wet season, there is high flow rate, high turbidity due to influx, decreased transparency and increased depth especially after heavy rainfall while in the dry season; there is low or no flow rate and increased transparency (Ekhator *et al*., 2013). The period of rainy season is usually from April to October, and dry season from November to March, with temperature ranging from 22 C – 31 C (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.

Sampling was carried out in four stations of the river.

Station 1: It is located about 500 m 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, palm wine and local gin (ogogoro) production, laundry, swimming and spiritual activities.

Station 2: This site is located at the opposite side station 1, 500 m before the Orhionmwon bridge, at latitude 6° 12' 24.18" N and longitude 5° 45' 15.99" E. It is surrounded by canopy

trees, raffia palm trees, sensitive plants, ferns, plantain trees, wild cocoyam plants and water hyacinth. A bathroom, a warehouse made of palm fronds and bamboo were seen on site. The station is quite transparent but has a moderate flow rate, presence of algae. Human activities like washing, cooking, bathing and spiritual activities are carried out.

Plate 1: Station 1 of Okhuaihe River, Ikpe, Edo State, Nigeria.

Plate 2: Station 2 of Okhuaihe River, Ikpe, Edo State, Nigeria.

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. It is transparent and has a higher flow velocity compared to other stations. 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, presence of algae, ferns and floating macrophytes. Human activities include lumber and timber production, spiritual activities and broom making.

Plate 3: Station 3 of Okhuaihe River, Ikpe, Edo State, Nigeria.

Plate 4: Station 4 of Okhuaihe River, Ikpe, Edo State, Nigeria.

3.1.3 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.

3.1.3.1 COLLECTION OF WATER SAMPLES

Water samples for the analysis of the following parameters: dissolved oxygen (DO), biological oxygen demand (BOD_5), 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 by immersing the sample bottles 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 from the river before collection was made.

Samples for Dissolved Oxygen (DO) at the four stations were collected by rinsing 250 ml reagent bottle with water from the river and then immersed into the water body, filled to the brim and carefully covered while still in the river in order to avoid air bubbles. The water samples collected are then fixed with 1.5 ml each of the Winkler's solution A and B, covered properly and shook thoroughly for about 10 seconds and left to rest. A white precipitate of manganic hydroxide is formed; this shows that the dissolved oxygen present has been trapped.

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 penetration of sunlight, hence preventing photosynthetic activities from occurring.

3.1.3.2 ZOOPLANKTON COLLECTION

Zooplankton samples were collected from the four stations using the qualitative sampling method. It was carried out using 55µm Hydrobios plankton net which was towed by hand against the water current for about 5 minutes. The water collected was poured into a sampling bottle and preserved in 4% formalin solution as recommended by UNESCO (1974).

3.2 DETERMINATION OF PHYSICOCHEMICAL PARAMETERS

At each sampling station, in-situ measurement (on site) such as air temperature, water temperature, water depth/width, flow velocity, turbidity, transparency were taken and water samples for ex-situ measurement (in laboratory) such as total solids, colour, total suspended solid, dissolved oxygen (DO), biochemical oxygen demands (BODs), alkalinity were collected and taken to University of Benin/ Benin Owena Joint Analytical Laboratory for analysis.

3.2.1 PHYSICAL PARAMETERS

3.2.1.1 ATMOSPHERIC TEMPERATURE (℃)

This parameter was measured in-situ using the mercury-in-glass thermometer graduated in ℃. This was done by suspending the thermometer in the air for 5 minutes until the red indicator became stable; the red indicator/red line is was red at eye level to avoid parallax error. The reading was recorded.

3.2.1.2 WATER AND SEDIMENT TEMPERATURE (℃)

Water temperature was determined by immersing part of the mercury-in-glass thermometer in the water until the red indicator was stabilized. The thermometer is read at eye level to avoid parallax error. The water temperature determines the sediment temperature. The readings were recorded.

3.2.1.3 FLOW RATE/VELOCITY (cm/s)

Flow velocity was determined using the technique known as surface floatation. Here, a floatable object (cork or bottle cap) was dropped on the water surface and allowed to flow freely through a known distance, and the time taken to flow through that distance was recorded using a stopwatch. The velocity was calculated using the formula below:

$$\text{Flow rate} = \frac{\text{Distance covered (cm)}}{\text{Time taken (s)}}$$

The result was recorded as well.

3.2.1.4 TRANSPARENCY

This parameter was measured using a secchi-disk. The secchi-disk was slowly dropped into the water body at the four stations using a calibrated rope; the values recorded were that of the depth at which the secchi-disk disappeared into the water, and the depth at which it reappeared when drawn out.

Transparency reading was taken as the average of the two depths:

$$\frac{\text{Point of disappearance} + \text{Point of appearance}}{2}$$

3.2.1.5 WATER DEPTH (cm)

This was carried out in-situ using the secchi-disk. The secchi-disk was dropped into the water body using a calibrated rope until it hits the river bed; at this point the measurement is noted on the rope and recorded.

This method is alternated with a calibrated pole dipped into the water body at the four sampling stations or a long stick dipped into the shallow sampling stations until it hits the water bottom and measured the wet part of the stick with a measuring tape and the reading was recorded.

3.2.1.6 ELECTRICAL CONDUCTIVITY (µS/cm)

The Electrical Conductivity (EC) of the water body was measured using the HACH 44600-00 conductivity meter/TDS meter. The probe of the meter was dipped into the sample containers, held still till a stable reading was obtained and then recorded in micro-siemens per centimetre (μS/cm).

3.2.1.7 TURBIDITY (NTU)

This parameter was measured using a visible spectrophotometer VS721G. The cuvettes of the meter was washed and rinsed properly with distilled water. One of these cuvettes was filled up to mark with the samples collected and the other cuvette with distilled water was used to standardize the spectrophotometer. The samples were read and recorded at a wavelength of 420 nm.

3.2.1.8 COLOUR (Pt-Co)

This was determined through the use of visible spectrophotometer VS721G. 50 ml of distilled water was measured and used to rinse a filter paper while another 50 ml distilled water was poured into a clean 50 ml flask through the filter paper. 50 ml of water sample was also added into a 50 ml flask using the filter paper, both aliquot were read and recorded at a wavelength of 455 nm. Colour of the sample was determined using the equation below:

Colour of water in mg/l Pt-Co = sample colour – water colour

3.2.1.9 TOTAL SOLIDS (mg/l)

This parameter was determined using gravimetric method. Here, 10ml of the water sample was measured into an oven dried pre-weighed evaporating dish, this dish was dried at a temperature between 103℃ and 105℃ for 2 and a half hours. The dish was cooled in a desiccator at room temperature and then weighed. The total solid was determined by the increase in the weight of the evaporating dish. The formula is represented below:

$$\text{Total solids (mg/l)} = \frac{(W2-W1)\ \text{mg} \times 1000}{\text{ml of sample used}}$$

Here W1 = First weight of evaporating dish

W2 = Final weight of the dish (evaporating dish + residue).

3.2.1.10 TOTAL DISSOLVED SOLIDS (mg/l)

Total dissolved solids (TDS) were analysed using the HACH 44600-00 conductivity/TDS meter. The meter's probe was dipped into the sample container, held still till a stable reading was gotten; the reading was recorded in mg/l.

3.2.1.11 TOTAL SUSPENDED SOLIDS (mg/l)

Total suspended solids (TSS) were determined in the four stations by subtracting the values calculated from the total dissolved solids (TDS) from the total solid (TS), that is by extrapolation.

TSS = TS - TDS.

Where TS = Total solid

TSS = Total suspended solid

3.2.2 CHEMICAL PARAMETERS

3.2.2.1 HYDROGEN ION CONCENTRATION (pH)

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

3.2.2.2 DISSOLVED OXYGEN (mg/l)

Dissolved oxygen (DO) is an important parameter that was determined using the Winkler method, which is otherwise known as trimetric method. After the collection of water samples using 250ml reagent bottles, they were fixed in-situ by adding 1ml each of Winkler A solution Manganese (II) sulphate ($MnSO_4$) and Winkler B solution Alkali-iodate azide (KI) respectively, immediately forming a precipitate indicating the oxygen had been trapped.

In the laboratory, the precipitates were dissolved adding 2ml of concentrated Sulphuric acid (H_2SO_4). Then, 100ml of the aliquot was measured into a 250ml conical flask, thereafter, two drops of freshly prepared starch indicator was added and mixed thoroughly. Titration was done on the solution against 0.025M sodium thiosulphate solution ($Na_2S_2O_3.5H_2O$) till it became colourless. The volume of sodium thiosulphate used till the solution became colourless is equal to the dissolved oxygen in mg/l in the water sample.

3.2.2.3 BIOCHEMICAL OXYGEN DEMAND (mg/l)

Water samples for this parameter was collected that of Dissolved Oxygen was, only that 250ml amber reagent bottles were used and they weren't fixed with Winkler solution but rather wrapped in polythene bags in-situ to prevent photosynthesis from occurring.

In the laboratory, the water samples were incubated at 20℃ for 5 days. Thereafter, the same procedure for Dissolved Oxygen was used, the samples were analysed and recorded. BOD_5 was determined from the equation:

$BOD_5 = DO_1 - DO_5$.

Where BOD_5 = Biological oxygen demand at day five

DO_5 = dissolved oxygen at day five

DO_1 = dissolved oxygen at day one.

3.2.2.4 CHEMICAL OXYGEN DEMAND (mg/l)

Chemical Oxygen Demand of the water samples was determined using the Dichromate method. 25ml of the water sample being analyzed was pipette into a conical flask, 10ml of 0.000833 Potassium dichromate ($K_2Cr_2O_7$) solution was added, and a pinch of Mercury (II) sulphate ($HgSO_4$) and 10ml of silver sulphate ($AgSO_4.H_2SO_4$) were also added to the sample and brought to boil gently on a hot plate for exactly 10minutes with plastic funnel on the mouth of the conical flask. The mixture was left to cool down for 30minutes. Thereafter, 2

drops of ferroin indicator was added and titrated against 0.025M Ammonium Iron (II) sulphate hexahydrate ($Fe(NH_4)_2(SO_4)_2.6H_2O$) until there was a colour change, that is, from blue-green to red-brown. The value of Chemical Oxygen Demand is determined by subtracting the Chemical Oxygen Demand of a pre-determined blank is subtracted from that of the water sample.

3.2.2.5 ALKALINITY (HCO_3^-)

To analyse the water samples for alkalinity, firstly, 50ml of the sample was pipetted into a clean 250ml conical flask. Thereafter, two drops of methyl orange indicator were added and the solution was titrated against a standard 0.01M Sodium hydroxide (NaOH) solution till it turned pink (Andersen, 2002).

$$\text{Whole alkalinity (mg/l)} = \frac{V \times M \times 100{,}000}{\text{ml of sample used}}$$

Where V = volume of acid used

M = Molarity of acid used.

3.2.2.6 CHLORINITY (mg/l)

This parameter was determined in the laboratory using a multiple parameter turbidimeter. The probe of the meter was dipped into the water samples, held still till a stable reading was obtained and then recorded (Beauchemin and Berman, 1989).

3.2.2.7 NITRATES (mg/l)

Nitrate was determined using the colorimetric method. Here, 5ml of the water sample was measured and pipetted into a 50ml flask, 1ml of Brucine was added, 5ml of Sulphuric acid (H_2SO_4) was added rapidly and carefully and 14ml of distilled water was added to the solution to make it up to 25ml, the solution was mixed thoroughly. The solution was then read at 470nm in the visible spectrophotometer VS721G (Beauchemin and Berman, 1989).

$$NO_3\ (mg/l) = \frac{\text{instrument reading} \times \text{slope reciprocal} \times \text{col.vol.}}{\text{Aliquot taken}}$$

Aliquot is the portion of the sample prepared.

3.2.2.8 PHOSPHATES (mg/l)

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

$$PO_4\ (mg/l) = \frac{\text{instrument reading} \times \text{slope reciprocal} \times \text{col.vol.}}{\text{Aliquot taken}}$$

Aliquot is the portion of the sample prepared.

3.2.2.9 SULPHATES (mg/l)

This parameter was determined in the laboratory by the colorimetric method. 5ml of the water sample was pipetted into a 50ml flask, thereafter, 1ml of Gelatin-$BaCl_2$- reagent was added, 19ml of distilled water was then added to make the solution up to 25ml. The sample was left to rest for 30mins and thereafter read at 420nm using the visible spectrophotometer VS721G (Beauchemin and Berman, 1989).

$$SO_4^{2-}(mg/l) = \frac{\text{instrument reading} \times \text{slope reciprocal} \times \text{col.vol.}}{\text{Aliquot taken}}$$

Aliquot is the portion of the sample prepared.

3.2.2.10 EXCHANGEABLE ANIONS (Sodium, Potassium, Calcium and Magnesium)

The exchangeable bases (Sodium, Potassium, Calcium and Magnesium) concentration in the water samples were determined using Flame photometric method. This involved the use of Technicon auto analyzer flame photometer IV, which was precalibrated using known

concentrations of Na^+, K^+, Ca^{2+} and Mg^{2+} with lithium as internal standards. The water samples were placed in small cups in the sample tray module and automatically aspirated into the mixing module where the mixing of lithium and the samples occurred, and the Teflon tube was checked regularly for good bubbles pattern. The mixed samples were then passed to the flame chamber where they were atomized and flared with the aid of propane gas. The concentrations of each anion were measured by the colour intensity of the flame and the values were obtained from an attached recorder (Philips and Greenway, 2008).

3.3 SORTING AND COUNTING OF ZOOPLANKTON

In the laboratory, the samples from the four stations were concentrated to 25 ml using a net of very small mesh size, after which the samples were taken in succession into a petri dish and viewed under the microscope. The zooplankton samples were sorted out for cladocerans, counted and identified under a binocular compound microscope with magnification x40. The cladocerans seen were carefully picked out using a sorting pin and a micro-pipette. Accurate count of each taxon of the cladocerans seen were taken and kept in well labelled transparent sample bottles and preserved in 4% formalin for future references. Parts of the organism like the number and orientation of segments on the antenna, caudal rami, rostrum, post-abdomen, antennules were used to identify the cladocerans using appropriate identification keys (Jeje and Fernando, 1986; Karuthapandi and Rao, 2016).

3.4 DATA ANALYSIS

Inter station comparisons were carried out to test for significant differences in the abundance of cladocerans using parametric analysis of variance (ANOVA). Here significant value ($p<0.05$) was obtained in the ANOVA, Duncan multiple range (DMR) test was performed to

determine the location of significant differences. These analyses were done using the computer application SPSS 20.0 and Microsoft Excel for windows.

3.4.1 ESTIMATION OF ABUNDANCE

The abundance score for species abundance were estimated by calculating the relative abundance (percentage) of each species as given in the formula below by Meye and Ikomi (2008).

$$R.A\% = \boldsymbol{S.Ax100/T.A}$$

Where: R.A = Relative Abundance

S.A = Species Abundance

T.A = Total Abundance

≥ 10% = Dominant

1 - 9% = Sub-dominant

< 1% (but caught more than once) = occasional

< 1% (caught only once) = rare

3.4.2 Calculating of Water Quality Index (WQI)

Water Quality Index is calculated by turning complex water quality data into information that the public can comprehend and use. Water Quality Index (WQI) is an efficient tool that is used to categorize the suitability of water resource. Over time, WQI has evolved as an efficient tool to recapitulate large amounts of water quality data into simple terms (excellent, good, poor) for reporting to management and public in a regular manner (Ashwani and Anish, 2009; Ramakrishniah *et al*., 2009). Therefore, Water Quality Index (WQI) is a very effective method which can provide a simple indicator of water quality and it is based on some relevant parameters. The parameters adopted in this study include chloride, colour, nitrate,

turbidity, conductivity, chromium, total dissolved solid, zinc, hardness, sulphate, magnesium, iron, cadmium, lead, etc.

In this study, Water Quality Index (WQI) was calculated by using the Weighted Arithmetic Index method as described by (Cude, 2001). In this model, several water quality components are multiplied by a weighting factor and are then summed up using simple arithmetic mean.

In determining the quality of water in this study, firstly, the quality rating scale (Qi) for each parameter was calculated by using the following equation;

$$Qi = \{[(V\ actual - V\ ideal) / (V\ standard - V\ ideal)] * 100\}$$

Qi = Quality rating of ith parameter for a total of n water quality parameters

V actual = Actual value of the water quality parameter obtained from laboratory analysis

V ideal = Ideal value of that water quality parameter can be obtained from the standard tables.

V ideal for pH = 7 and for other parameters it is equalling to zero, but for DO, V ideal = 14.6 mg/L

V standard = Recommended Federal Ministry of Environment permissible limits standard of the water quality parameter.

After calculating the quality rating scale (Qi), the Relative (unit) weight (Wi) was determined by a value inversely proportional to the recommended standard (Si) for the corresponding parameter using the following expression;

$$Wi = K/ Si \quad ,$$

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

Where,

Wi = Relative (unit) weight for nth parameter

Si= Standard permissible value for nth parameter

K= Proportionality constant.

Finally, the entire WQI was calculated by aggregating the quality rating with the unit weight linearly by using the following equation:

$$WQI = \Sigma WiQi / \Sigma Wi$$

Where,

Qi = Quality rating

Wi = Relative weight

In general, WQI is defined for an explicit and intended use of water. In this study, the WQI was regarded for human consumption amidst other uses and the maximum permissible WQI for the drinking water was taken as 100 score.

3.4.3 DIVERSITY INDICES

Diversity indices combine the information on multiple species into a single number. Cladocerans collected at the sampled stations were subjected to diversity indices.

The following indices were evaluated: Margalef's Index for species richness, Shannon-Wiener Index (H') for general species diversity, Evenness index (E). These indices which express the degree of uniformity in the distribution of individuals among the taxa in the collections are based on the proportional abundances of the individual species in the samples. A high value for Margalef's index, Evenness index and Shannon-Wiener index indicates high diversity. PAST (Paleontological Statistics) software package for education and data analysis was used to compute the diversity (Hammer et. al. 2001).

CHAPTER FOUR

RESULTS

4.1 PHYSICAL AND CHEMICAL PARAMETERS OF OKHUAIHE RIVER.

The summary of the physical and chemical parameters of water of Okhuaihe River are presented in Table 4.1 for spatial comparisons and Table 4.2 for seasonal comparisons respectively. Graphics for these comparisons are also presented in Figures 4.1 – 4.22.

4.1.1 AIR TEMPERATURE

The spatial and seasonal variations of air temperature of the four different stations during the period of investigation are given in Tables 4.1 and 4.2 respectively and represented in Fig. 4.1. Values of air temperature varied between 25.00 – 30.00 °C in station 1 with a mean value of 28.33°C, 26.00 – 30.00 °C in station 2 with a mean value of 28.33 °C, 24.00 – 30.00 °C in station 3 with a mean value of 27.67 °C and 25.00 – 31.00 °C with mean value of 28.33 °C in station 4. The highest value of 31.00 ^{o}C was recorded at station 4 in December, 2021 and January, 2022 while the least value of 24.00 ^{o}C was obtained at station 3 in October, 2021. Analysis of variance (ANOVA) showed that there was no significant difference in the mean values at the study stations ($p>0.05$) (Table 4.1). The mean value and standard deviation for air temperature in the dry season (29.50±1.17^{o}C) was higher than the wet season value of (26.83±1.75^{o}C) as shown in Table 4.2. There was a high significant difference ($p < 0.01$) between the wet and dry season values (Table 4.2).

Table 4.1: Spatial Variation of Physical and Chemical Parameters 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	FME Limits	WHO Limits
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)	$p > 0.05$	35.00	-
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)	$p > 0.05$	6.50	8.50
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)	$p > 0.05$	-	100
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)	$p > 0.05$	1000	30
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)	$p > 0.05$	7.50	5.00
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)	$p > 0.05$	20.00	-
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)	$p > 0.05$	500.00	500.00
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)	$p > 0.05$	10.00	50.00
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)	$p > 0.05$	< 1.00	-
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)	$p < 0.05$	5.00	-

Chloride (mg/L)	10.59±3.87 (7.06-14.12)	10.59±3.87 (7.06-14.12)	11.77±3.65 (7.06-14.12)	10.59±3.87 (7.06-14.12)	$p > 0.05$	5.00	400.00
Turbidity (NTU)	42.33±61.26 (5.00-165.00)	9.50±5.99 (0.00-18.00)	12.50±6.98 (5.00-25.00)	17.33±6.15 (10.00-25.00)	$p > 0.05$	15.00	-
Iron (mg/L)	0.59±0.36 (0.37-1.32)	0.53±0.11 (0.43-0.75)	0.52±0.17 (0.39-0.87)	0.89±0.64 (0.41-2.14)	$p > 0.05$	1.00	-
Zinc (mg/L)	0.42±0.19 (0.25-0.74)	0.34±0.04 (0.28-0.38)	0.39±0.14 (0.24-0.65)	0.43±0.22 (0.25-0.84)	$p > 0.05$	1.00	-
Copper (mg/L)	0.33±0.03 (0.29-0.38)	0.32±0.03 (0.29-0.36)	0.33±0.04 (0.28-0.37)	0.32±0.06 (0.21-0.38)	$p > 0.05$	0.10	-
Manganese (mg/L)	0.05±0.01 (0.04-0.06)	0.04±0.01 (0.03-0.05)	0.04±0.01 (0.03-0.06)	0.05±0.01 (0.04-0.07)	$p > 0.05$	0.05	-
Chromium (mg/L)	0.07±0.02 (0.05-0.09)	0.06±0.02 (0.04-0.10)	0.06±0.02 (0.04-0.09)	0.07±0.01 (0.05-0.10)	$p > 0.05$	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 value.

