PHYSICOCHEMICAL PARAMETERS AND MACROINVERTEBRATE FUNCTIONAL FEEDING GROUPS IN RIVER CHANCHAGA, MINNA, NIGER STATE

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background to the Study

Water is necessary for human survival. This well-recognized fact is the basis for the emerging view of basic human water needs as a human right to water (Glieck, 1998; Cunha, 2009). Rivers are among the most-threatened ecological systems of the globe (Arimoro and Keke, 2016; Edegbene *et al.,* 2020). Freshwater bodies in the tropics are recognised as important resources for global biodiversity preservation and protection (Arimoro *et al.,* 2015; Tonkin *et al.,* 2016). The inadequate water quality monitoring to address the complex and emerging environmental and sustainability issues currently is impacting the society (Wet and Odume 2019). Hence, there is the need to recognize the conservation of macroinvertebrates biodiversity as an effective tool in planning and supporting management processes towards sustainability of water resources.

In generally, the quality of water may be monitored by observing the composition of freshwater macroinvertebrates of a given “test” community with that of an actual or hypothetical community in a waterway known to be relatively unpolluted. Furthermore, macroinvertebrates can be used to determine aquatic life stressors, set pollutant load reductions, and indicate possible remediation successes (Nieto *et al.*, 2017; Zabbey and Arimoro 2017).

The functionality of streams can be affected in different ways through the loss of biodiversity. The efficiency of stream communities to capturing essential resources, producing biomass, decomposing, and recycling essential nutrients is affected by biodiversity loss (Nieto *et al.,* 2017). The preservation and protection of good water quality, both sanitary and environmental, is paramount, since it depends largely on the conservation of biodiversity (Fernandez-Díaz *et al.,* 2008; Ishaku *et al.,* 2011; Arimoro and Keke, 2016).

River Chanchaga is a lotic freshwater body situated in Chanchaga Local Government Area of Niger State. It serves many important purposes and has many tributaries. The river cut across many riparian communities and serves as sources of consumable water and for other domestic activities as well as agricultural purposes. The water is faced with serious anthropogenic activities which in turn affect the usability of the water body. Anthropogenic activities resulting in accelerated pollution and eutrophication of rivers and streams are an increasing concern worldwide (Mason, 2003; Azrina *et al*., 2006; Arimoro and Ikomi, 2008; Beyene *et al*., 2009).

The interactions of both the physical and chemical properties of water play a significant role in composition, distribution, abundance, movements and diversity of aquatic organisms (Mustapha and Omotosho, 2005; Sangpal *et al.,* 2011; Murungan and Prabaharn, 2012; Deepak and Singh, 2014). Physicochemical factors such as temperature, dissolved oxygen, pH, turbidity, water transparency and current among others, and their regular or irregular fluctuations, have been identified as determinants in riverine ecology (Boyd, 1998; Whitfield 1998; Ali, 1999; Albaret, 1999; Blaber, 2000; Thirumala *et al.*, 2011; Mushahida-Al-Noor and Kamruzzaman, 2013).

The chemistry of the water of an aquatic environment can be determined by disturbance from the local surroundings, land use patterns and other human activities in their various reaches of the water body (Sundermann *et al., 2013).* In view of this, to sustain and protect the aquatic resources, it is important to know the factor having negative impact on the resources and proffer management measures Arimoro *et al.*, (2015).

Macroinvertebrates are a diverse array of animals without backbones operationally defined as those that are retained by a sieve or mesh with pore size of 0.2 to 0.5 mm, as used most frequently in stream sampling devices. Stream macroinvertebrates include various groups of worms (flatworms, eelworms and segmented round-worms), molluscs (snails and bivalves), crustaceans (shrimps, crayfish and other shrimp-like groups), mites, and above all insects. A study on the biodiversity distribution patterns of macroinvertebrate traits in relation to seasonality is pertinent to gain insight into how seasonal environmental changes may confer adaptation traits to macroinvertebrates. This is particularly important given that tropical streams are extremely dynamic in nature, with strong seasonality assuming a vital component in community structuring (Tonkin *et al.*, 2016**).**

Aquatic macroinvertebrates are often utilized in studying the biological responses of the system because they clearly reflect changes in food resource availability in relation to stream size (Vannote *et al.*, 1980). Most invertebrates are important components of stream ecosystems. They graze periphyton (and may prevent blooms in some areas), assist in the breakdown of organic matter and cycling of nutrients and, in turn, may become food for predators (Hynes, 1970; Jimoh *et al*., 2011; Uwem *et al*., 2011). In a recent study in the neotropics, scientists have demonstrated that the detrimental effects of environmental change on macroinvertebrate biodiversity can be drastically reduced by protecting riparian vegetation around streams (Dala-Corte *et al.*, 2020).