Table 4.2: Seasonal Variation of Physical and Chemical Parameters 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 (cm)	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

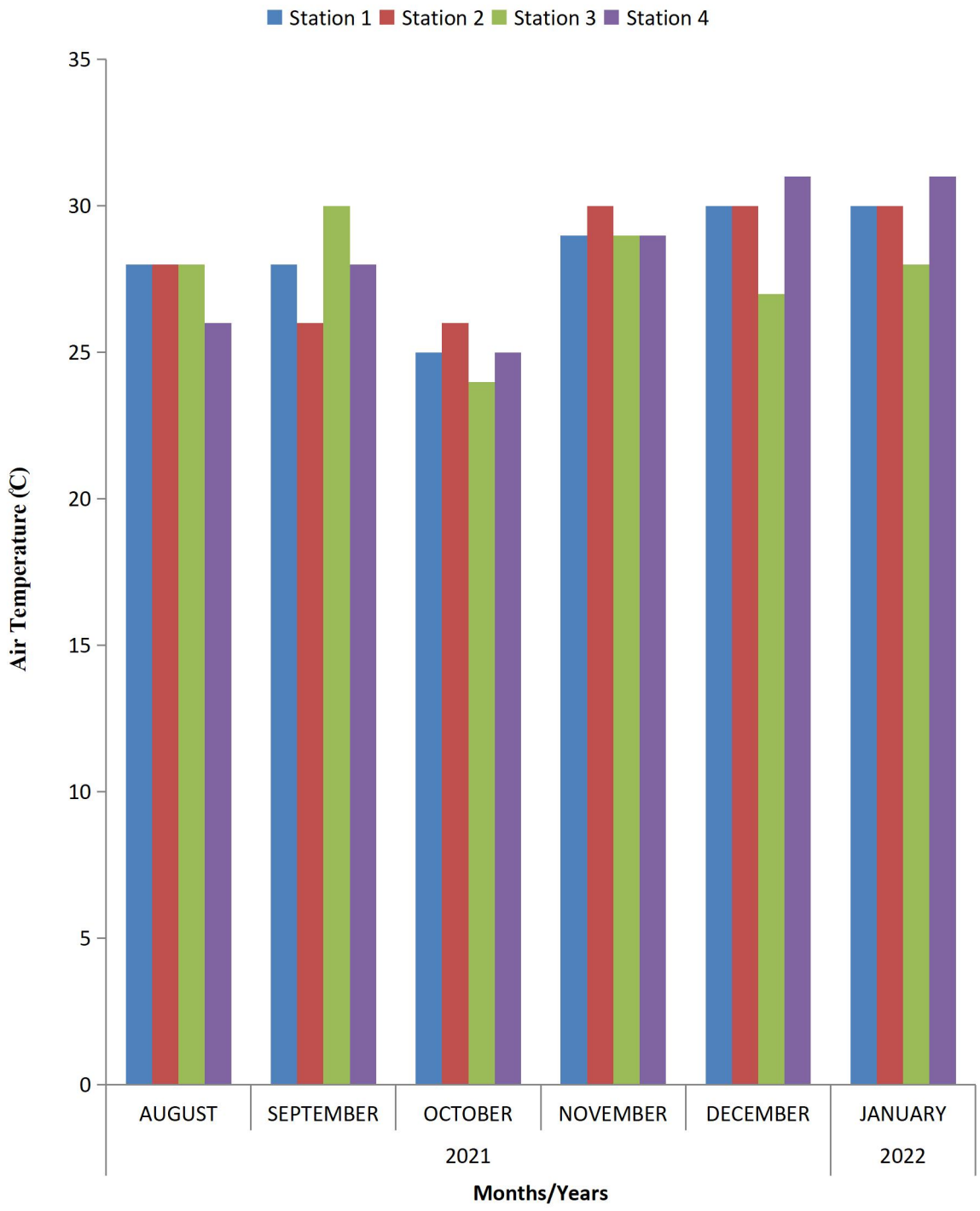

Fig. 4.1: Spatial and temporal variation of Air temperature

4.1.2 WATER TEMPERATURE (°C)

The spatial and seasonal variations of water temperature of the 4 different sample stations recorded during the period of investigation as shown in Table 4.1 – 4.2 respectively and represented in Fig. 4.2 ranged between 25.00 - 26.00 °C in station 1 with a mean value of 25.50 °C, 24.00 - 26.00 °C in station 2 with a mean value of 24.83 °C, 25.00 – 27.00 °C in station 3 with a mean value of 25.83 °C and 25.00 - 30.00 °C in station 4 with a mean value of 26.67 °C. The highest value of 30.00 ^{o}C was recorded at station 4 in November, 2021 while the least value of 24 ^{o}C was obtained at station 2 in October, 2021. Analysis of variance (ANOVA) showed that there was no significant difference in the mean values of the study stations ($p>0.05$) (Table 4.1). The mean value and standard deviation for water temperature in the wet season (25.83±0.83 °C) was higher than the dry season value of (25.58±1.56 °C) in Table 4.2. There was no significant difference ($p > 0.05$) between the wet and dry season values (Table 4.2).

4.1.3 DEPTH (cm)

The spatial and temporal variations in the depth of the sample stations are shown in Table 4.1 – 4.2 respectively and represented in Fig. 4.3. The depth of the various sample stations recorded during the period of investigation ranged between 0.38 - 1.00 cm in station 1 with a mean value of 0.48 cm, 0.13 - 0.60 cm in station 2 with a mean value of 0.36 cm, 0.11 – 0.81 cm in station 3 with a mean value of 0.36 cm and 0.14 - 0.40 cm with a mean value of 0.28 cm in station 4. The greatest depth of 1.00 cm was recorded at station 1 in September, 2021 and shallowest depth of 0.11 cm was recorded at station 3 in October, 2021. Analysis of variance (ANOVA) showed that there was no significant difference in the mean values of the study stations ($p>0.05$) (Table 4.1). The mean value and standard deviation for depth in the wet season (0.41±0.28 cm) was higher than the dry season value of (0.33±0.17 cm) in Table 4.2. There was no significant difference ($p > 0.05$) between the wet and dry season values (Table 4.2).

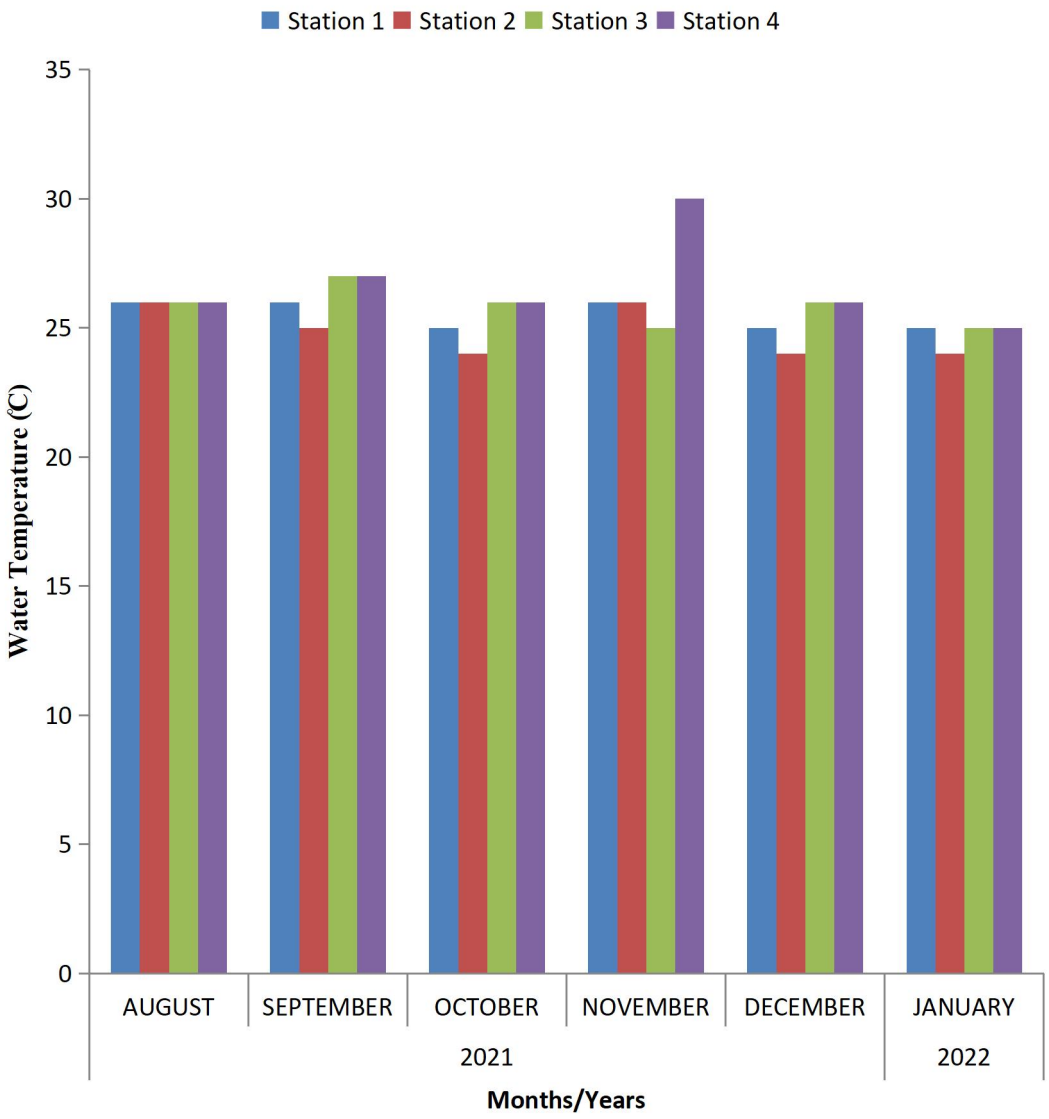

Fig. 4.2: Spatial and temporal variation of Water temperature

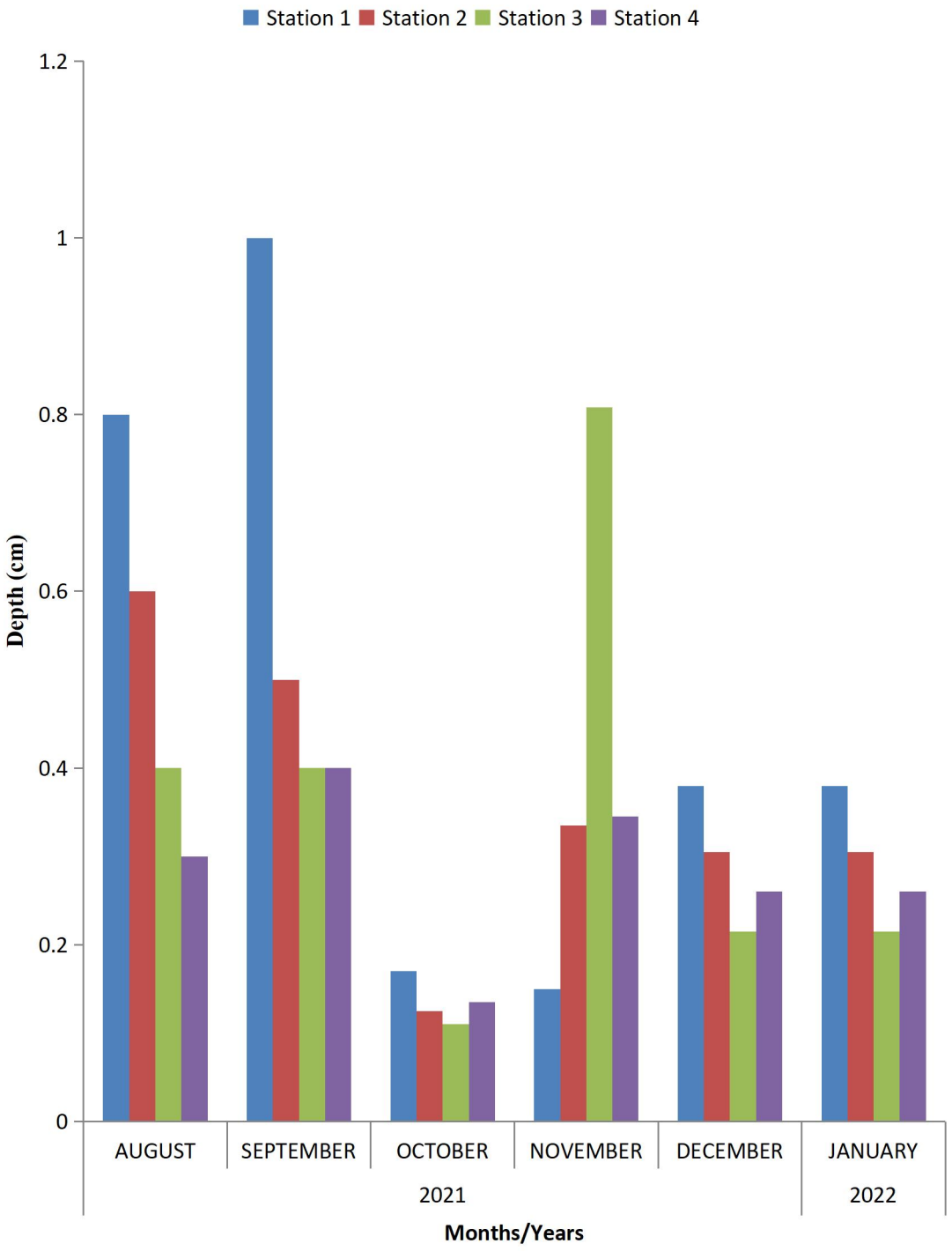

Fig. 4.3: Spatial and temporal variation of Depth

4.1.4 HYDROGEN CONCENTRATION (pH)

The spatial and seasonal comparisons in the values of pH for water are shown in Table 4.1 – 4.2 respectively and represented in Fig. 4.4. The pH values recorded during the period of investigation for the 4 sample stations ranged between 5.90 - 6.30 in station 1 with a mean value of 6.08, 5.58 - 6.30 in station 2 with a mean value of 5.90, 5.30 – 6.30 in station 3 with a mean value of 5.70 and 5.70 – 6.30 with a mean value of 5.92 in station 4. The highest pH value of 6.30 was recorded at station 1, 2, 3 and 4 in October, 2021 and lowest pH of 5.30 recorded at station 3 in September, 2021. Analysis of Variance (ANOVA) showed that there was no significant difference in the mean values of the study stations (p >0.05) (Table 4.1). The mean value and standard deviation for pH in the dry season (5.88±0.20) was lower than the wet season value of (5.93±0.33) in Table 4.2. There was no significant difference (p > 0.05) between the wet and dry season values (Table 4.2).

4.1.5 ELECTRICAL CONDUCTIVITY (µS/cm)

The spatial and temporal variations in electrical conductivity values for water are shown in Table 4.1 – 4.2 respectively and represented in Fig. 4.5. The electrical conductivity values ranged between 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. The highest electrical conductivity value of 219.80 µS/cm was recorded at station 3 in September, 2021 while the lowest value of 39.30 µS/cm was recorded at station 3 in December, 2021. Analysis of Variance (ANOVA) showed that there was no significant difference in the mean values of the study stations (p > 0.05) (Table 4.1). The mean value and standard deviation for electrical conductivity in the dry season (72.95±31.04 µS/cm) was lower than the wet season value of (128.73±46.48 µS/cm) in Table 4.2. There was high significant difference (p < 0.01) between the wet and dry season values (Table 4.2).