Aquatic macroinvertebrates are often used as bio-indicators because they are affected by changes in environmental factors arising from natural human activity on aquatic ecosystem and thus provide information on habitat and water quality changes (Woodcock and Huryn, 2007; Arimoro and Ikomi, 2008). Functional feeding group classification is useful in examining ecological relevant community-level associations with the physical habitat (Rempel *et al.,* 2000). A number of functional feeding macroinvertebrate groups (a non-taxonomic unit) have been identified as being involved in the processing of organic matter in streams (Rawer-Jost *et al.,* 2000). These functional feeding groups are shredders, collector-filterers, collector-gatherers, scrapers/grazers, and predators (Rempel *et al.,* 2000, Dobson *et al.,* 2002; Miserendino and Pizzolon 2000, 2003).

According to Allan and Castillo (2007) distribution of functional feeding groups are determined by mechanisms of food acquisition and changes in food availability which indeed is influenced by stream size, shading and substrate. Considering the importance of the functional feeding group approach in biomonitoring and conservation, the assessment of the functional organization of macroinvertebrate community turns out to be essential.

1.2 Statement of the Research Problem

Disturbances caused through the activities of man such as building, agriculture, mining, and other domestic activities around this river could bring about pollution thereby reducing the composition, abundance and biodiversity of the macroinvertebrate species.

1.3 Justification of the Study

I. Monitoring the water quality of the river will provide information about how to sustain and advance on the aquatic ecosystem. This will reveal whether or not macroinvertebrates and other animals are striving well in the water body.

II. The study will add to the data build up in macroinvertebrates community studies in Nigeria, Niger State and River Chanchaga in particular.

III. The study will provide information on the physicochemical characteristics and macroinvertebrates species composition, abundance and diversity.

IV. The study will also provide information on the favorable environmental variables for the macroinvertebrates.

1.4 Aim and Objectives of the Study

The aim of this study was to investigate the spatial and temporal distribution and functional feeding structure of aquatic macro-invertebrates along the River Chanchaga.

The specific objectives of the study were to determine;

i. The spatial and temporal variation in the physicochemical parameters of the river.

ii. The macroinvertebrates composition, abundance and diversity in River Chanchaga.

iii. The functional feeding groups (FFG) in the river.

CHAPTER TWO

2.0 LITERATURE REVIEW

Ecological studies on macroinvertebrates of tropical freshwaters is gradually building up in recent time (Edegbene and Arimoro, 2012). In Africa, studies have been conducted in different parts and have shown knowledge of the habitat quality problems. Abebe *et al.*, (2009) studied the pollution status of Kebena and Akiki Rivers in Addis Ababa, Ethiopia. The results revealed that all the sixteen (16) sites sampled were impaired having qualitative habitat evaluation index (QHEI) of 30.6%, 43.3%, 48.7%, 42.7%, 48.7%, 42.2%, 48%, 59.3%, 44.3%, 55.3%, 52.7%, 44.4%, 62.7%, 54.7%, 54% and 59% respectively. This habitat impairment eliminated most of the pollution sensitive organisms in the stations sampled. They also asserted that urgent mitigation measures should be put in place to curb the deteriorating effect of pollution in the rivers.

Arimoro (2009) conducted a study in Adofi River, Niger Delta area of Nigeria and showed that there was slight impairment of the habitat quality in station 2 and 3 of the study area, with mean qualitative habitat evaluation index (QHEI) score of 58 and 71percent respectively while station 1 with mean value of 84 percent was not impaired. However, it was reported in this study that degradation of the biological community at station 2 was not a true reflection of the habitat quality which was only slightly impaired. The toxicant and organic pollution loadings may have probably affected the biota of Adofi River more than the slight degradation in habitat quality observed. The presence of relatively high levels of heavy metals (Ni, Cu, Pb and Zn) at station 2 lends credence to the fact that sediments as well as the water chemistry were severally altered by the effluent.

2.1 Variation in Physicochemical Parameters of Rivers and Streams

Effluents from five major textile industries in Kaduna (Nigeria) were considered for a proposed central effluent treatment plant by Yusuf and Sonibare (2004). It was discovered that seven of the measured parameters exceeded the limit set by the Federal Ministry of Environment. Colour intensity exceeded it in all the samples (Mills 1 – 5) by about 350 folds on the average while COD, TSS, NH_3, BOD_5, and S_2- were by 24, 13, 8, 7 and 3 folds respectively. Total dissolve solids was detected in all samples with limit exceeding only in Mill 2. Nitrate, oil and grease were detected in Mills 1 and 2 and within the limit. Aluminium (Al), Magnisium (Mn), and Zinc (Zn) were detected in 80 % and within the limit while Iron (Fe) was detected in 60 %. Copper (Cu) was detected in 80 % with limit exceeded about 3 folds on the average. Their study was focused on the pollution implications of these effluents from textile operations in the city. Asonye *et al.* (2007) carried out a study on some physico-chemical characteristics and heavy metal profiles of Nigerian rivers, streams and waterways. Water samples of 72 rivers, streams and waterways in Southern Nigeria were carefully collected by them and the following physico-chemical analyses were subjected on the samples: Temperature, colour, taste, turbidity, pH, total dissolved solids (TDS), conductivity and heavy metal profiles (Pb, Cr, Cd, Fe, Zn, Mn, Cu) were assessed among the entire samples collected. The turbidity (NTU) of 93 % of all the samples was higher than World Health Organization (WHO) and European Economic Community (EEC) standards. Fifty seven percent (57 %) of the entire samples had conductivities above normal limits. The pH of 81% of the entire samples also were above WHO and EEC guide limits. Profiles of the heavy metals showed Pb, Cd, Cr, Zn and Mn levels in some of the samples being above the guidelines of WHO and EEC. Iron had 55% of all the samples exceeding recommended standard of 0.20 ppm; Cr had 15% exceeding the recommended 0.05 ppm, Cd had 11 % exceeding 0.003 ppm while 7 % of both Zn and Pb exceeded 3 ppm and 0.10ppm respectively. Their results indicate that heavy metal pollution and toxicity might pose serious risks to the health of communities residing around and using these surface waters for domestic, commercial and socio-cultural purposes.

Physico-chemical characteristics of some rivers and hand-dug well waters used for drinking and domestic purposes in the oil rich Niger Delta area of Nigeria were assessed using standard methods (Akpofure *et al.,* 2007). The concentrations of the parameters in the water samples ranged in the following order: pH (5.6–6.9), temperature (26.90–28.60 °C), turbidity (23–63 NTU), electrical conductivity (52–184 µs/cm), DO (5.4– 7.2 mg/L), BOD (21– 57 mg/L), TDS (6.0–217 mg/L), PO_4 (0.19–1.72 mg/L), SO_4 (25–36.8 mg/L), NO_3 (20.3–28 mg/L), Fe (6.07– 15.71 mg/L), Zn(0.04–0.24 mg/L), Pb(0.01–0.17 mg/L), Ni (0.01–0.13 mg/L), Vn (0.01–0.20 mg/L) and Hg (0.001–0.002 mg/L). The concentrations of these parameters in the hand-dug well water ranged in the following order: pH (5.7–6.8) temperature (26–30 °C), turbidity(134–171 NTU),electrical conductivity(160– 340 µs/cm), DO (5.4–6.4 mg/L), BOD (13–34 mg/L), TDS (110–190 mg/L), PO_4 (0.84–1.84 mg/l), SO_4 (10.6– 28.1 mg/L), NO3− (11.3– 23 mg/L), Fe (13.17–16.31 mg/L), Ni (0.01–0.02 mg/L), Vn (0.01–0.04 mg/L) and Hg (0.001–0.004 mg/L). The concentrations of BOD, turbidity, NO^{3-} and Fe in the water samples were above World health organization (WHO) and Federal ministry of environment (FMEV), Nigeria permissible limits for safe drinking water. Their results suggested that the use of such waters for drinking and domestic purposes pose a serious threat to the health of the users and calls for the intervention of government agencies.

2.2 Abundance, Composition, Diversity and Distribution of Macroinvertebrates in Water Bodies

A large number of studies have been conducted on the structure, composition, abundance, diversity and distribution of macroinvertebrates in diversed water bodies. Olomukoro and Ezemonye (2007) investigated the macroinvertebrate fauna in water bodies of southern Nigeria spanning the rainforest and derived savanna ecozones. Fifty five (55) taxa, belonging to 13 major groups were recorded by the authors. They found that the abundance of major taxonomic groups varied considerably among the surveyed aquatic ecosystems. Chironomidae (Diptera) were well represented and dominant in 11 of the 20 water bodies surveyed. It was recorded that the most rare and restricted species were gastropods (Mollusca), one of such species, *Mutela cf. dibia*, being endemic to the catchment. The overall abundance was maximal (97) at Okomu River in the lowland forest and minimal (5) at Avielle River in derived savanna, respectively. The human impact on macro-invertebrate biodiversity was documented, including changes in benthic fauna distribution patterns.

Arimoro and Keke (2016) in their study of the intensity of human-induced impacts on the distribution and diversity of macroinvertebrates and water quality of Gbako River, North Central, Nigeria. Collected a total of 676 macroinvertebrates individuals from 41 invertebrate taxa in 27 families from 9 orders were documented during the study period, the aquatic insects represented 85.4 % of the taxa and 76.6 % of all individuals reported. The rest of the fauna was composed of Mollusca, Crustacea, and Gastropoda. The abundance of benthic invertebrates was not significantly different ($p > 0.05$) among the sampling stations. Stations 2 and 3 with higher human disturbance recorded lower richness compared with the less disturbed stations (1 and 4). However, the abundance of Ephemeroptera, Coleoptera and Anisoptera in all the sites studied indicated that the sites were relatively free from gross pollution, especially at the upper reaches. Overall, relatively less human impacts in some of the study stations and the heterogeneous nature of the stations served as suitable habitat for a more diverse benthic fauna. This could be responsible for the high abundance and diversity of benthic invertebrates that were recorded in this study. This study proves that macroinvertebrate communities responded to changes in disturbance as well as water quality along the river stations.