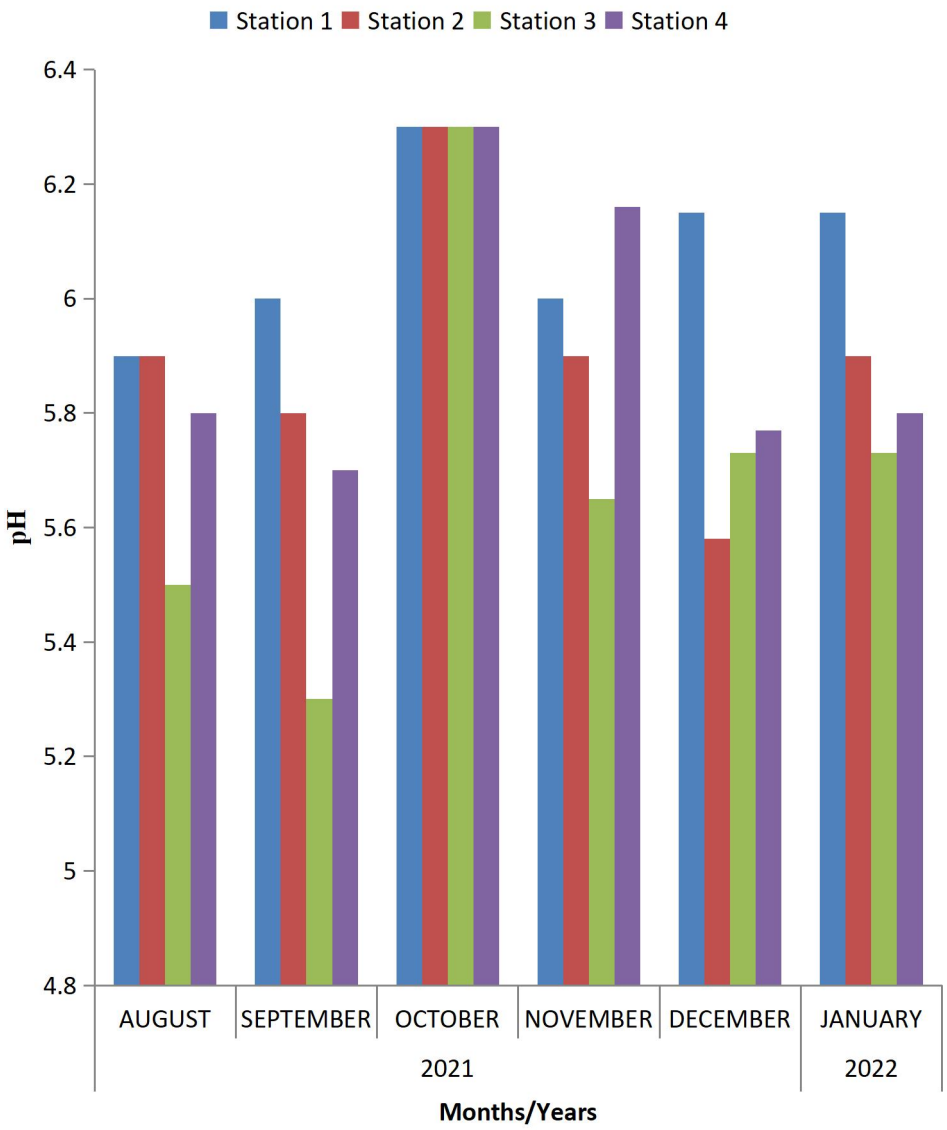

Fig. 4.4: Spatial and temporal variation of pH

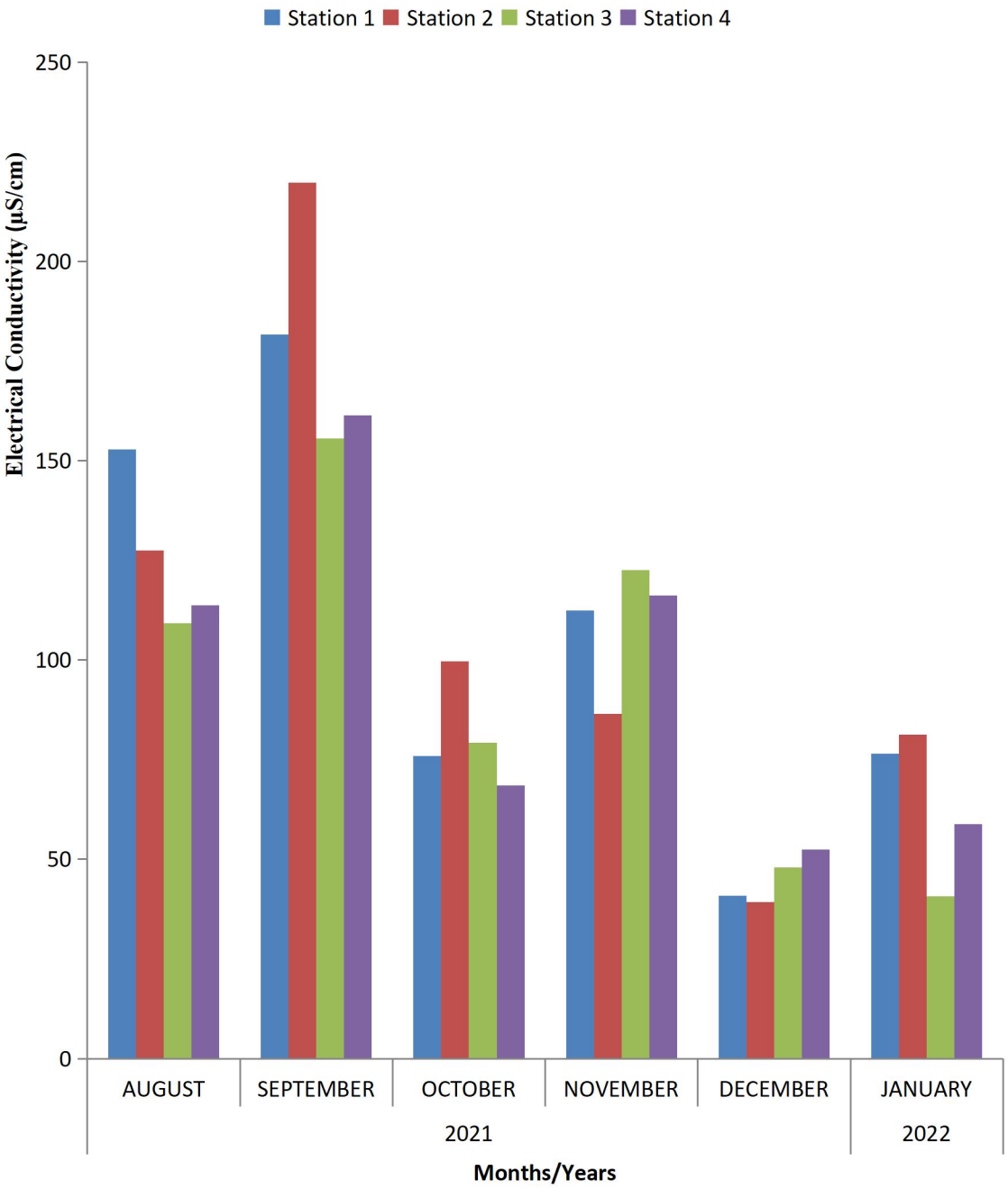

Fig. 4.5: Spatial and temporal variation of Electrical conductivity

4.1.6 FLOW RATE (cm/s)

The flow rate of the 4 different sample stations recorded during the period of investigation as seen in Table 4.1 – 4.2 respectively and represented in Fig. 4.6 ranged between 0.00 – 0.20 cm/s in station 1 with a mean value of 0.09 cm/s, 0.01 – 3.00 cm/s in station 2 with a mean value of 1.51 cm/s, 0.00 – 2.00 cm/s in station 3 with a mean value of 1.01 cm/s and 0.00 – 0.1 cm/s with a mean value of 0.01 cm/s in station 4. The highest flow rate of value 3.00 cm/s was recorded at station 2 in August, 2021, September, 2021 and January, 2022 and lowest value of 0.00 cm/s was recorded at station 1, 3 and 4 in December, 2021. Analysis of Variance (ANOVA) showed that there was a significant difference in the mean values of the study stations ($p < 0.05$) (Table 4.1). Duncan Multiple Range test showed that station 2 was significantly different from stations 1, 3 and 4 (Table 4.1). The mean value and standard deviation for flow rate in the dry season (0.44±0.99 cm/s) was lower than the wet season value of (0.87±1.24 cm/s) in Table 4.2. There was no significant difference ($p >0.05$) between the wet and dry season values (Table 4.2).

4.1.7 TOTAL DISSOLVED SOLIDS (mg/l)

The spatial and temporal variations in the total dissolved solids values 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 54.25 mg/l and 20.50 – 90.70 mg/l in station 4 with a mean value of 52.97 mg/l. The highest value of 108.40 mg/l was recorded at station 3 in September, 2021 while the lowest value of 19.50 mg/l was recorded at station 3 in December, 2021. Analysis of Variance (ANOVA) showed that there was no significant difference in the mean values of the study stations ($p >0.05$) (Table 4.1). The mean value and standard deviation for total dissolved

solids in the dry season (35.98±14.33 mg/l) was lower than the wet season value of (63.86±23.24 mg/l) in Table 4.2. There was high significant difference ($p < 0.01$) between the wet and dry season values (Table 4.2).

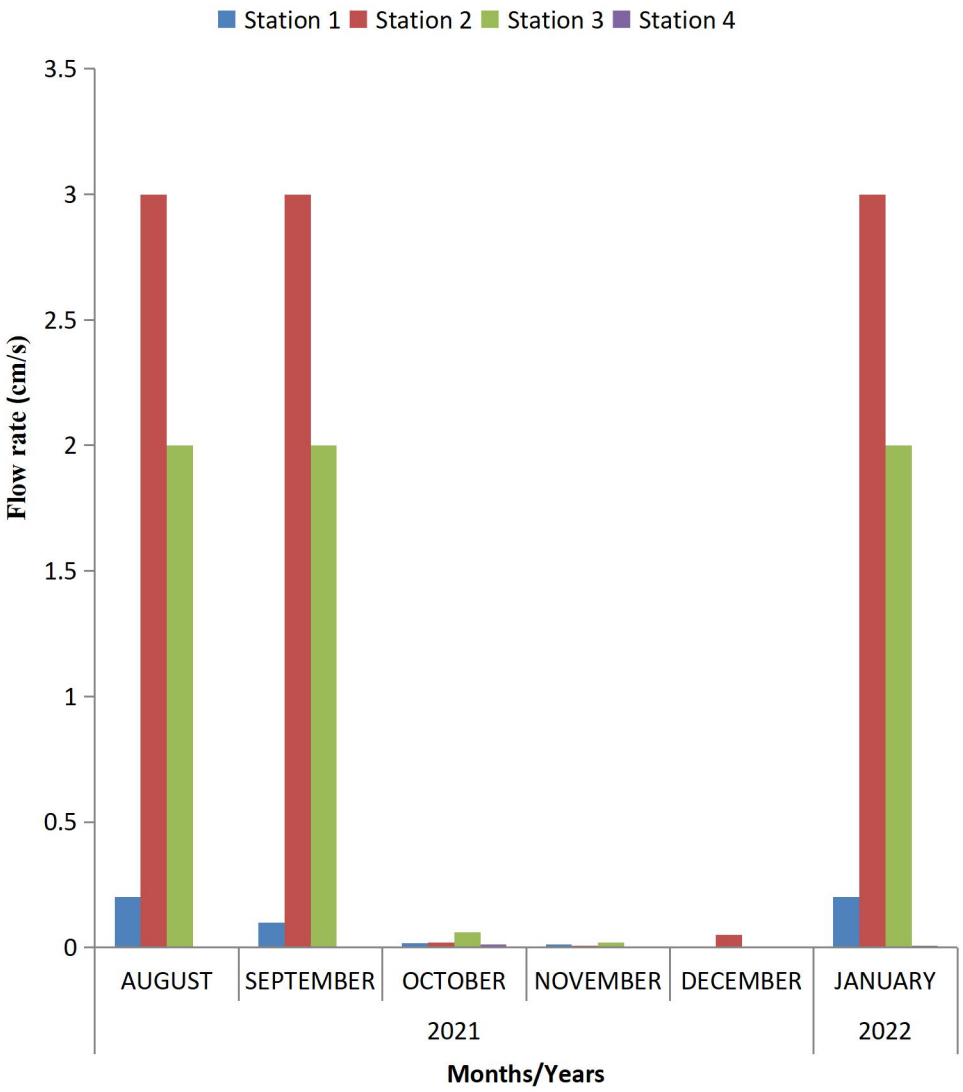

Fig. 4.6: Spatial and temporal variation of Flow rate

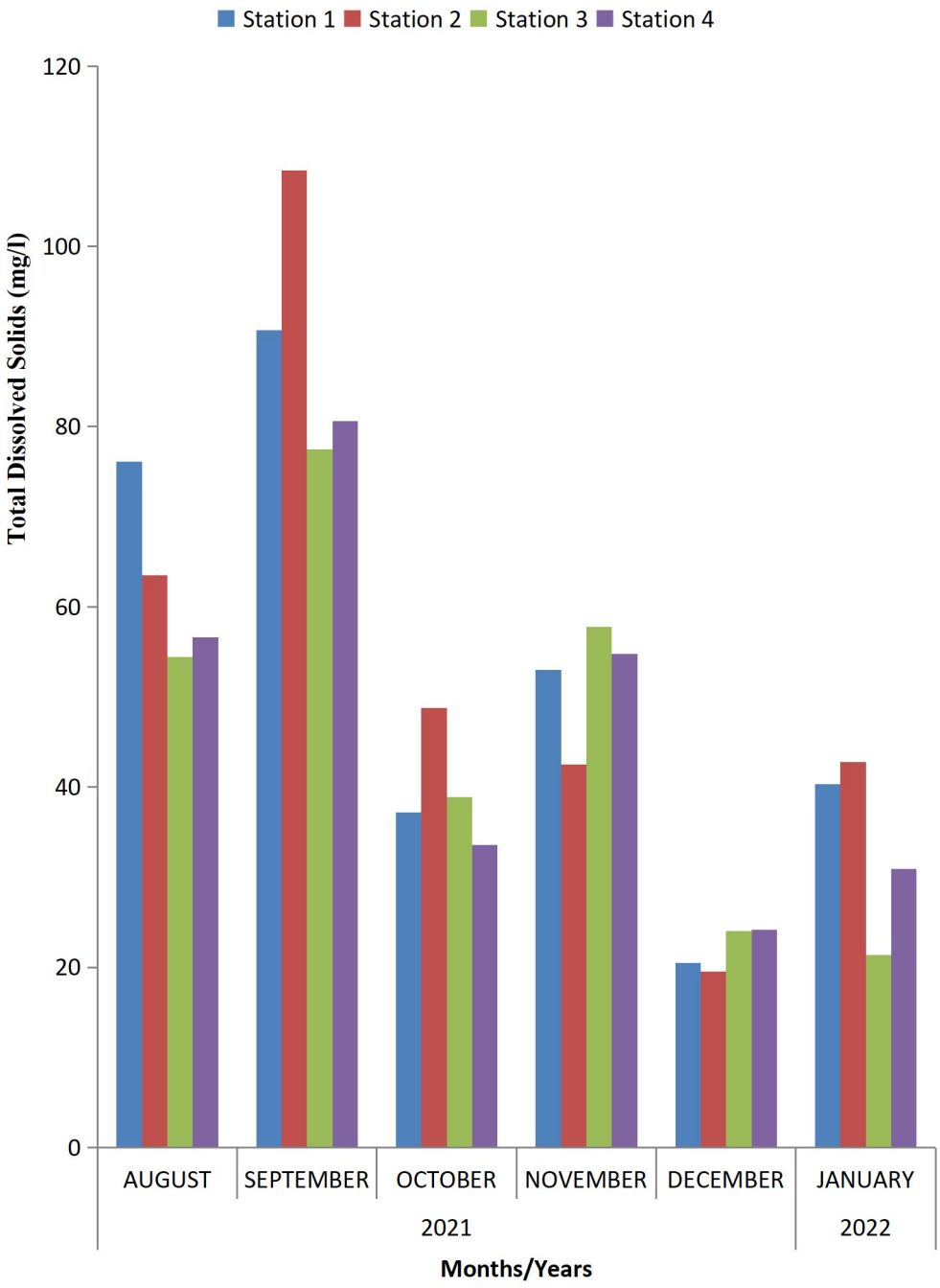

Fig. 4.7: Spatial and temporal variation of Total dissolved solids

4.1.8 TRANSPARENCY

The transparency across the sample stations recorded during the period of investigation as seen in Table 4.1 – 4.2 respectively and represented in Fig. 4.8 ranged from 0.70 – 1.20 in station 1 with a mean value of 0.95, 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 highest clarity of value 2.00 was recorded at station 3 in November, 2021 and lowest value of 0.20 was recorded at station 3 in October, 2021 and station 4 in September, 2021 and December, 2021. Analysis of Variance (ANOVA) showed that there was no significant difference in the mean values of the study stations (p >0.05) (Table 4.1). The mean value and standard deviation for transparency in the dry season (0.79±0.54) was higher than the wet season value of (0.68±0.42) in Table 4.2. There was no significant difference (p > 0.05) between the wet and dry season values (Table 4.2).

4.1.9 WIDTH (cm)

The spatial and temporal variations in the width of the sample stations are shown in Table 4.1 – 4.2 respectively and represented in Fig. 4.9. The width of the various sample stations recorded during the period of investigation ranged between 14.00 – 20.00 cm in station 1 with a mean value of 16.58 cm, 10.00 – 15.00 cm in station 2 with a mean value of 11.50 cm, 9.00 – 13.00 cm in station 3 with a mean value of 10.58 cm and 2.00 – 5.00 cm in station 4 with a mean value of 3.17 cm in station 4. The greatest width of 20.00 cm was recorded at station 1 in August, 2021 and lowest width of 2.00 cm was recorded at station 4 in August, 2021, November, 2021 and January, 2022. Analysis of Variance (ANOVA) showed that there was high significant difference in the mean values of the study stations (p < 0.01) (Table 4.1). The mean value and standard deviation for width in the dry season (9.46±4.56 cm) was lower

than the wet season value of (11.46±5.72 cm) in Table 4.2. There was no significant difference ($p > 0.05$) between the wet and dry season values (Table 4.2).

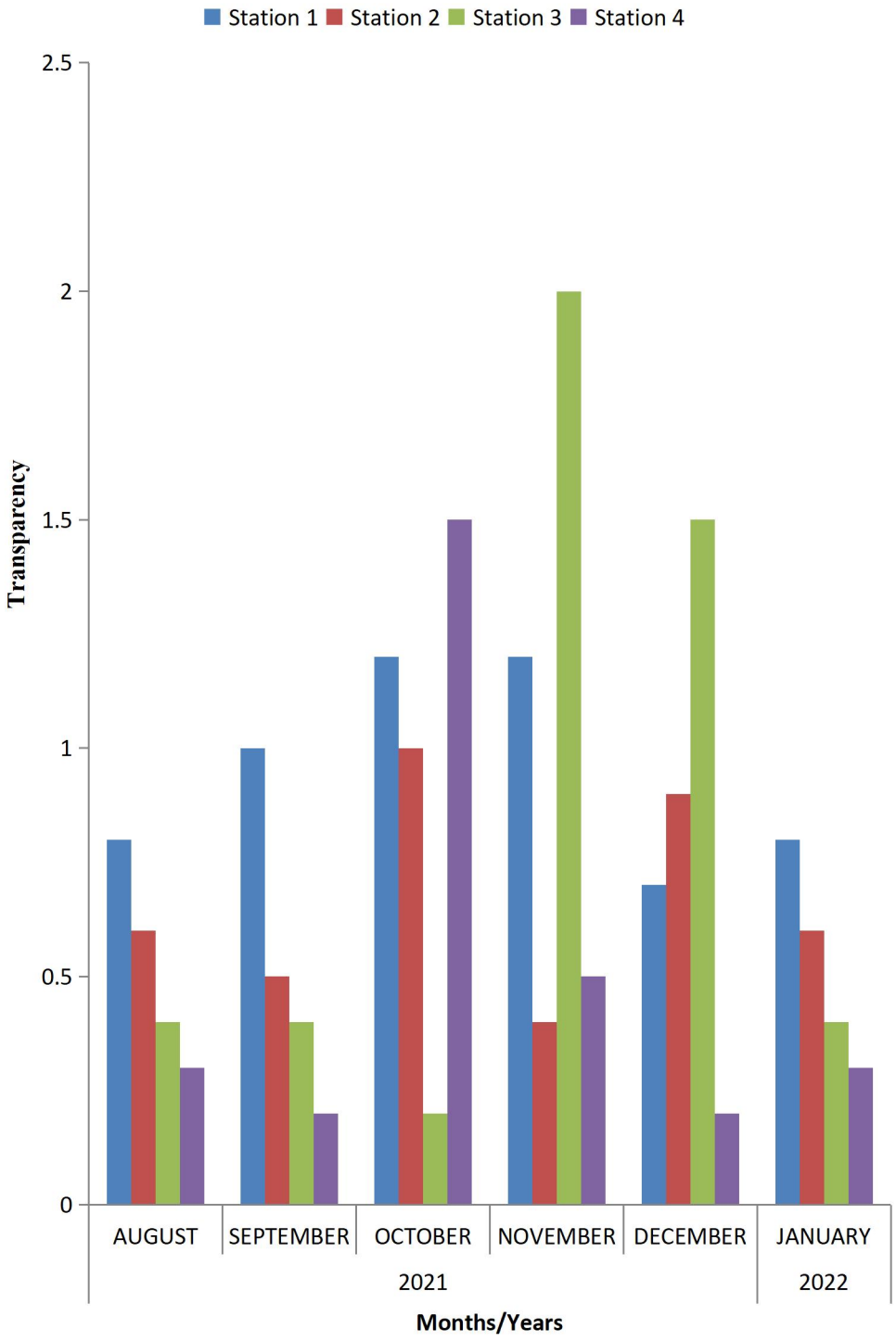

Fig. 4.8: Spatial and temporal variation of Transparency

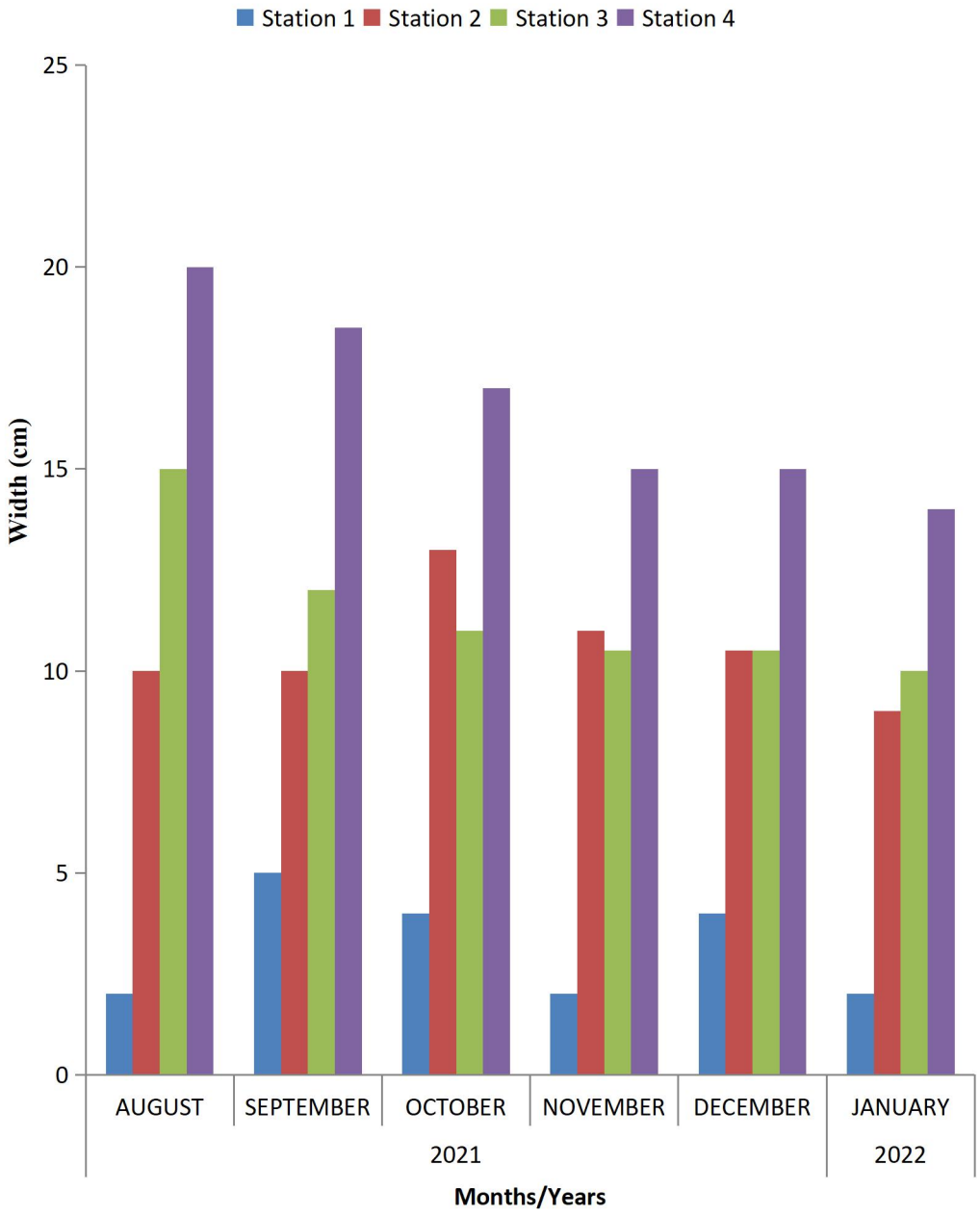

Fig. 4.9: Spatial and temporal variation of Width

4.1.10 DISSOLVED OXYGEN (mg/l)

The dissolved oxygen recorded during the period of investigation for the 4 sample stations as shown in Table 4.1 – 4.2 respectively and represented in Fig. 4.10 ranged between 0.20 – 2.00 mg/l in station 1 with a mean value of 1.15 mg/l, 0.60 – 2.30 mg/l in station 2 with a mean value of 1.00 mg/l, 0.50 – 4.60 mg/l in station 3 with a mean value of 1.75 mg/l and 0.50 – 6.80 mg/l with a mean value of 1.97 mg/l in station 4. The highest dissolved oxygen value of 6.80 mg/l was recorded at station 4 in January, 2022 and lowest value of 0.20 mg/l was recorded at station 1 in November, 2021. Analysis of Variance (ANOVA) showed that there was no significant difference in the mean values of the study stations (p >0.05) (Table 4.1). The mean value and standard deviation for dissolved oxygen in the dry season (1.90±1.94 mg/l) was higher than the wet season value of (1.03±0.55 mg/l) in Table 4.2. There was no significant difference (p > 0.05) between the wet and dry season values (Table 4.2).

4.1.11 BIOCHEMICAL OXYGEN DEMAND (mg/l)

The biological oxygen demand for the 4 sample stations recorded during the period of investigation as seen in Table 4.1 – 4.2 respectively and represented in Fig. 4.11 ranged between 0.50 – 5.40 mg/l in station 1 with a mean value of 3.60 mg/l, 1.10 – 4.30 mg/l in station 2 with a mean value of 3.37 mg/l, 2.80 – 4.60 mg/l in station 3 with a mean value of 3.55 mg/l and 3.20 – 4.60 mg/l with a mean value of 3.82 mg/l in station 4. The highest biochemical oxygen demand of value 5.40 mg/l was recorded at station 1 in November, 2021 and lowest of value 0.50 was recorded at station 1 in January, 2021. Analysis of Variance (ANOVA) showed that there was no significant difference in the mean values of the study stations (p >0.05) (Table 4.1). The mean value and standard deviation for biochemical

oxygen demand in the dry season (3.34±1.39 mg/l) was lower than the wet season value of (3.83±0.43 mg/l) in Table 4.2. There was no significant difference ($p > 0.05$) between the wet and dry season values (Table 4.2).

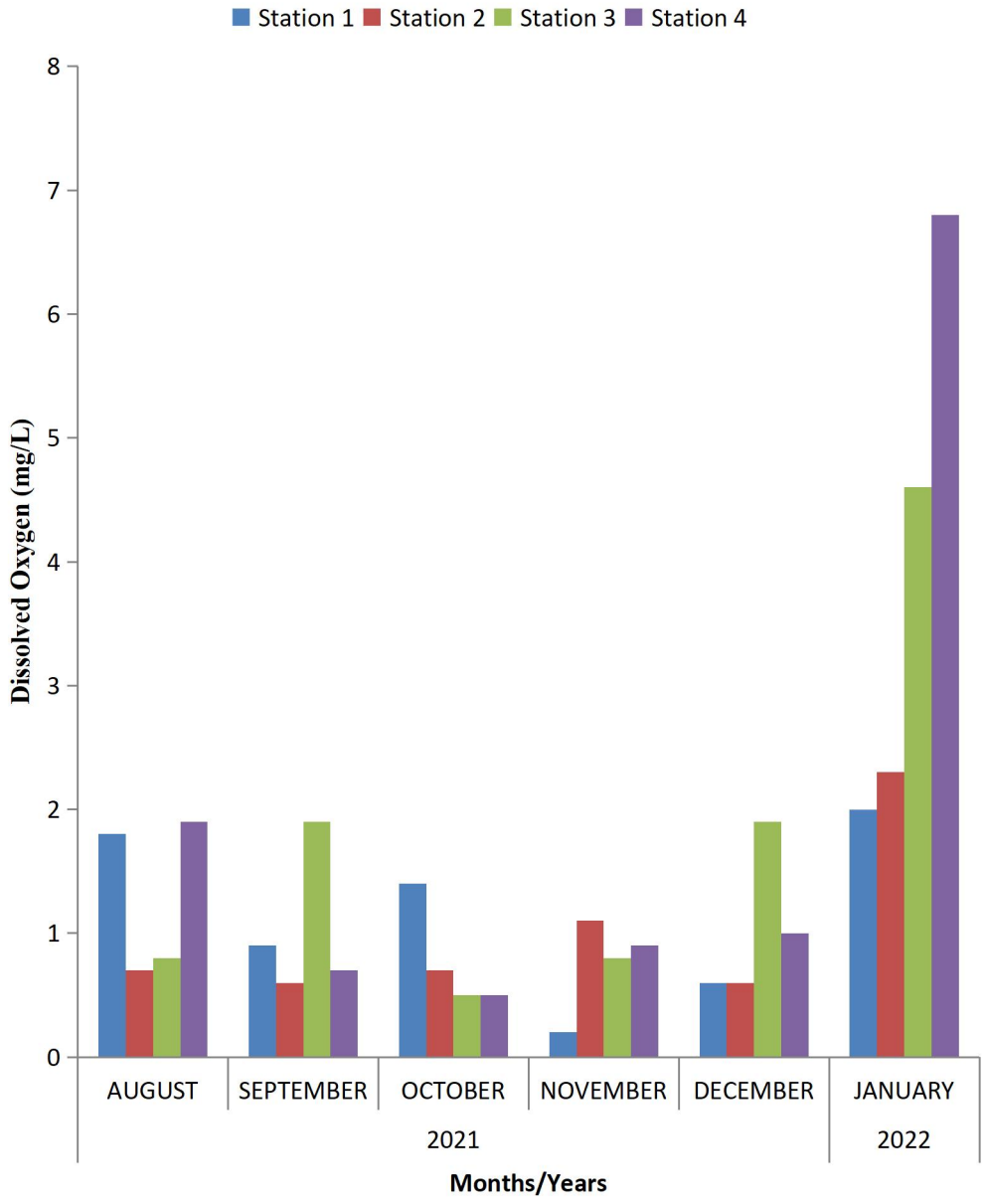

Fig. 4.10: Spatial and temporal variation of Dissolved oxygen

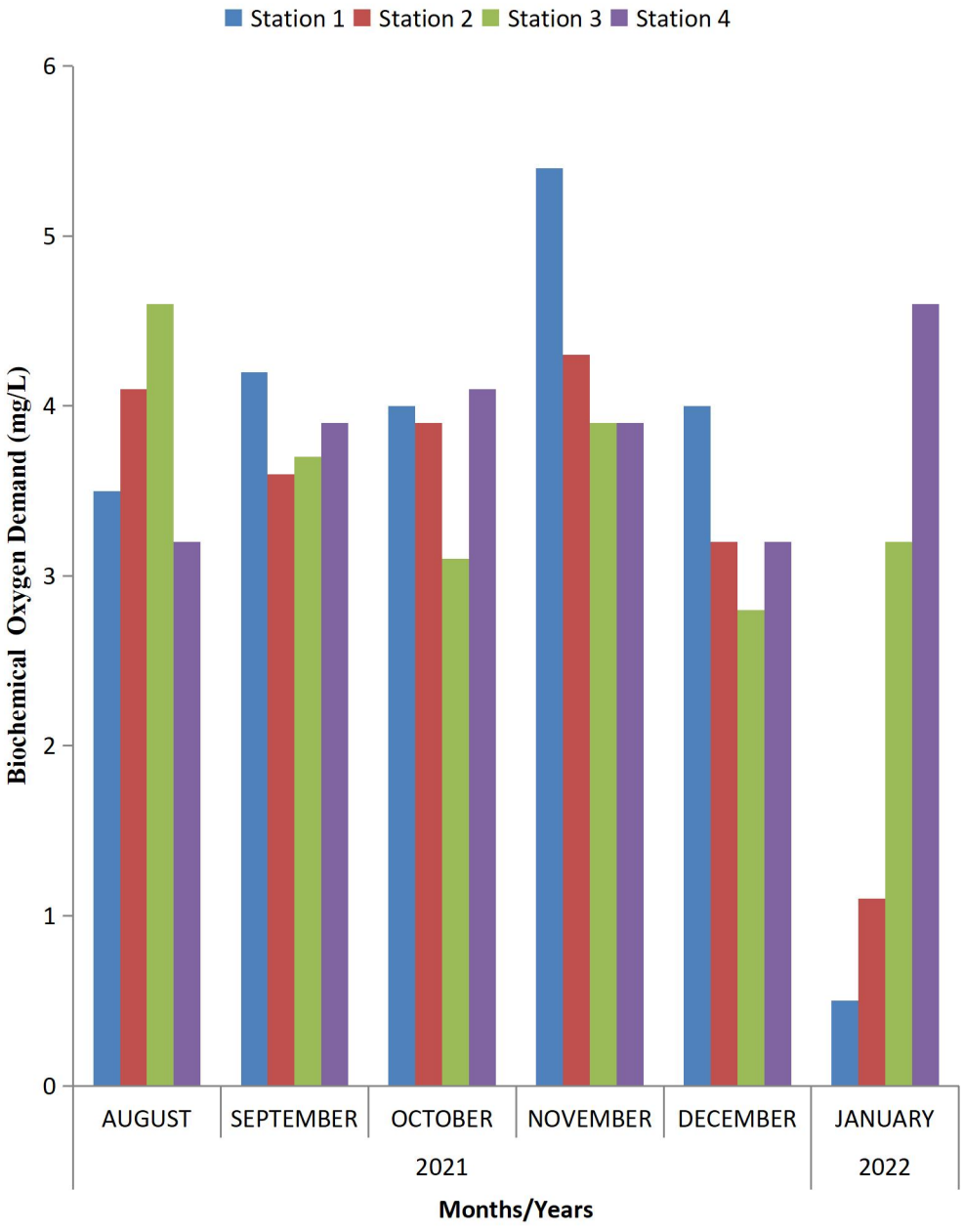

Fig. 4.11: Spatial and temporal variation of Biochemical oxygen demand

4.1.12 SULPHATE (mg/l)

The nutrient values based on sulphate for the 4 sample stations recorded during the period of investigation as shown in Table 4.1 – 4.2 respectively and represented in Fig. 4.12 ranged between 3.00 – 43.00mg/l in station 1 with a mean value of 13.17 mg/l, 3.00 – 10.00 mg/l in station 2 with a mean value of 4.67 mg/l, 2.00 – 21.00 mg/l in station 3 with a mean value of 6.00 mg/l and 3.00 – 17.00 mg/l with a mean value of 7.67 mg/l in station 4. The highest sulphate value 43.00 mg/l was recorded at station 1 in October, 2021 and the lowest value of 2.00 mg/l was recorded at station 3 in August, 2021, September, 2021 and October, 2021. Analysis of Variance (ANOVA) showed that there was no significant difference in the mean values of the study stations (p >0.05) (Table 4.1). The mean value and standard deviation for sulphate in the dry season (7.67±5.85 mg/l) was lower than the wet season value of (8.08±11.58 mg/l) in Table 4.2. There was no significant difference (p > 0.05) between the wet and dry season values (Table 4.2).

4.1.13 NITRATES (mg/l)

The nitrates content for the 4 sample stations recorded during the period of investigation as shown in Table 4.1 – 4.2 respectively and represented in Fig. 4.13 ranged between 0.25 – 2.12 mg/l in station 1 with a mean value of 0.86 mg/l, 0.25 – 1.61 mg/l in station 2 with a mean value of 0.85 mg/l, 0.21 – 1.47 mg/l in station 3 with a mean value of 0.72 mg/l and 0.22 – 4.36 mg/l in station 4 with a mean value of 1.16 mg/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) showed that there was no

significant difference in the mean values of the study stations (p >0.05) (Table 4.1). The mean value and standard deviation for nitrate in the dry season (1.11±1.16 mg/l) was higher than the wet season value of (0.69±0.42 mg/l) in Table 4.2. There was no significant difference (p > 0.05) between the wet and dry season values (Table 4.2).

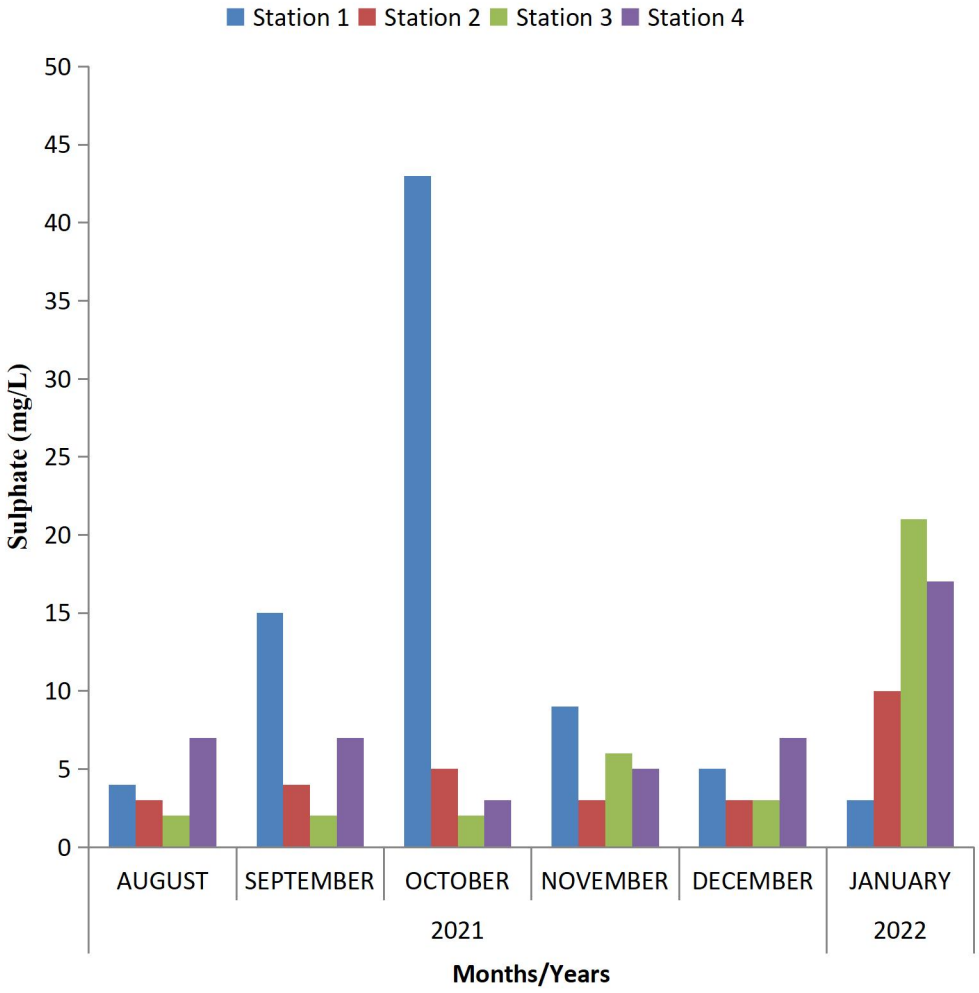

Fig. 4.12: Spatial and temporal variation of Sulphate

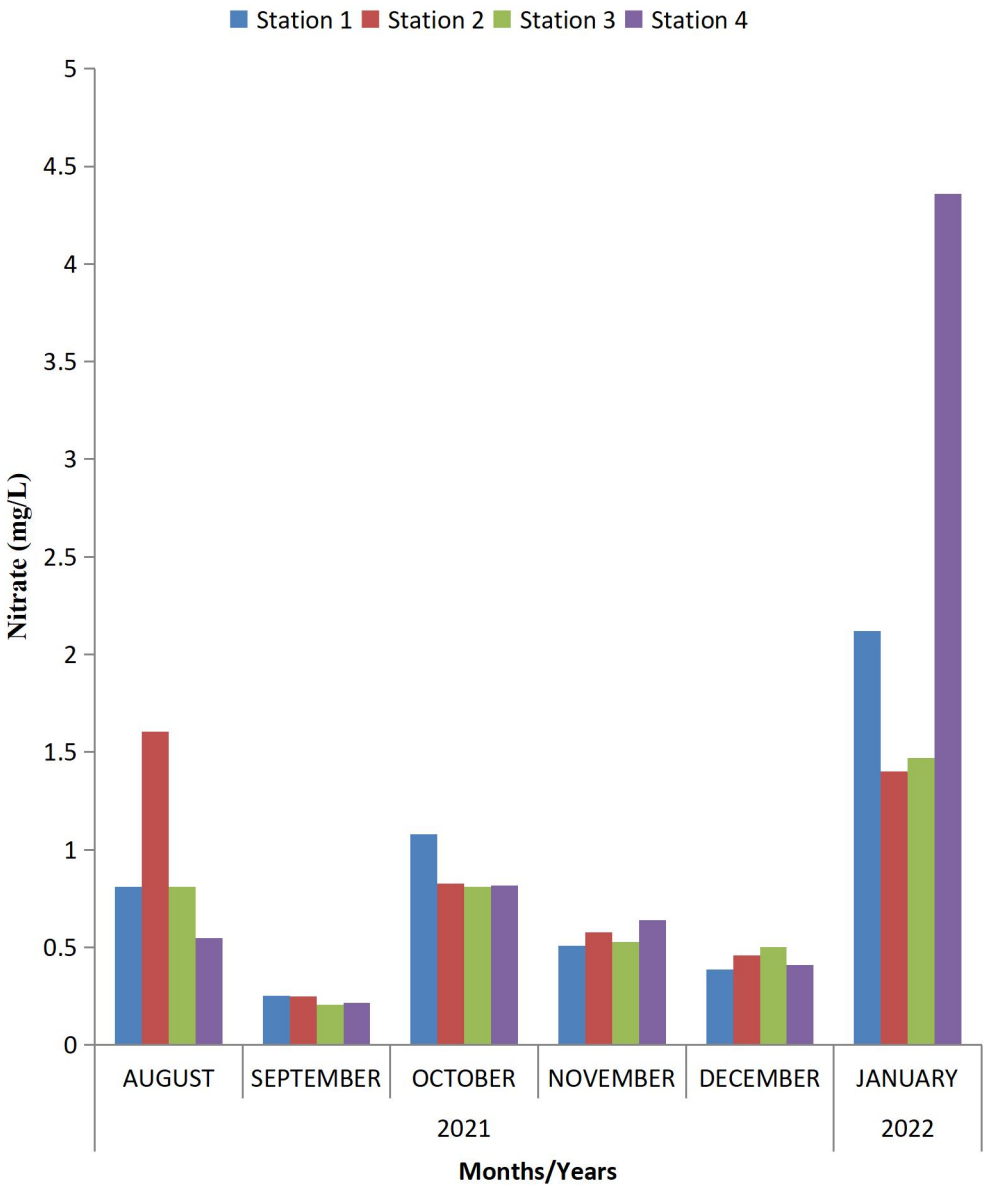

Fig. 4.13: Spatial and temporal variation of Nitrate

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. The highest ammonium value of 2.04 mg/l was recorded at station 4 in January, 2022 and lowest value of 0.01 mg/l was recorded at station 3 in January, 2022. Analysis of Variance (ANOVA) showed that there was no significant difference in the mean values of the study stations (p >0.05) (Table 4.1). The mean value and standard deviation for ammonium in the dry season (0.27±0.56 mg/l) was higher than the wet season value of (0.27±0.15 mg/l) in Table 4.2. There was no significant difference (p > 0.05) between the wet and dry season values (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) showed that there was significant difference in the mean

values of the study stations ($p < 0.05$) (Table 4.1). The mean value and standard deviation for phosphate in the dry season (0.10±0.07 mg/l) was lower than the wet season value of (0.16±0.12 mg/l) in Table 4.2. There was no significant difference ($p > 0.05$) between the wet and dry season values (Table 4.2).