A study conducted by Adakole *et. al.*, (2008) recorded 87 benthic macroinvertebrate taxa comprising of 12,078 individuals during a two-year study of Bindare stream in Zaria, Northern Nigeria. The catchment areas of the stream in the upper reaches were mainly farmlands with few isolated human settlements suggesting a less polluted water environment. This allowed the survival of sensitive species such as Ephemeroptera, Hemiptera, Odonata and Neuroptera at upstream.

2.3 Macroinvertebrate Functional Feeding Groups and River Continum Concept (RCC)

Examination of the mouth parts and accessory structures in the front legs is a first step in assigning a FFG. These are the parts used by the organism to capture, manipulate, and consume food resources. Sharp and pointed teeth are characteristics of predators and shredders. Modified mouth parts that look like plates or flat structures are an indication of a scraper. Collectors and filterers often have a large number of hairs and setae or fan-like structures to collect particles. Mouth parts often have to be observed in live insects to understand the proper location of each structure and their position relative to feeding substrates (Polegatto and Froehlich, 2001).

To examine the functional structure of aquatic macroinvertebrates in River Orogodo, Southern Nigeria, benthic macroinvertebrate samples were collected from four ecological distinct stations monthly for two years between July 2003 and June 2005 by Arimoro (2007). Taxa recorded were allocated to functional feeding groups using published literature and examination of gut contents. Clearly, the spatial distribution of most species reflected morphological and trophic suitability to particular environmental conditions. Predators (Hemiptera and Coleoptera) dominated the functional groups at stations I, II and IV. Collector-gatherers, particularly Chironomid larvae dominated the abundance at station III. Scrapers (*Melanoides*, elmids) and Collector-filterers (*Polypedilum*) were only sporadically present mostly in the downstream reach (station IV). The paucity of shredders at all stations examined could be explained by the enhanced microbial activity replacing shredder activity at high temperatures common in most tropical streams. The functional organization did not however conform to the River Continuum Concept (RCC) model. This could be related to the degredation of station III with organic wastes from the Agbor abbattoir.

In a study by Tomanova *et al*. (2007) on the longitudinal and altitudinal changes of macroinvertebrate functional feeding groups in neotropical streams in Bolivia along a broad altitudinal gradient (from 1120 to 4300 m.a.s.l) was conducted aiming to understand how altitude can affect the longitudinal feeding groups (FFG) and richness predicted by the River Continuum Concept (RCC). The RCC predictions for functional structure were not completely matched when analyzing FFGs in relation to an index of longitudinal stream gradient. However, after removing the effect of altitude by using residuals from regression between FFGs and altitude, FFGs patterns matched RCC predictions more closely. They detected significant relationships between altitude and the relative abundance of collector-gatherers, shredders and scrapers which may be related to changes in temperature, ultraviolet (UV) radiation and canopy cover along the altitudinal gradient. Their results indicate that altitude combined with position along the longitudinal gradient is an important factor governing the FFG structure of macroinvertebrate communities in neotropical streams.

River Continuum Concept (RCC) predicts that as the form of particulate organic matter available in streams and rivers varies longitudinally, so will the functional feeding groups (FFGs) of benthic macroinvertebrates. The RCC was developed based on data from continental streams; therefore, its applicability to the unique ecology of inland streams is virtually untested. Hynes. (1970) conducted a research to discover if the RCC works in the small streams of Moorea, French Polynesia. Three sites along an elevational gradient were sampled for benthic macroinvertebrates in five streams of similar catchment size. Each sample was sorted and all taxa were assigned to a FFG. Species richness and FFG variation along a longitudinal gradient were compared to RCC predictions. Patterns in the longitudinal variation of crustacean/mollusc species richness and shredder, grazer, and predator percent composition were found to match RCC predictions. However, total species richness, insect species richness, and the percent composition of collecting organisms did not. Therefore, it was asserted that an alternative theoretical framework is needed to accurately describe FFG variation in tropical stream.

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Description of Study Area:

River Chanchaga is located in Chanchaga local Government Area of Niger State, it originates from Zhabyala of Tungan Mutum Daya, the river navigates through many villages, the main occupation of the dwellers along the river include farming, fishing and other anthropogenic activities. The study area has a tropical climate with mean annual temperature of 30.2^{o}C, relative humidity of 61% and annual rainfall ranging between 1200 mm and 1300 mm. The vegetative cover reflects that of guinea savanna zone, characterized by sparsely distributed trees species, shrubs and dominated by grassland. The area shows two distinct seasons rainy and dry seasons. The rainy season is between April and October with a peak rainfall occurring in September and dry season between November and March.

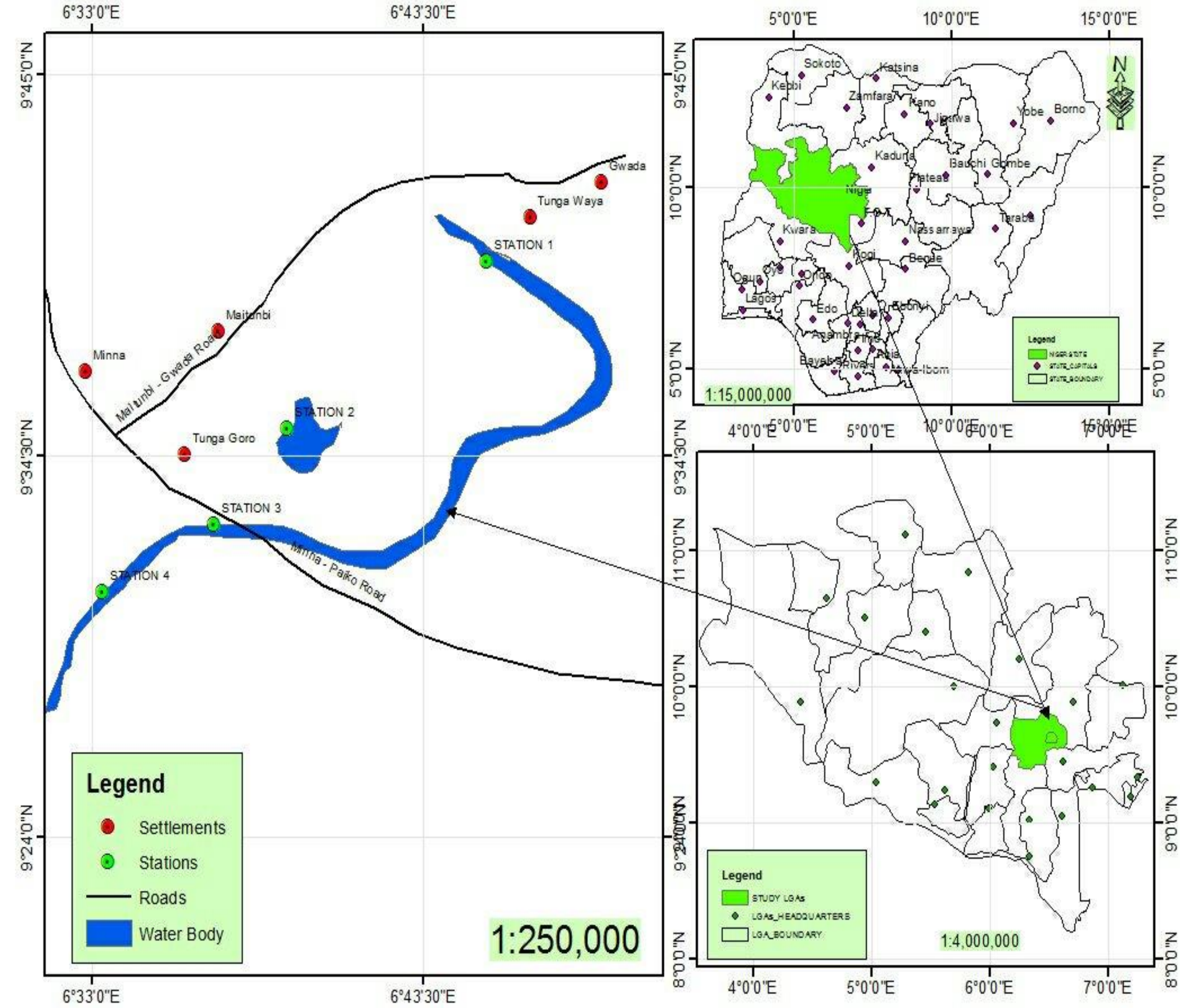


Figure 3.1 Map of the Study Area Showing River Chanchaga, Minna, Niger State.
Source: Remote Sensing Laboratory, Department of Geography, Federal University of Technology, Minna, Nigeria

3.2 Sampling Stations

3.2.1 Station 1 (zhabyala)

This is located at Zhabyala community (Plate 3.1), Latitude 9^{o}40′N and longitude 6^{o}46′E in Shiroro Local Government Area. This station is about 1.74 km from the source of the river. The rural dwellers are mostly farmers who are mainly dominated by the Gbagyi, a few of Nupe and a mixture of other tribes. This station is the reference site as the site is relatively unperturbed. The riparian vegetation is mostly native. It is mainly like a forested stream with dense canopy cover of bamboo trees (*Bambusa* sp.) and other trees species. The stream bed is more of sand, less of mud, boulders and cobbles. The station is highly sinuous with a large portion of riffle, less of run and pool microhabitats. The station is highly sinuous with a large portion of riffle, less of run and pool microhabitats.