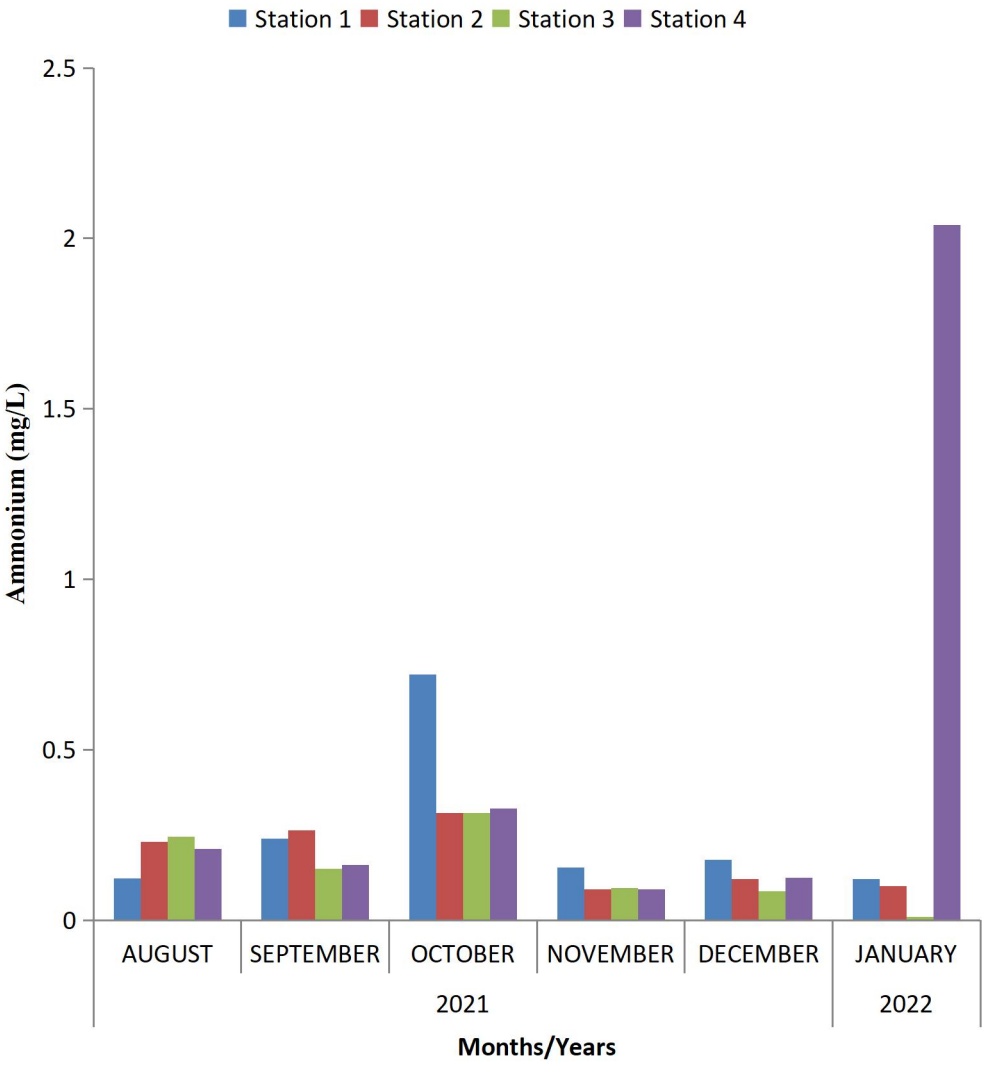

Fig. 4.14: Spatial and temporal variation of Ammonium

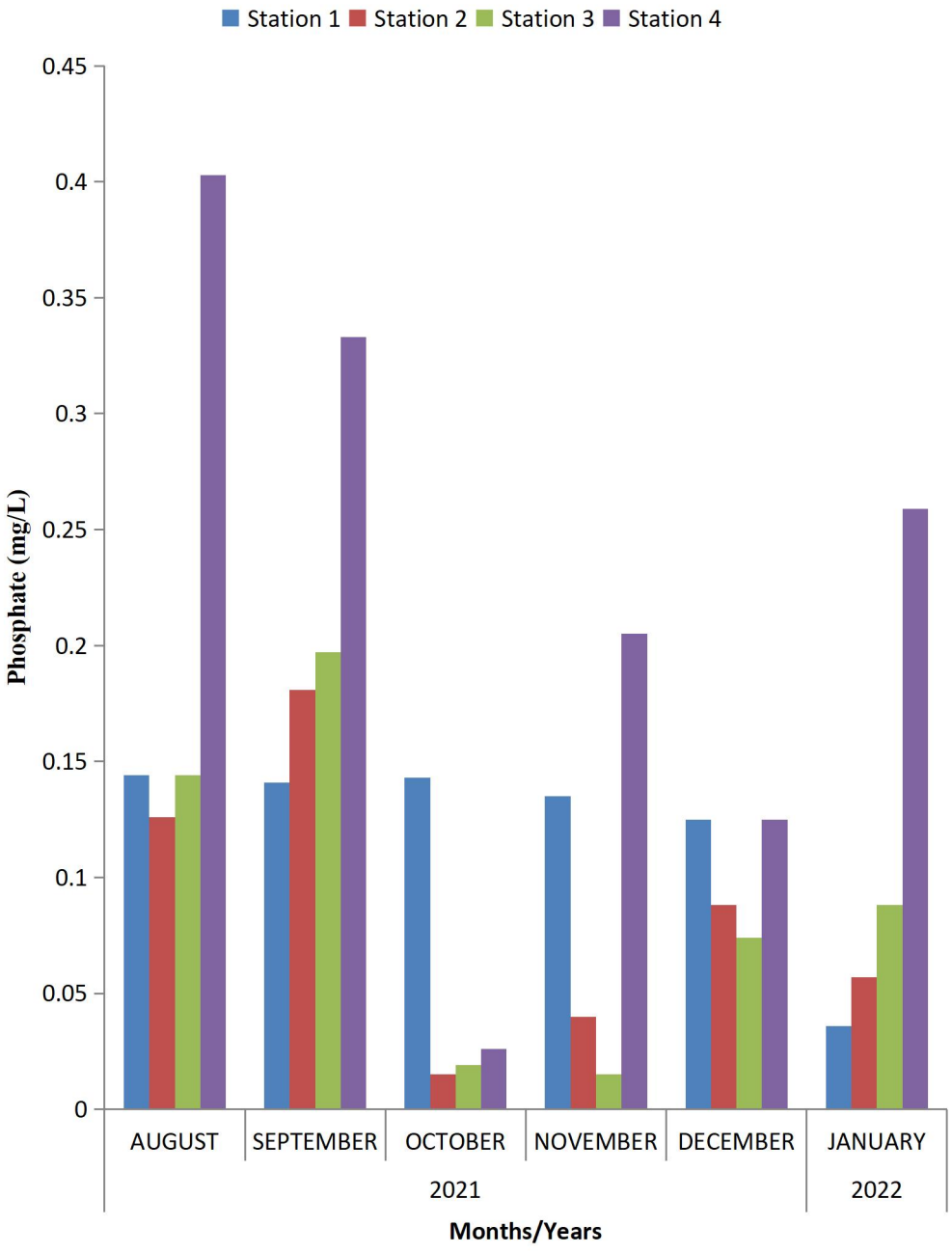

Fig. 4.15: Spatial and temporal variation of Phosphate

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. The highest and lowest chloride value of 14.12 and 7.06 mg/l was recorded across the 4 sample stations. Analysis of Variance (ANOVA) showed that there was no significant difference in the mean values of the study stations ($p > 0.05$) (Table 4.1). The mean value and standard deviation for chloride in the dry season (9.41±3.48 mg/l) was lower than the wet season value of (12.36±3.19 mg/l) in Table 4.2. There was a significant difference ($p < 0.05$) between the wet and dry season values (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 highest turbidity value of 165.00 NTU was recorded at station 1 in October, 2021 and lowest value of 0.00 NTU was recorded at station 2 in January, 2022. Analysis of Variance (ANOVA) showed that there was no significant difference in the mean values of the study stations ($p > 0.05$) (Table 4.1). The mean value and standard deviation for turbidity in the dry season

(13.17±9.33 NTU) was lower than the wet season value of (27.67±43.89 NTU) in Table 4.2. There was no significant difference ($p > 0.05$) between the wet and dry season values (Table 4.2).

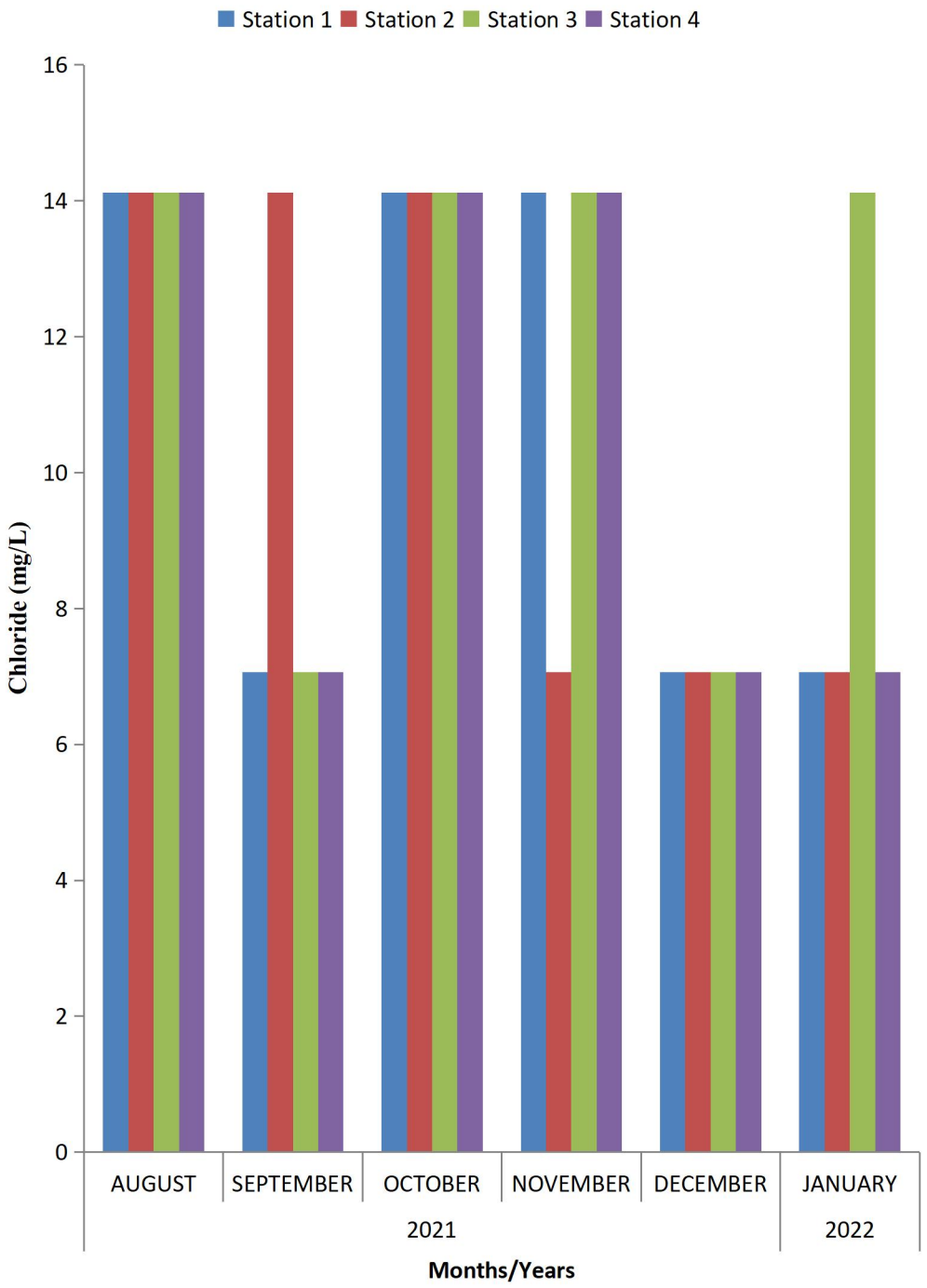

Fig. 4.16: Spatial and temporal variation of Chloride

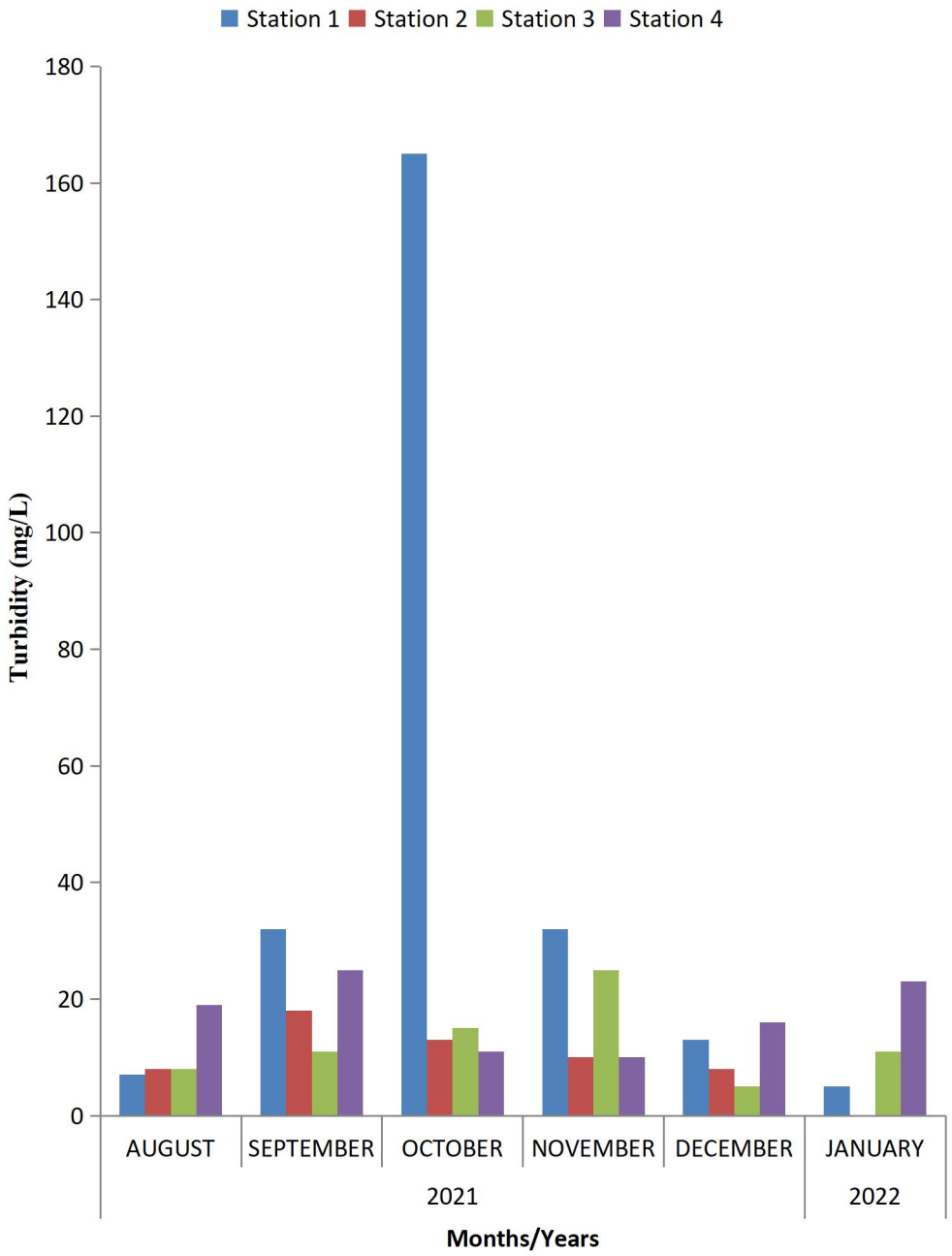

Fig. 4.17: Spatial and temporal variation of Turbidity

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. The highest iron value of 2.14 mg/l was recorded at station 4 in September, 2021 and lowest value of 0.37 mg/l was recorded at station 1 in November, 2021. Analysis of Variance (ANOVA) showed that there was no significant difference in the mean values of the study stations (p >0.05) (Table 4.1). The mean value and standard deviation for iron in the dry season (0.46±0.07 mg/l) was lower than the wet season value of (0.80±0.49 mg/l) in Table 4.2. There was a significant difference (p < 0.05) between the wet and dry season values (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. The highest zinc value of 0.84 mg/l was recorded at station 4 in September, 2021 and lowest value of 0.24 mg/l was recorded at station 3 in November, 2021. Analysis of Variance (ANOVA) showed that there was no significant difference in the mean values of the study stations (p >0.05) (Table 4.1). The mean value and standard deviation for zinc in the dry season (0.29±0.03 mg/l)

was lower than the wet season value of (0.50±0.17 mg/l) in Table 4.2. There was a high significant difference ($p < 0.01$) between the wet and dry season values (Table 4.2).

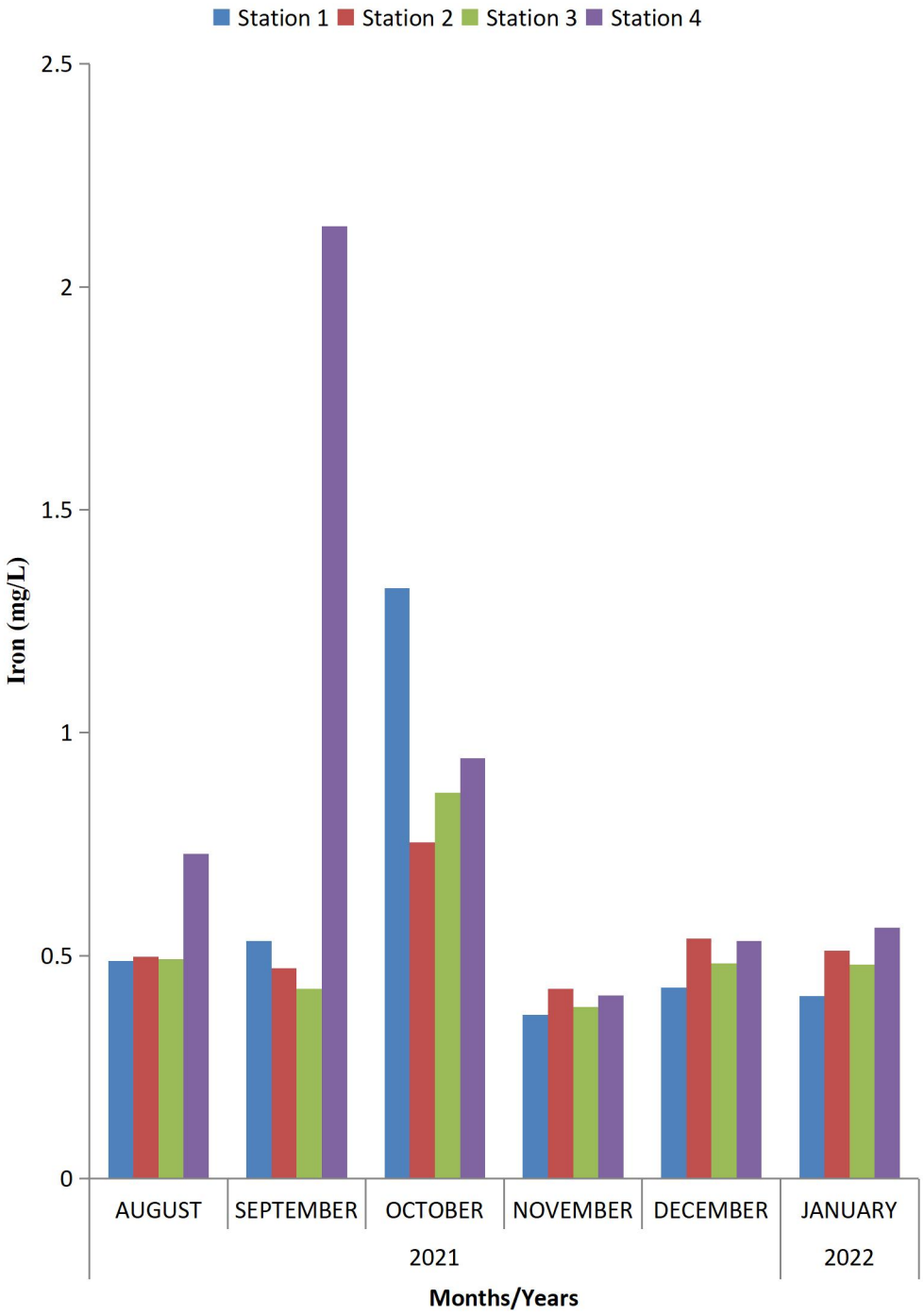

Fig. 4.18: Spatial and temporal variation of Iron

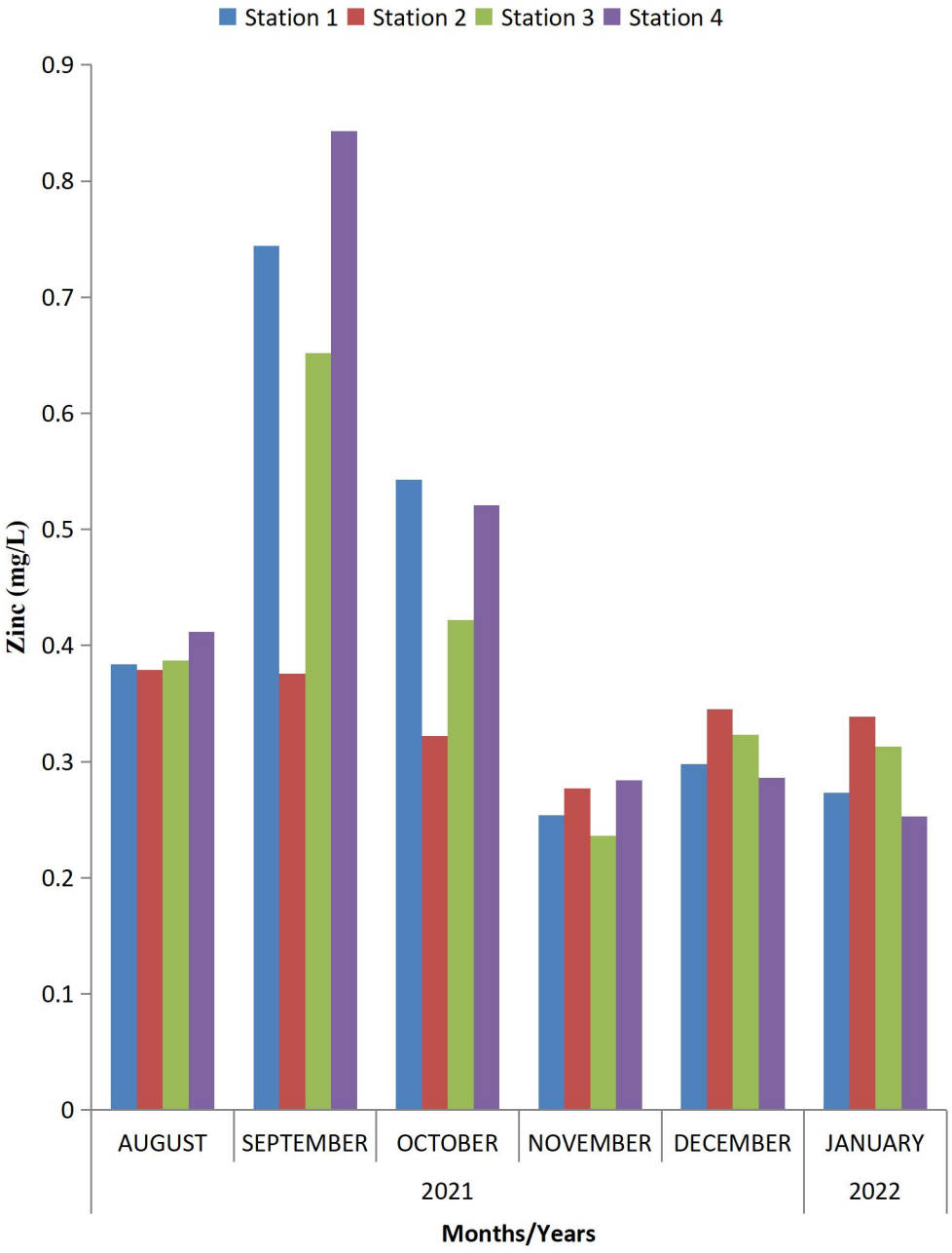

Fig. 4.19: Spatial and temporal variation of Zinc

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. The highest copper value of 0.38 mg/l was recorded at station 1 and 4 in September, 2021 and August, 2021 respectively and lowest value of 0.21 mg/l was recorded at station 4 in November, 2021. Analysis of Variance (ANOVA) showed that there was no significant difference in the mean values of the study stations (p >0.05) (Table 4.1). The mean value and standard deviation for copper in the dry season (0.32±0.04 mg/l) was lower than the wet season value of (0.34±0.03 mg/l) in Table 4.2. There was no significant difference (p > 0.05) between the wet and dry season values (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. The highest manganese value of 0.07 mg/l was recorded at station 4 in September, 2021 and lowest value of 0.03 mg/l was recorded at station 2 and 3 in August, 2021 and January, 2022 respectively. Analysis of Variance (ANOVA) showed that there was no significant difference in the mean

values of the study stations (p >0.05) (Table 4.1). The mean value and standard deviation for manganese in the dry season (0.04±0.00 mg/l) was lower than the wet season value of (0.05±0.01 mg/l) in Table 4.2. There was a high significant difference (p < 0.01) between the wet and dry season values (Table 4.2).

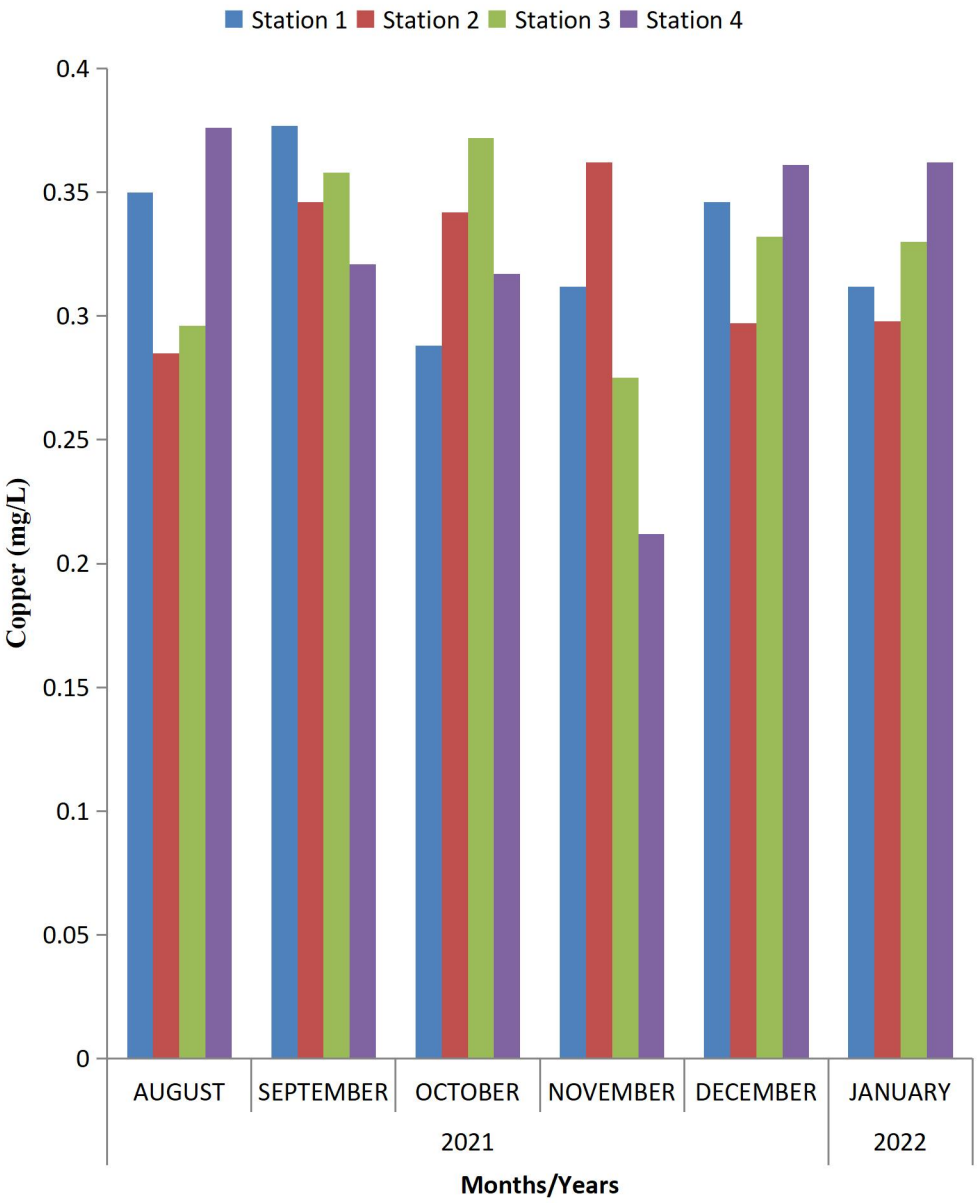

Fig. 4.20: Spatial and temporal variation of Copper

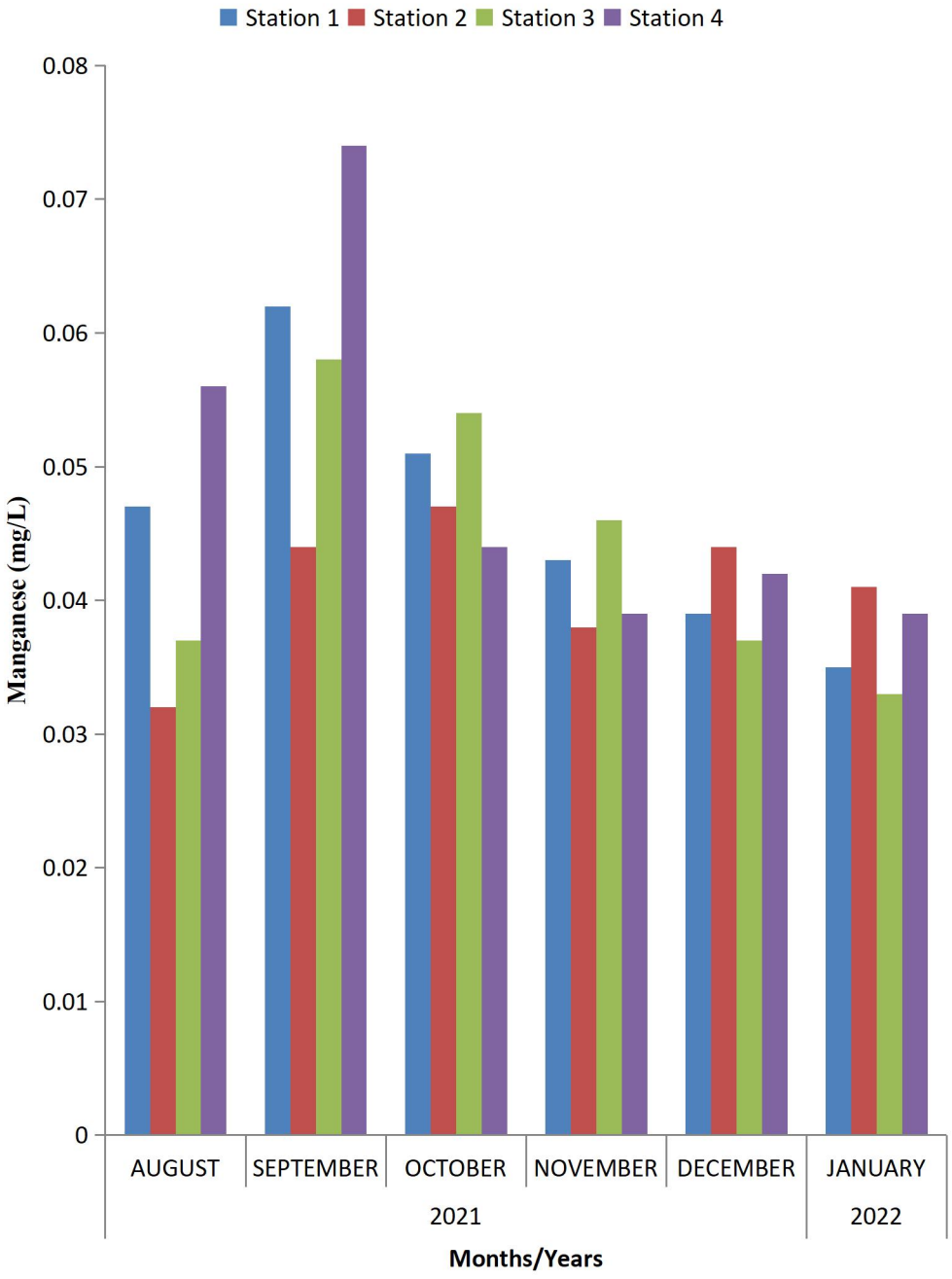

Fig. 4.21: Spatial and temporal variation of Manganese

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 highest chromium value of 0.10 mg/l was recorded at station 2 and 4 in September, 2021 and lowest value of 0.04 mg/l was recorded at station 2 and 3 in August, 2021. Analysis of Variance (ANOVA) showed that there was no significant difference in the mean values of the study stations (p >0.05) (Table 4.1). The mean value and standard deviation for chromium in the dry season (0.06±0.01 mg/l) was lower than the wet season value of (0.07±0.02 mg/l) in Table 4.2. There was no significant difference (p > 0.05) between the wet and dry season values (Table 4.2).

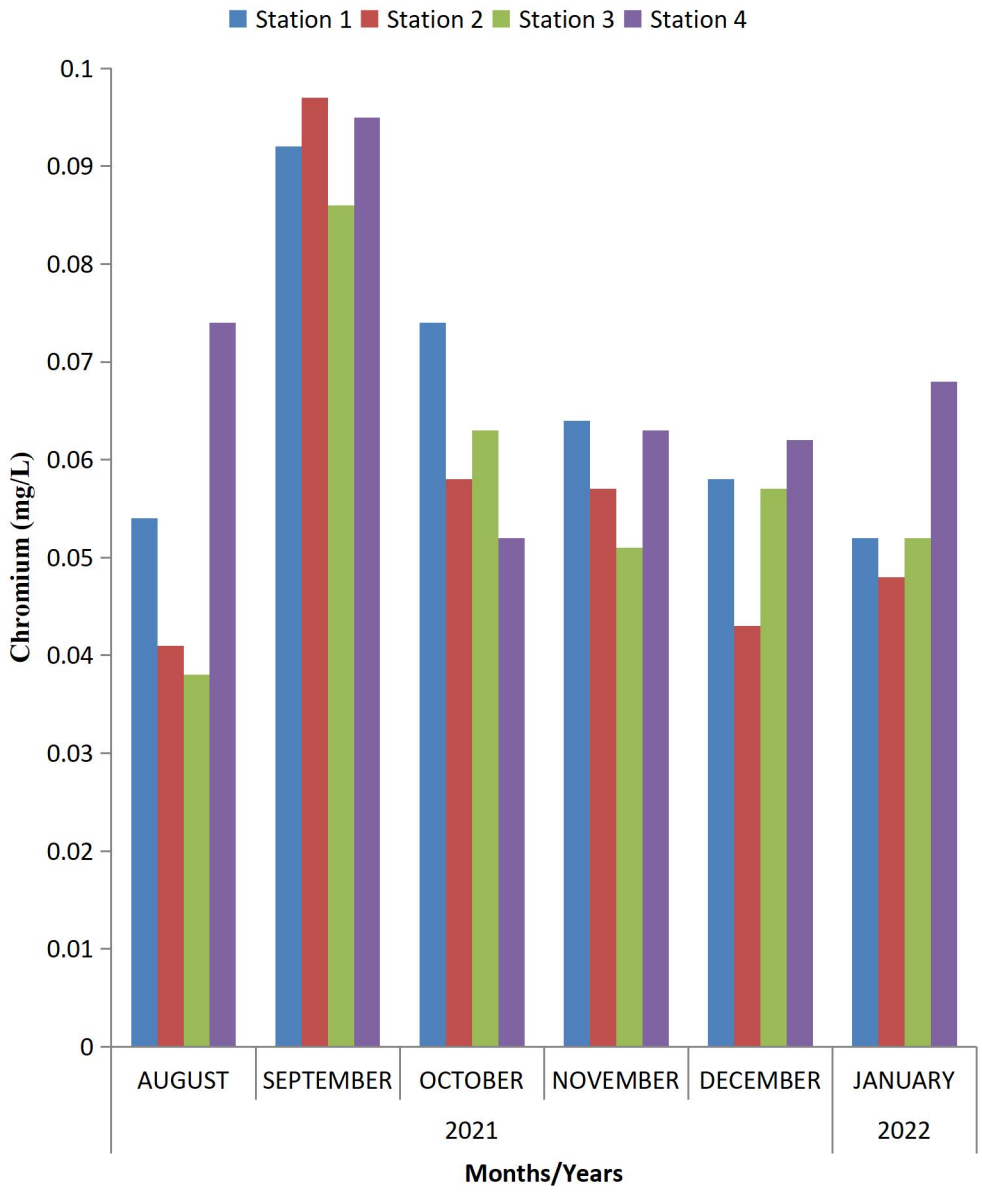

Fig. 4.22: Spatial and temporal variation of Chromium

4.2 WATER QUALITY INDEX (WQI)

The water quality computation of the study stations are shown in Table 4.3. The acceptable limits by the Federal ministry of Environment (FMEnv) of some of the parameters as shown in Appendices 4.1 – 4.4 were compared with the values of some of the physicochemical parameters obtained in 4 sampling stations.

The values recorded at the different study stations are 12.50, 10.25, 11.94 and 11.92 for stations 1, 2, 3 and 4 respectively (Table 4.3). The results of the water quality at stations 1 to 4 indicate that the sampled stations are safe for man's consumption, support aquatic life and 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 = Too poor (bad) water

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

4.3 CLADOCERANS OF OKHUAIHE RIVER

4.3.1 CHECKLIST

PHYLUM ARTHROPODA

Sub-phylum: Crustacea

Class: Branchiopoda

Order: Cladocera

Family: Daphniidae

Daphnia longispina	Muller, 1776	Plate 5
Ceriodaphnia rigaudi	Richard, 1894	Plate 6

Family: Chydoridae

Alona davidi davidi	Richard, 1895	Plate 7
Alona monacantha	Sars, 1901	Plate 8
Alona setulosa	Megard, 1967	Plate 10
Alonella globulosa	Daday, 1898	Plate 11
Chydorus sphaericus	Leach, 1816	Plate 9
Euryalona orientalis	Daday, 1898	Plate 12

Family: Bosminidae

Bosmina longirostris	Muller, 1785	Plate 13

Family: Macrothricidae

Macrothrix spinosa	King, 1853	Plate 14

Family: Sididae

Diaphanosoma brachyurum	Lievin, 1848	Plate 15
Diaphanosoma excisum	Sars, 1885	Plate 16
Diaphanosoma sarsi	Richard, 1894	Plate 17