Plate 3.1 Sampling station 1 Zhabyala

3.2.2 Station 2 (tungan waya)

Tungan Waya community (Plate 3.2), Latitude 9°35 ′N and longitude 6°39′E Bosso Local Government Area. It is about 19.71 km from station 2. The rural dwellers are mostly farmers. They cultivate yam, maize, melon, okra and cowpea. Apart from the farming activities going on around the riparian zone of the station, other activities like cattle grazing, bathing, washing and irrigation process are carried out here. The riparian vegetation is mixed probably because of the degree of anthropogenicity. The canopy cover is sparse with more of shrubs and grass which make the station to be open most part of the year, especially during the dry season. The station microhabitat is dominated by pool, the riffle and run microhabitats are sparse. Due to the level of perturbation, the station is prone to erosional process. The station bottom consists more of mud and hardpan (clay). Sand, silt and cobbles biotopes are less.

Plate 3.2 Sampling station 2 Tungan Waya

3.2.3 Station 3 (koropkan)

Korokpan community (Plate 3.3), Latitude 9°31′N and longitude 6°32′E, station 3 is located in Chanchaga below the bridge. Local Government Area. This station is about 4.49 km from station 2. The riparian zone harbours residential structure, thus leading to the absence of native vegetation. Agricultural activities are very high. Local mining activities, sand dredging, bathing, defecation, washing of cars, clothes and other households are among the numerous anthropogenic activities going on around the bank of this station. The streambed consists of sand, boulders, mud; stump of wood and decay organic particles. The decay organic matters are mainly at the littoral zone of the station. The instream cover is relatively poor, rendering the water body open.

Plate 3.3 Station 3 Korokpan

3.2.4 Station 4 (lapai gwari)

Lapai Gwari (Plate 3.4), (latitude 9^o 32 N and longitude 6^o 38 E) is located in the Chanchaga local government area of Niger state. The major occupation of the inhabitant is farming. The water is polluted by the heavy influx of effluents from the fish farm located around the station thereby rendering the water unfit for consumption.

Plate 3.4 Station 4 Lapai gwari

3.3 Sample Collection

3.3.1 Water samples and determination of physicochemical parameters

The water sample for physicochemical parameters were collected monthly for a period of ten (10) months (January-October 2019) from four (4) stations (Zhabyala, Tungan Waya, Korokpan and Lapai Gwari) along the river course. Samples were collected in 200 mls reagent bottles properly cleaned with distilled water prior to usage. Collection was carried out by careful immersion of the sample containers in the water. The containers were sealed with tight fitting corks or stoppers after collection, in order to avoid air bubbles. Samples were transferred to a refrigerator (4 ^{0}C) prior to analysis.

Water samples were processed according to the method prescribed by the American Public Health Association (APHA, 2012). The pH, Electrical conductivity (EC) and total dissolved solids (TDS) of the water samples were tested using pre-calibrated pH, TDS and conductivity meter *in-situ* with (Hanna microprocessor pH/ EC/TDS Meter), while the determination of dissolved oxygen (DO), was determined *in-situ* using a portable dissolved oxygen analyser, Model JPB-607. Similarly, air/water temperatures of the stations were meassured with a mercury-in-glass thermometer *in-situ* and the reading was expressed in degree celcius (^{0}C). Collected and preserved water sample were used to test the phosphate (PO_4), Nitrate (NO_3), Hardness, Alkalinity, Biological Oxygen Demand (BOD), potassium and sodium using the method of the APHA (2012) in WAFT laboratory, (SAAT) in Federal University of Technology, Minna (FUT, MINNA) for each sample station.

3.3.2 Water temperature

Temperature reading was taken by inserting mercury in glass thermometer inside the water at 5 cm below the water surface and the thermometer was allowed for some minutes to stabilize. The process is repeated twice and the reading was recorded.

3.3.3 Water depth

The depth of the streams was measured by using a calibrated rod or stick. The rod was lowered below the water body at a selected point readings were taken to estimate the mean depth (APHA, 2012; Arimoro *et al.*, 2015).

3.3.4 Water transparency

Water transparency (or water clarity) is a first-order indicator of water quality and generally quantified as the Secchi disk depth (Doron *et al.*, (2007)

3.3.5 Flow velocity

A weighted cork was used to measure the rate of water flow per second using the formula:

$$\text{Velocity} = D(CM)/T(SEC)$$

Where D = distance covered, T = time

Two fixed points was then chosen and a weighted cork was dropped at a point upstream at each station and the time it took the cork to reach a predetermined point was noted. The time taken was used to divide the distance covered. This exercise was then repeated three times in each sampling station and the average was taken as the velocity of the water at the station according to Gordon *et al.* (1994) method

3.3.6 Electrical conductivity

Electrical Conductivity of the samples was determined using a conductivity meter as described by APHA (1998) method. The conductivity meter has a measurement range 1-1000 µs/cm, a precision within this range of 0.5% and a reference temperature of 25^{0}C. The water samples were kept in the tubes at 25 ^{0}C temperature and allowed to stay for 3 minutes to attain thermal equilibrium. The conductivity cell was rinsed with the first tube while the measurement was taken from the second tube. The cell constant was calibrated at 25 ^{0}C. Conductivity values were obtained from the calculation below:

$$\mathrm{E} = \frac{c}{Ru}\ X\ \frac{1}{1.002225-(t)}$$

Where, E = Electrical conductivity of sample

C = Constant

Ru = Electrical resistance measured

t = time used for the sample to reach thermal equilibrium

1.002225 = constant

3.3.7 Hydrogen ion concentration (pH)

A washed bottle rinsed with the river water was used to collect water sample for pH determination. It was corked, labeled and taken to the laboratory for analysis using a battery operated pH meter (Model ETh 3055) standardized with the pH 4-8 buffer. The probe was immersed in the water before it was switched to “on position” to measure the pH. The recording was to the nearest 0.1 pH unit.

3.3.8 Dissolved oxygen

The dissolved oxygen (DO) was determined using the Winkler's method (APHA, 1998). A 250 m1 stoppered bottle was immersed beneath the water surface, the stopper was removed until the bottle was filled and then stoppered tightly under the water to exclude air bubbles. The dissolved oxygen was then fixed by adding 1ml of Winklers Solution, A (Manganese (II) Sulphate) followed by 1ml of solution B (Potassium Iodide). After Winkler's solution A and B were added to the water, the stoppered bottle was inverted several times to mix the sample and the reagents. The Potassium Iodide in solution B reacts with Manganese in solution A to form a brown precipitate of Manganous Iodide. The precipitate was allowed to settle completely for 15 minutes; the precipitate settled in the lower half of the bottle leaving clear solution above. In the laboratory, the precipitate was dissolved with I ml of concentrated tetraoxosulphate VI acid (H_2S0_4). 100ml of the treated water sample was titrated against 0.025 N sodium thiosuiphate solution ($Na_2S_2O_3$) to a pale yellow color. At this point 2 drops of starch indicator was added and swirled to mix, the titration was continued until the color changed from the blue black to colorless. The volume of the sodium thiosophate used was recorded.

The dissolved oxygen was calculated with the formula:

$$Dissolved\ oxygen = \frac{\mathrm{V(D)} x\ N(D) x 1000}{volume\ of\ sample\ (ml)}$$

Where, 8 and 1000 are constants.

$V(_D)$ = Volume of $Na_2S_2O_3$ used in titration

$N(_D)$ = Normality of the titrant

The resultant volume was expressed in mg/L

All chemicals were freshly prepared.

3.3.9 Biochemical oxygen demand (BOD)

This was determined according to APHA (1998) method. At the field, the reagent bottles were set aside for BOD and were filled with water samples and tied in black polythene bags to avoid any form of photosynthesis. They were taken to the laboratory and kept in a dark cupboard. After five (5) days, they were fixed using the Winklers solution (A) and (B). The procedure for carrying out dissolved oxygen was then repeated to check the amount of oxygen that has been used up by microorganisms.

$BOD = DO_o – DO_5$ (mg/L)

DO_o = Initial dissolved oxygen at the first day

DO_5 = dissolved oxygen value after 5 days

Results expressed in mg/L

3.3.10 Sulphate-sulphur

This was also determined using the spectrophotometer, 50ml of the sample was mixed with 10 ml or glycerol-alcohol solution (APHA 1998). The absorbance was then measured against blank at a wavelength of between 380-420 nm. About 0.15 g (a constant spoonful) or $BaCl_2$- crystals was then added and the resulting solution shaken for 15 minutes. The absorbance was then measured again after 30 minutes.

3.3.11 Phosphate content

This parameter was determined by stannous chloride method (APHA, 1992). A drop of phenolphthalein indicator was added to 100 ml of the sample and in all the cases no colour change was observed, thus there was no need for further dilution. To each sample, 4 ml of ammonium molybdate reagent (1) and 0.5 ml or 10 drops of stannous chloride reagent was added after both reagents have been thoroughly mixed together. A blue colour was developed as a result of the mixture. The mixture was allowed to stand for 11 minutes for colour development and thereafter the absorbance was measured with a Gallenkamp Bausch and lamb spectromic 20 at a wavelength of 690 nm using a distilled water blank. Standard phosphate calibration curve was prepared by measuring the transmittance of the serially diluted standard phosphate solution as in the case of nitrate. The phosphate concentration of the water sample in mg PO_4 were read from the prepared phosphate standard calibration curve.