Family: Moinidae

Moina micrura	Kurz, 1875	Plate 18

Plate 5: *Daphnia longispina*

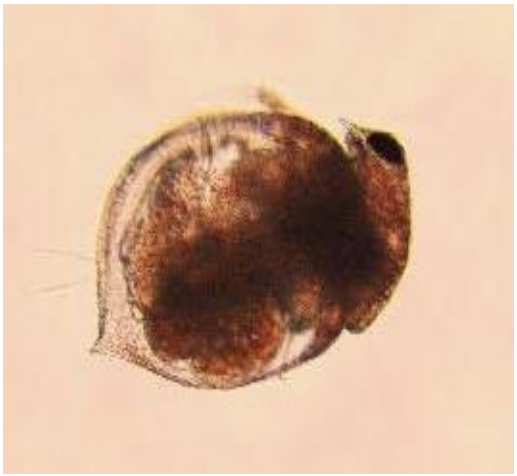

Plate 6: *Ceriodaphnia rigaudi*

Plate 7: *Alona davidi davidi*

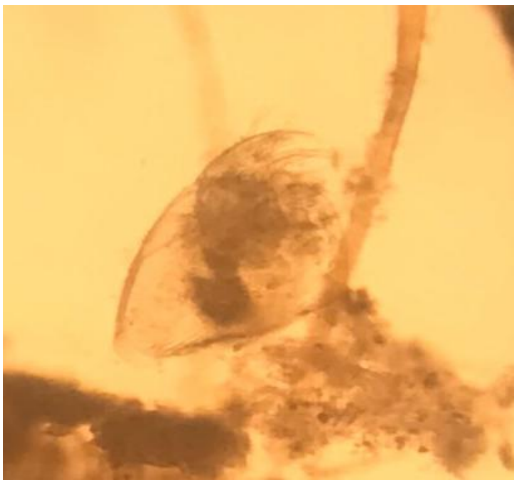

Plate 8: *Alona monacantha*

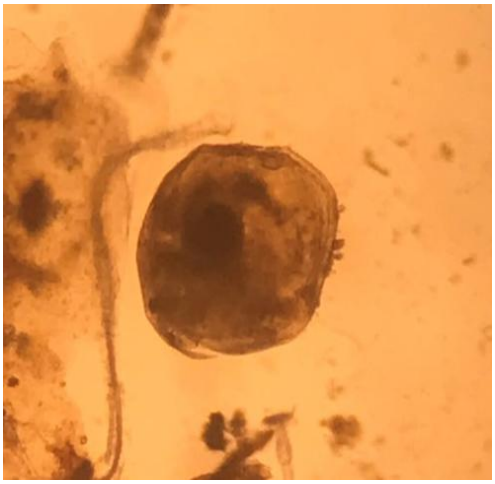

Plate 9: *Chydorus sphaericus*

Plate 10: *Alona setulosa*

Plate 11: *Alonella globulosa*

Plate 12: *Euryalona orientalis*

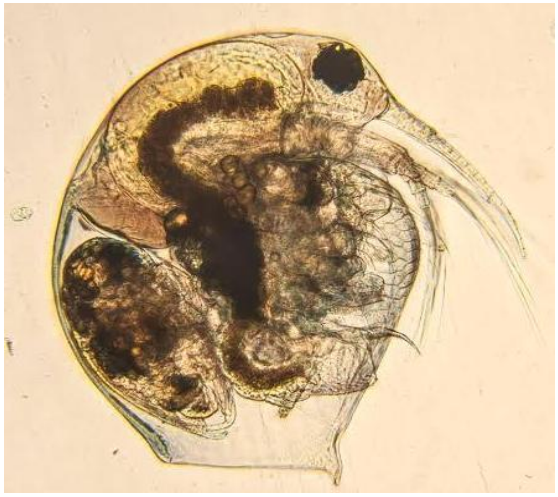

Plate 13: *Bosmina longirostris*

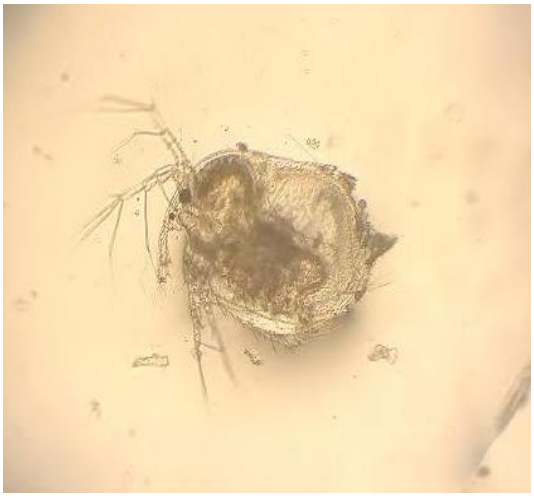

Plate 14: *Macrothrix spinosa*

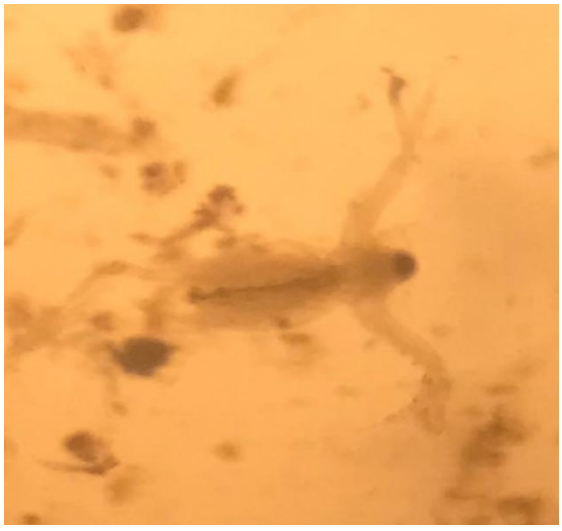

Plate 15: *Diaphanosoma brachyurum*

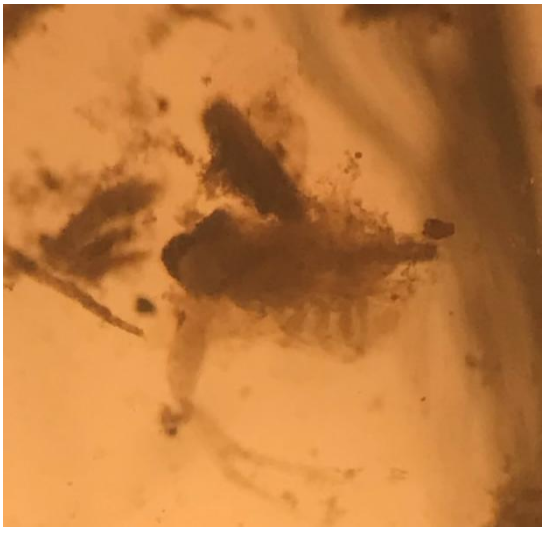

Plate 16: *Diaphanosoma excisum*

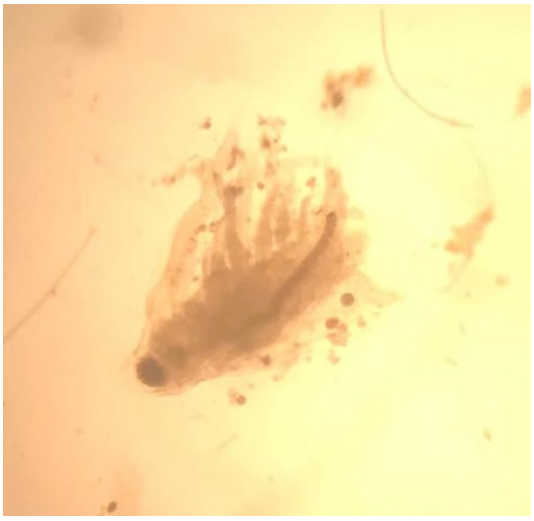

Plate 17: *Diaphanosoma sarsi*

Plate 18: *Moina micrura*

4.3.2 COMMUNITY STRUCTURE

The Cladocera samples collected from the study areas were analyzed to assess the taxa composition, distribution, abundance, diversity and dominance of the species. The data acquired are used to evaluate the spatial distribution of the Cladocera community of Okhuaihe River. Cladocera recorded in this study comprises members of the family Daphniidae, Chydoridae, Bosminidae, Macrothricidae, Sididae and Moinidae.

4.3.2.1 COMPOSITION, DISTRIBUTION, ABUNDANCE AND DOMINANCE OF CLADOCERA COMMUNITY

The overall taxa composition, abundance and distribution of the Cladocera community are presented in Table 4.4 – Table 4.5 and graphically represented in Fig. 4.23. Daphniidae accounted for 14.67% of the total number of individuals, Chydoridae 33.33%, Bosminidae 8.00%, Macrothricidae 1.33%, Sididae 26.67% and Moinidae 16.00%.

The spatial distribution of the different families of Cladocera when subjected to Chi-square goodness of fit test showed highly significant difference in the density ($p < 0.01$) for the family Chydoridae and no significant difference in the density ($p > 0.05$) for family Daphniidae, Bosminidae, Macrothricidae, Sididae and Moinidae (Table 4.6) (Fig. 4.24).

Temporally, the highest number of Cladocera species were recorded in October, 2021 (34 individuals), closely followed by September, 2021 (19 individuals) and November (14 individuals) and the least number of species were recorded in August, 2021 (2 individuals), closely followed by December, 2021 (3 individuals) and January 2022 (3 individuals) (Fig. 4.25).

Relatively, Fig. 4.26 indicates that the Cladocera species varied in relation to seasons. There was higher total abundance of Cladocera species in the rainy season and lower total abundance of Cladocera species in the dry season.

Table 4.4: Composition, Abundance and Distribution of Cladocera

Taxa	Station 1	Station 2	Station 3	Station 4
Family: Daphniidae				
Ceriodaphnia rigaudi	0	0	0	2
Daphnia longispina	0	0	3	6
Family: Chydoridae				
Alona davidi davidi	1	0	1	1
Alona monacantha	0	0	0	1
Alona setulosa	0	3	1	11
Alonella globulosa	0	0	0	1
Chydorus sphaericus	0	0	0	4
Euryalona orientalis	0	0	0	1
Family: Bosminidae				
Bosmina longirostris	0	1	0	5
Family: Macrothricidae				
Macrothrix spinosa	0	0	1	0
Family: Sididae				
Diaphanosoma brachyurum	0	0	0	16
Diaphanosoma excisum	0	0	0	3
Diaphanosoma sarsi	0	0	0	1
Family: Moinidae				
Moina micrura	2	0	0	10

Table 4.5: Relative Abundance of Cladocera across the Study Stations

Taxa	No. of Individuals	Relative Abundance (%)
Daphnia longispina	9	12
Ceriodaphnia rigaudi	2	2.666667
Alona davidi davidi	3	4
Alona monacantha	1	1.333333
Alona setulosa	15	20
Alonella globulosa	1	1.333333
Chydorus sphaericus	4	5.333333
Euryalona orientalis	1	1.333333
Bosmina longirostris	6	8
Macrothrix spinosa	1	1.333333
Diaphanosoma brachyurum	16	21.33333
Diaphanosoma excisum	3	4
Diaphanosoma sarsi	1	1.333333
Moina micrura	12	16
Total	**75**	**100**

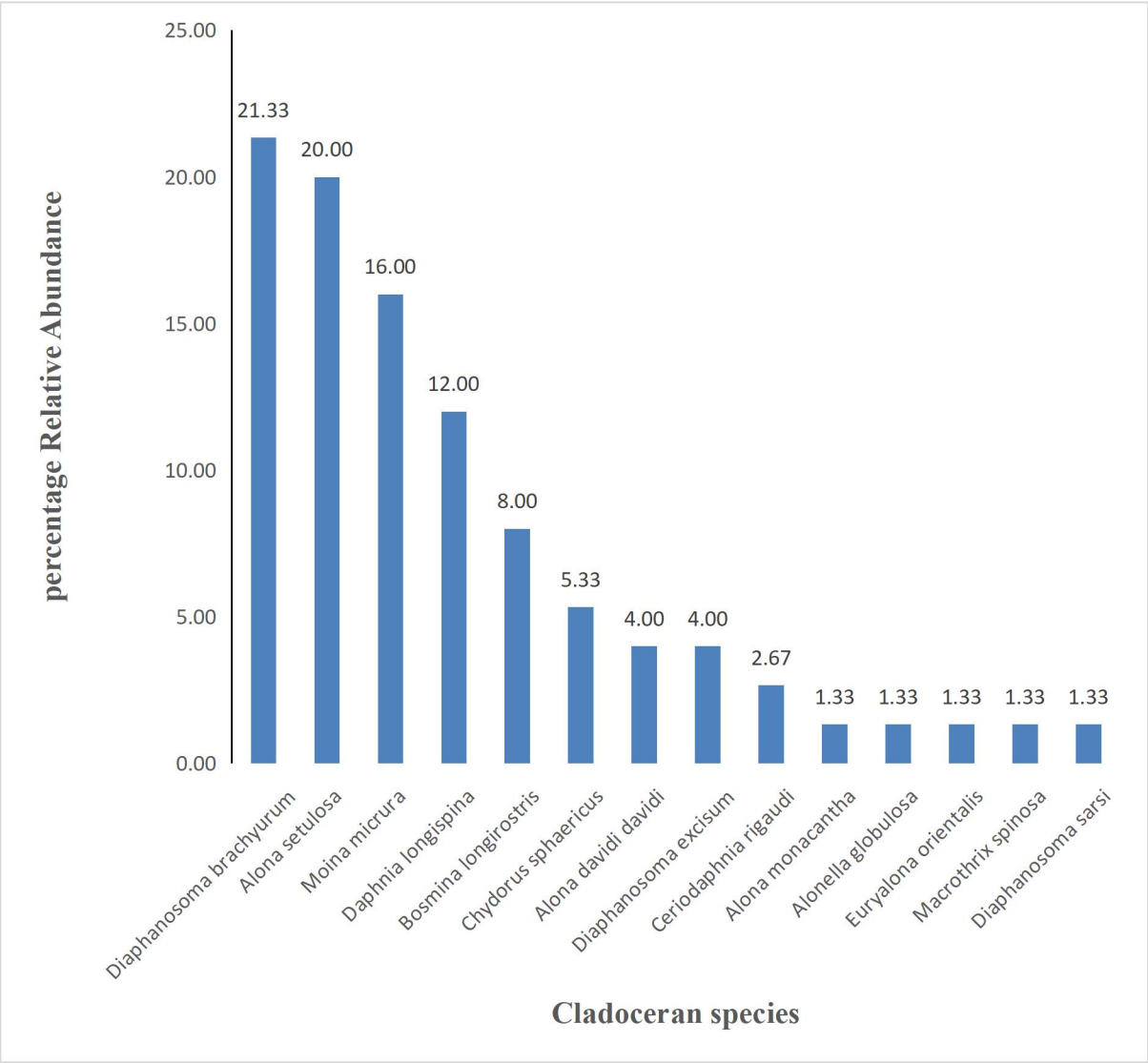

Fig. 4.23: Percentage Relative Abundance of Cladocera in Okhuaihe River.

Table 4.6: Spatial Distribution of Cladocera

Cladocera Composition Across the Stations					
Taxa	**Station 1**	**Station 2**	**Station 3**	**Station 4**	**P-Value**
Daphniidae	0	0	3	8	*p > 0.05*
Chydoridae	1	3	2	19	*p < 0.01*
Bosminidae	0	1	0	5	*p > 0.05*
Macrothricidae	0	0	1	0	*p > 0.05*
Sididae	0	0	0	20	*p > 0.05*
Moinidae	2	0	0	10	*p > 0.05*
Total	**3**	**4**	**6**	**62**	

Note: P < 0.01 = High Significant difference, P > 0.05 = No Significant difference.

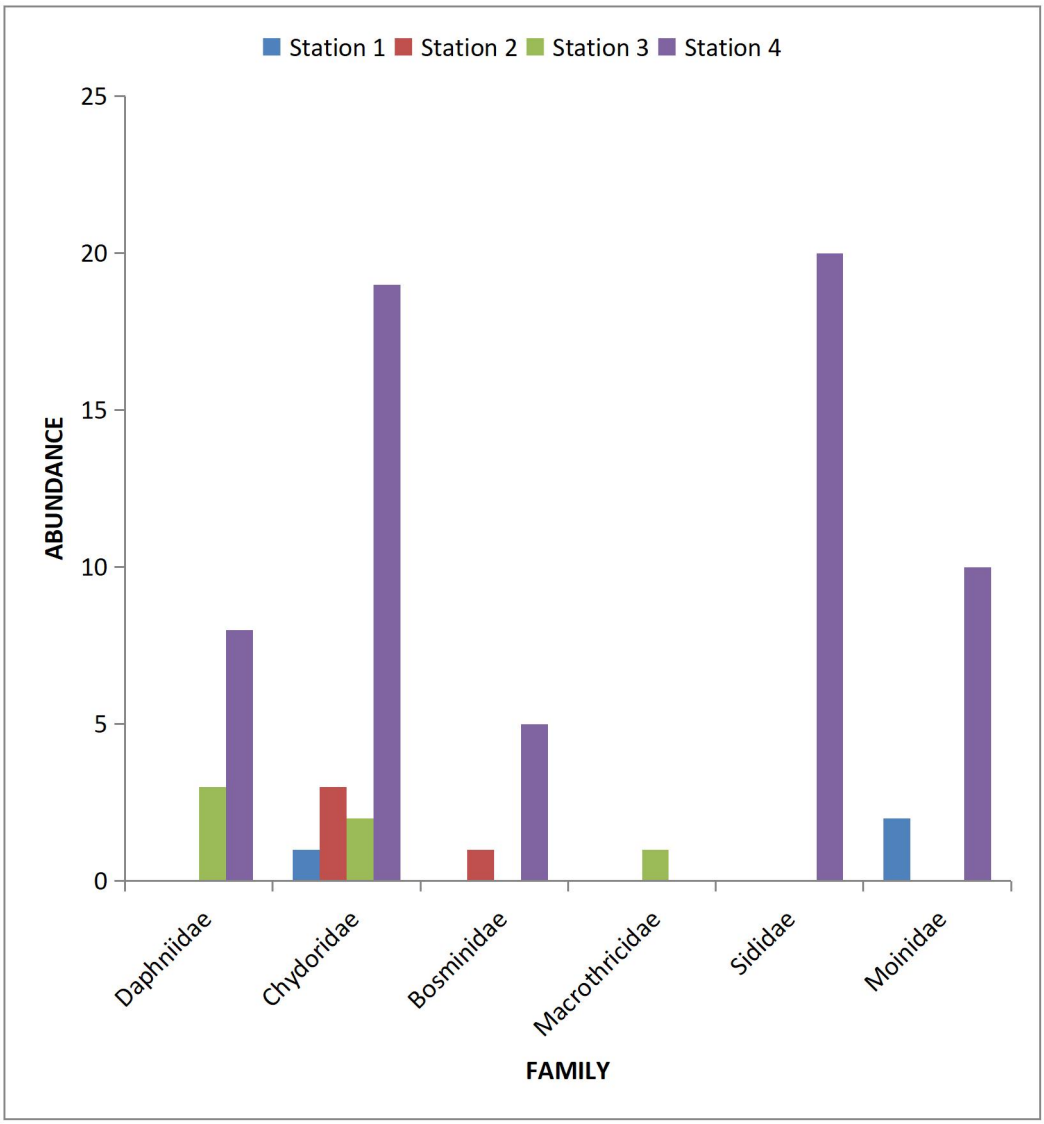

Fig. 4.24: Spatial Distribution of Cladocera across the Stations.

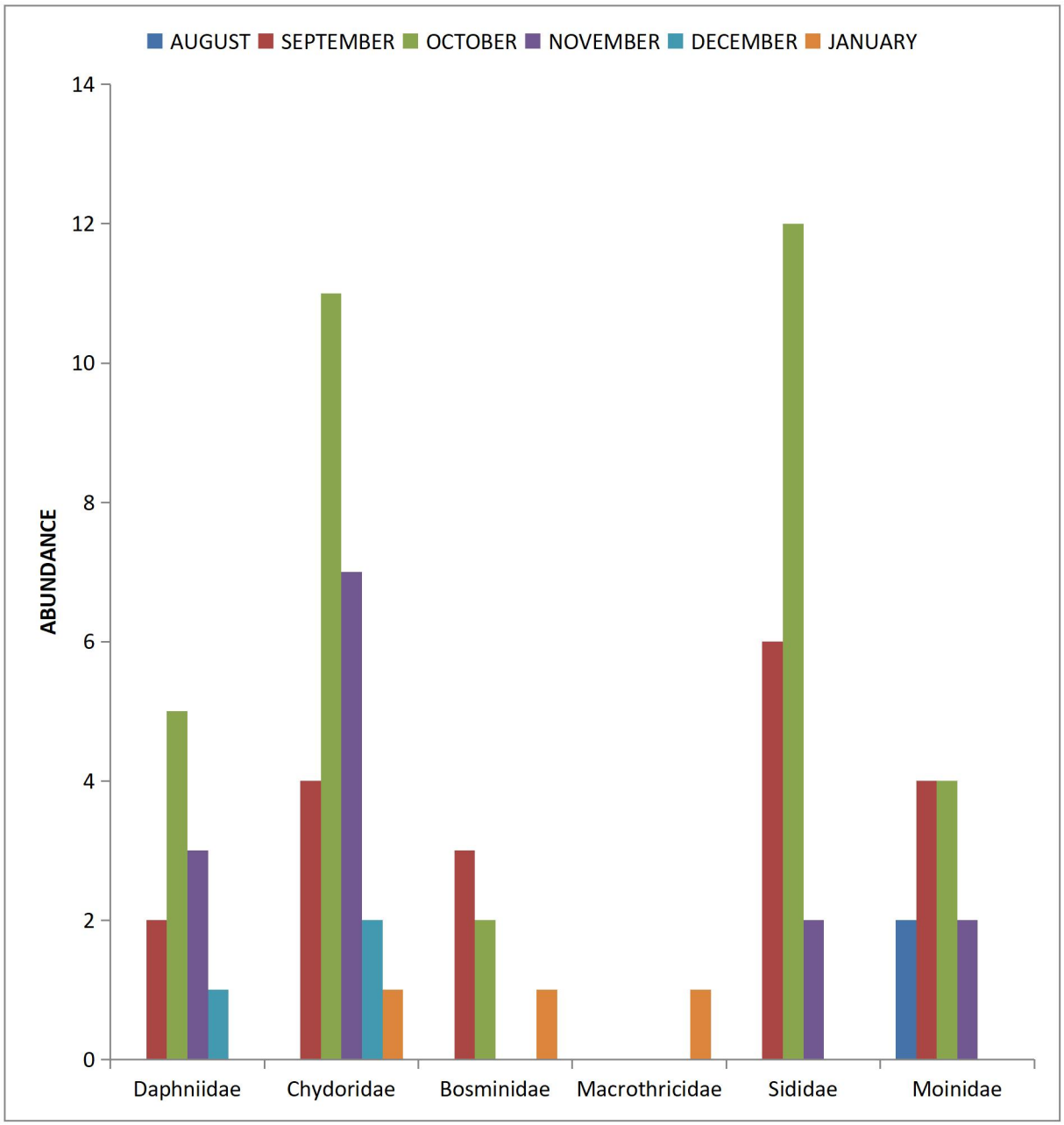

Fig. 4.25: Temporal distribution of Cladocera across the Sampling Months.

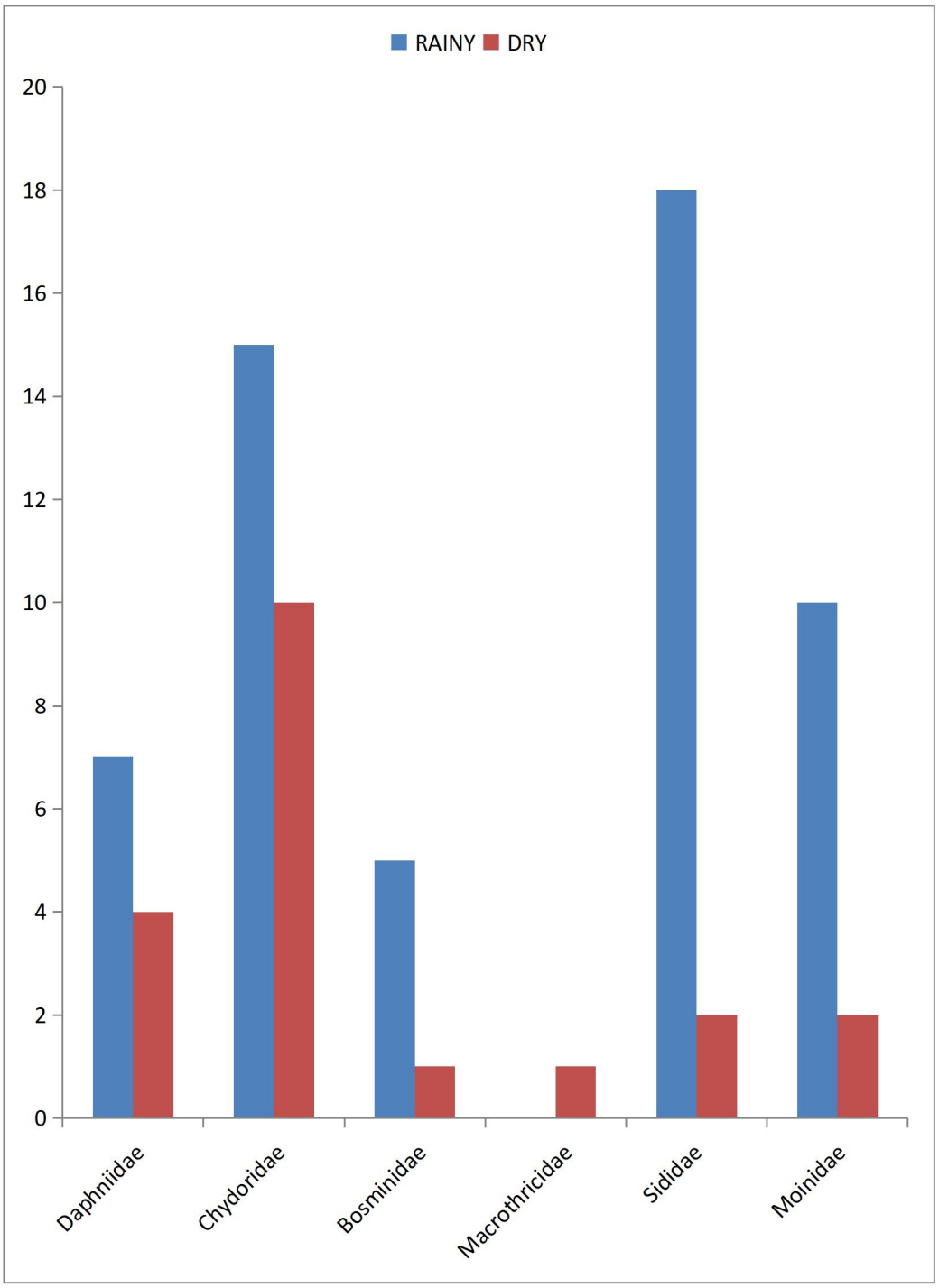

Fig.4.26: Total abundance of Cladocera (Seasonally)

4.3.3 DIVERSITY INDICES

Dominance, Shannon Wiener, Evenness and Margalef's index were used in assessing the occurrence of Cladocera (Table 4.11). The measure of species richness as indicated by Margalef's index showed the highest value with an index of 2.908 at station 4 and lowest value with an index of 0.721 at station 2. The general diversity computation (Shannon wiener index) showed that station 4 had the highest diversity among the study stations with an index of 2.147. This was followed by station 3 with the value of 1.242. While the least diverse of the study station was station 2 with an index of 0.562.

Evenness was highest in station 1 (0.945), this was closely followed by station 2 (0.877). Station 3 had an evenness of 0.866 which was closely followed by station 4 with the least value of 0.6582. Dominance was highest in station 2 (0.625), this was closely followed by station 1 (0.556). Station 3 had a value of 0.333 while the least value was recorded at station 4 (0.149).

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

DIVERSITY INDICES	STATION 1	STATION 2	STATION 3	STATION 4
Taxa_S	2	2	4	13
Individuals	3	4	6	62
Dominance_D	0.556	0.625	0.333	0.149
Shannon_H	0.637	0.562	1.242	2.147
Simpson_1-D	0.444	0.375	0.667	0.851
Evenness_eˆH/S	0.945	0.877	0.866	0.6582
Margalef	0.910	0.721	1.674	2.908
Equitability_J	0.918	0.811	0.896	0.837

4.4 CORRELATION ANALYSIS

Correlation analysis was carried out in testing the relationship between the Cladocera abundance and variations in the physiochemical parameters of the water; Table 4.12 shows the correlation matrix between the Cladocera abundance and the physicochemical parameters of the study area. Positive significant correlation was observed between the concentration of turbidity and the abundance of Daphniidae. Macrothricidae exhibited positive and significant correlations with sulphate and turbidity. The other relationships especially those between the physicochemical parameters are also shown in Table 4.12.

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

	Daphniidae	*Chydoridae*	*Bosminidae*	*Macrothricidae*	*Sididae*	*Moinidae*	*D.O*	*B.O.D*
Daphniidae	1							
Chydoridae	**0.951597**	1						
Bosminidae	**0.912897**	**0.992285**	1					
Macrothricidae	0.314948	0.052405	-0.05159	1				
Sididae	**0.934518**	**0.982021**	**0.980285**	-0.04348	1			
Moinidae	**0.912897**	**0.970654**	**0.959184**	-0.05159	**0.980285**	1		
D.O	-0.17854	-0.19494	-0.19855	-0.0097	-0.18429	-0.17265	1	
B.O.D	0.385446	0.400008	0.394525	0.085687	0.373597	0.366054	-0.13658	1
SULPHATE	0.322341	0.13572	0.059846	**0.833613**	0.026699	0.008214	0.366981	0.119036
NITRATE	-0.07434	-0.11541	-0.12459	0.043689	-0.09463	-0.09781	**0.806112**	-0.12555
AMMONI	0.026328	-0.04316	-0.06424	0.238055	-0.06156	-0.07651	**0.657599**	0.280423
PHOSP	0.020348	0.019103	0.015461	0.028124	0.010872	0.01674	0.22848	0.240162
CHLOR	0.250548	0.185496	0.144841	0.191805	0.191805	0.227608	-0.21395	0.323028
TURBI	**0.417394**	0.185654	0.091778	**0.965379**	0.077342	0.058764	-0.02362	0.233397
IRON	-0.00362	-0.1187	-0.15559	0.380049	-0.14633	-0.16048	-0.12617	0.089779
ZINC	-0.10804	-0.09376	-0.09361	0.199508	-0.18854	-0.18921	-0.20259	0.134528
COPPER	-0.14642	-0.04778	-0.02118	-0.20674	-0.07659	-0.05014	0.210193	0.022069
MANG	0.002755	0.02796	0.027527	0.126692	-0.04461	-0.036	-0.24104	0.145732
CHROM	0.072019	0.089705	0.095147	0.149061	0.019911	-0.00192	-0.01645	0.186274
W. TEMP	0.004274	0.04791	0.059797	-0.12238	0.050391	0.059797	-0.18148	0.275233
pH	0.186199	0.122962	0.092682	0.314383	0.078104	0.077106	-0.2144	-0.05397
EC	0.013637	0.097974	0.120433	-0.14345	0.068146	0.078673	-0.15106	0.37691
FLOW	-0.15965	-0.15591	-0.14211	-0.12125	-0.12258	-0.13835	0.090143	-0.18417
TDS	-0.01057	0.074992	0.09815	-0.14696	0.043983	0.055399	-0.11467	0.351826
TRANS.	0.272722	0.250083	0.230055	0.208781	0.208781	0.212359	-0.25784	0.08053

SULPHATE	*NITRATE*	*AMMONI*	*PHOSP*	*CHLOR*	*TURBI*	*IRON*	*ZINC*	*COPPER*
1								
0.277996	1							
0.403038	**0.791304**	1						
0.135854	0.0347	0.270044	1					
0.110646	-0.09634	-0.09147	-0.03931	1				
0.863364	0.01757	0.297101	0.12029	0.205074	1			
0.308957	-0.10651	0.121111	0.35446	-0.00519	**0.426026**	1		
0.169591	-0.33445	-0.05962	0.381301	-0.15854	0.267506	**0.681193**	1	
-0.07642	-0.00166	0.182762	0.138784	-0.30147	-0.13346	0.011622	0.207873	1
0.103367	-0.40149	-0.02828	**0.458899**	-0.11235	0.258296	**0.677644**	**0.826945**	0.31922
0.224232	-0.24417	0.148981	**0.558726**	-0.16035	0.297291	0.414639	**0.63209**	0.390921
-0.19991	-0.25163	-0.16888	0.390152	0.124142	-0.09185	0.088272	0.241863	-0.29011
0.234527	0.107331	0.093942	-0.32985	0.293491	0.303799	0.162238	-0.10307	-0.07966
-0.15485	-0.32474	-0.09525	**0.551766**	0.120105	-0.03248	0.213045	**0.62196**	0.225666
-0.07899	0.061067	-0.14738	-0.00995	0.140078	-0.20866	-0.23265	0.018433	-0.12859
-0.14207	-0.29496	-0.07643	**0.563079**	0.111193	-0.03691	0.222234	**0.634013**	0.239948
0.106841	-0.16115	-0.12827	-0.48316	0.191385	0.230641	-0.12832	-0.12351	-0.3227

MANG	*CHROM*	*W. TEMP*	*pH*	*EC*	*FLOW*	*TDS*	*TRANS.*
1							
0.727244	1						
0.186424	0.257047	1					
-0.07437	-0.05624	-0.02532	1				
0.61029	**0.648336**	**0.471123**	-0.36273	1			
-0.2676	-0.06743	-0.15052	-0.36928	0.20844	1		
0.614065	**0.652743**	**0.447547**	-0.38093	**0.998234**	0.228974	1	
-0.10527	-0.22629	-0.23457	0.19698	-0.32583	-0.27988	-0.33871	1

BOLD FACE = SHOW SIGNIFICANT CORRELATION

df = 2 r 0.05. Any value > 0.415 is significant

Critical level of correlation coefficient ($p<0.05$; df_{23}) 0.415.

CHAPTER FIVE

DISCUSSION

5.1 PHYSICAL AND CHEMICAL PARAMETERS OF WATER

Regular evaluation of the physico-chemical parameters of water has become an important tool in the protection of the ecosystem against menacing anthropogenic activities. The air temperature (24.00 – 31.00 °C) varied similarly with that of the water temperature (24.00 – 30.00 °C) in every sampling month across each station. The values of air temperature and water temperature were higher during the dry season than those recorded during the rainy season (Awachie, 1981; Ikhuoriah and Oronsaye, 2016), this is because there is abundant sunshine during the dry season and the warm winds (harmattan) that transit from the Sahara desert to the north results to low humidity.

The pH value range (5.30 – 6.30) recorded was slightly acidic when compared to the accepted range of 6.50 to 8.50 (FME, 2001; WHO, 2011) for tropical water bodies. This may be due to the anthropogenic activities such as local brewing (production of ogogoro) and lumbering activities that were observed during the sampling period. This is similar to the study carried out by Ogbeibu and Ogiesoba-Eguakun (2019) where the pH range recorded was 4.03 – 6.72 on Okhuaihe River.

The mean values of Electrical conductivity ranged from 92.52 – 109.00 µS/cm. Conductivity in water is determined by the presence and degree of sodium concentration, magnesium ions and calcium ions. These ions help stabilize the effect of carbonate and bicarbonate ions, hence maintaining the pH level (Raymont, 1983).

The mean flow velocity ranged from 0.01 - 1.51 m/s across the sampled stations. The least flow velocity recorded was in station 4 and the highest flow velocity recorded was in Station

2, this may be due to the vegetation encroaching into the river pathways and the level of suspended solids in station 4. Also, there was increase in flow velocity in the rainy season than dry season due to surface run-off leading to an increase in water level. Study carried out by Olomukoro and Egborge (2004) on Warri River and that of Ikhuoriah and Oronsaye (2016) on Ossiomo River, were in agreement with this finding.

The mean values of the total dissolved solids ranged between 45.67 - 54.25 mg/l. Values decreased from rainy season to dry season; this could be due to the fact that there are more run-offs during the rainy season and this is peculiar to most Nigeria's inland waters. This finding is similar to that recorded by Udofia *et al*., (2014) on Akpa Yafe River.

The width of the river varied across all sampled stations, with station 4 having the lowest width and station 1 with the highest width. During the rainy season, the mean value of the width of the river was high compared to that of the dry season. This could be as a result of the high temperature recorded during the dry season, leading to rapid evaporation of the water body.

The mean values of phosphate ranged from 0.08 - 0.23 mg/l; these low values were due to the usage by micro-organisms, removal by water movement and absorption by the water bed (sediment) (Anyanwu, 2012). An important source of phosphate in Okhuaihe River is likely to be from soaps and detergents used in washing of motorcycles, bathing and other laundry activities, which commonly take place in the river.

Chloride values range from 10.59 - 11.77 mg/l. High values of chloride were recorded in the rainy season months and lower values were recorded in the dry season, resulting to a significant difference ($p < 0.05$) observed across seasons. The values of chloride is quite low compared to the WHO limit which is 200 mg/l, this may be due to the fact that there are no industries discharging effluents high in chloride around the study area. This is similar to the

study carried out by Edori *et al*. (2021) who recorded 11.50 – 18.65 mg/l as the values of chloride.

The values of iron element ranged from 0.37 – 2.14 mg/l. The mean value of iron was higher during the rainy season than the dry season, this is because some rocks and soil contain mineral that are very rich in iron, so when it rains, the water on land seeps through iron-rich rocks and soil into the River, hence the presence of dissolved iron in the River. This is in agreement with the findings of Ikhuoriah and Oronsaye (2016) on Ossiomo River.

The values of zinc ranged from 0.24 – 0.84 mg/l across the sampled stations. Zinc is naturally present in water; the presence of algae is one of the factors that contribute to the level of zinc in the River. Ogbeibu and Ogiesoba-Eguakun (2019) study on Okhuaihe River had similar findings.

Manganese ranged from 0.03 – 0.07 mg/l across the sampled stations. Manganese is naturally present in surface water and ground water but anthropogenic activities such as applying the manganese as fertilizer could increase its level in surface water. The mean value of manganese in rainy season was slightly higher than that of dry season; this could be as a result of surface runoff into the water body. This is same with the report by Omoregie (2017) on Osse River.

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. 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 CLADOCERA COMMUNITY OF OKHUAIHE RIVER

Cladocerans are believed to be good indicators of their ambient environment; this is because of their ability to respond rapidly to changes in their habitat (Omoigberale and Oronsaye, 2011, Zawisza *et al*., 2016). The spatial distribution of Cladocera is based on the water chemistry and the temporal condition of the environment (Choedchim *et al*., 2017).

A total of 75 individuals of Cladocera (Daphniidae, Chydoridae, Bosminidae, Macrothricidae, Sididae and Moinidae) were encountered in this study. These were made up of 2 species of Daphniidae, 6 species of Chydoridae, 1 species of Bosminidae, 1 species of Macrothricidae, 3 species of Sididae and 1 species of Moinidae. This study is similar to the work carried out on a different region of Okhuaihe River by Omoigberale and Oronsaye (2011) which recorded 4 species of Chydoridae, 1 species of Bosminidae, 1 species of Sididae and 1 species of Moinidae. Similar reports were also found in studies done on River Ossiomo by Ikhuoriah e*t al*. (2015) which encountered 2 species of Daphniidae, 4 species of Chydoridae, 1 species of Bosminidae, 1 species of Macrothricidae, 1 species of Sididae and 1 species of Moinidae. Also, studies on tropical coastal estuary by Abdul *et al*. (2016) revealed 3 species of Daphniidae, 1 species of Chydoridae, 1 species of Bosminidae, 1 species of Macrothricidae and 1 species of Moinidae.

The family Chydoridae was the most abundant of the encountered Cladocera, accounting for 33.33% of the total number of individuals, followed by Sididae 26.67%, Moinidae 16.00%, Daphniidae 14.67%, Bosminidae 8.00% and Macrothricidae 1.33%, this is similar to the study carried out by Imoobe *et al*. (2008) with Chydoridae accounting for 10% followed by Macrothricidae 6.1%, Bosminidae 5.2%, Moinidae 3.3% and Sididae 2.5%. In contrast, is the

study by Adeniyi *et al*. (2020) which recorded Chydoridae with the lowest relative abundance of 0.13%, the highest being Bosminidae 6.33%, followed by Sididae 3.85%, Moinidae 2.63% and Daphniidae 0.54%.

The overall distribution, diversity, composition, abundance and dominance of the Cladocera species varied spatially in the study stations. Station 4 recorded the highest abundance of Cladocera species, while the lowest value was recorded at station 1. The low abundance of the Cladocera species in station 1 may be due to the common anthropogenic activities (Ikhuoriah *et al*., 2015) done in the station, such as, swimming, laundry, timber and lumber production, fishing, palm wine and local gin (ogogoro) production and spiritual activities.

The density of Cladocera recorded from August, 2021 to January, 2022 coincides with the wet and dry seasons. During the wet season, nutrients become significantly higher due to increased surface runoff (Kitheka, *et al*., 1999), these nutrients in the water body initiates food production, i.e. phytoplankton, therefore enabling the water body to support the high abundance of Cladocera species present (Manickam *et al*., 2017; 2018). This explain the peaks of Cladocera species in the rainy months of September and October. This was in agreement with the studies carried out on Ogbei stream by Ibemenuga (2020) and Kenyir Reservoir, Malaysia by Yusoff *et al*. (2002) which observed increase in zooplankton abundance during the rainy season. This is in contrast with works carried out by Omoboye *et al*. (2022) and Anyanwu *et al*. (2022) where there was increase in zooplankton abundance recorded during the dry season. There was however, low Cladocera abundance in August, 2021, despite being part of the rainy months, this was due to the short dry period known as "August break" which is generally observed 2 to 3 weeks in late July and early August in most part of southern Nigeria (Chineke *et al.*, 2010; Asadu, 2002; Adejuwon and Odekunle, 2006).

The calculated diversity indices using Shannon's index revealed that station 4 (2.147) had high diversity followed by station 3 (1.242Margalef'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 4 (2.908) was higher in species richness followed by station 3 (1.674). Simpson's index which considers both richness and diversity showed that station 4 (0.851) had the greatest diversity followed by station 3 (0.667) and the study station with the least diversity was station 2 (0.375). The high values of Shannon's index, Margalef's index and Simpsons' index recorded during the course of this study indicate high diversity and the nutrient-rich status of station, this may be because station 4 has the lowest flow velocity and less anthropogenic activities compared to the other stations of Okhuaihe River. This is in agreement with the study by Imoobe (2011) that suggested that Okhuo River wasn't under pollution threat due to the high diversity of organisms present in it.

RECOMMENDATION

Okhuaihe River was of good water quality during the course of this study, so I recommend that continuous monitoring should be carried out periodically on the River so that a deviation in the quality of the water could be detected timely as increased anthropogenic activities in the river would deteriorate the water quality which would in turn affect the species abundance, richness and diversity in years to come.

CONCLUSION

All the physico-chemical properties observed in this study with the exceptions of Electrical Conductivity, Ammonium, Chloride, Turbidity, Iron, Copper, Manganese and Chromium were in agreement with Federal Ministry of Environment and WHO permissible limits for surface water. However, water quality index reveals that the deviation of the aforementioned parameters from the permissible limits did not affect the quality of the water. The diversity of

Cladocera community in Okhuaihe River was quite low. However, it didn't reflect the prevailing physico-chemical conditions and the Cladocerans encountered are characteristics of a typical freshwater habitat.