3.4 Macroinvertebrate Samples

Macroinvertebrates samples were collected from a 100 m stream reach using a 0.09 m^2 surber sampler with a 250 µm mesh size. The collection method considered the three microhabitats/flow regimes (the pools, riffles, and runs) and all the different substrata (vegetation, sand, gravel biotopes), were included to avoid bias, three random samples were collected from each of the three microhabitats for a total of three times, and then pooled to form one composite sample per station. This was to ensure that all microhabitats were adequately sampled, the three microhabitats per sampling event per site were pooled into one composite sample. The collected samples were preserved in a 10 % formaldehyde solution and transported to the laboratory for sorting and subsequent identification. In the laboratory, samples were washed in a 500 mm mesh sieve to remove sediment and macroinvertebrates were sorted using a stereoscopic microscope (magnification x 10). All animals were separated, enumerated and identified under a binocular dissecting microscope. All sorted macroinvertebrates were identified to the lowest taxonomic level possible using Merritt and Cummins (1996), Day *et al.,* (2002) and De Moor *et al.,* (2003). References were made to the taxonomic lists of species known to be present in Nigeria (Arimoro and James, 2008; Arimoro *et al.*, 2012).

3.4.1 Classification of macroinvertebrates into functional feeding groups

Classification into the functional feeding groups was done using the designation and criteria of Cummins (1975), Merritt and Cummins 1996, Rempel *et al*. (2000), Mandaville (2002) and Arimoro (2007). Functional feeding group method of analysis establishes linkages to basic aquatic food resource categories; coarse particulate organic matter (CPOM, particles > 1mm), fine particulate organic matter (FPOM, particles < 1 mm and > 0.45 μm). The major functional feeding groups are:

a. Scrapers/grazers which consume algae and associated materials.

b. Shredders, which consume leaf litter or other CPOM including wood.

c. Collector-gatherers, which collect FPOM from the stream bottom

d. Collector-filterers, which collect FPOM from the water column using a variety of filterers.

e. Predators, feed on other consumers, piercer or engulfers

3.5 Data Analysis

The data of the physicochemical parameters were subjected to descriptive statistical test, using Microsoft Excel 2010 and PAST to determine one way ANOVA and also biological indices. The mean values and standard error of each physicochemical characteristic were calculated per station. Biological indices such as taxa richness and evenness (E) abundance, number of taxa, diversity index, dominance as well as physicochemical variables among all stations were compared using one way analysis of variance (ANOVA) at significant difference ANOVA ($p < 0.05$).

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

4.1 Results

4.1.1 Spatial and temporal variations in physicochemical parameters of river Chanchaga.

Results of spatial and temporal variation in physicochemical parameters of River Chanchaga over a period of ten (10) months (January to October 2019) are presented in Table 4.1. The transparency, depth, flow velocity, BOD, sulphate and phosphate varied significantly ($p < 0.05$) among the sampling stations as indicated by ANOVA. There was no significant difference ($p > 0.05$) in temperature, conductivity, pH and DO among the sampling stations of the River.

4.1.1.1 Water temperature

The spatial and temporal variation in water temperature in Chanchaga River Stations 1, 2, 3 and 4 are presented in Figure 4.1. The values of water temperature range from 25.40 ^{0}C in station 1 to 32.5 ^{0}C in station 4. There was no significant difference ($p > 0.05$) in the months sampled but there was significant difference in the stations. The least temperature value was recorded in station 1 while the highest temperature value was recorded in station 4.

Table 4.1 Physicochemical Parameters of the Study Stations of River Chanchaga (January – October 2019)

Variables	Station 1	Station 2	Station 3	Station 4	Monthly Variation		Station Variation		FEPA Standard Units
					F-value	P-value	F-value	P-value	
Water Temperature (^{0}C)	28.33±0.46 (25.40-31.10)	28.32± 0.43 (25.5-31.40)	28.27±0.49 (26.05-31.50)	28.43±0.52 (27.0-32.50)	4.589	0.00	0.03	0.99	
Depth (m)	0.28±0.05 (0.12-0.58)	0.34±0.05 (0.10-0.73)	0.34±0.06 (0.12-0.63)	0.48±0.06 (0.18-0.84)	13.85	5.37E-08	8.09	0.00	
Transparency (cm)	17.68±2.28 (5.50-28.00)	11.12±2.68 (2.00-23.00)	12.08±2.52 (3.5-24.50)	8.58±1.54 (3.5-18.23)	4.94	0.01	5.56	0.00	
Flow Velocity (m/s)	0.25±0.06 (0.00-0.49)	0.36±0.07 (0.06-0.80)	0.38±0.14 (0.02-1.49)	0.31±0.09 (0.02-0.90)	2.64	0.02	0.60	0.62	
Conductivity (µŞ/cm)	8.58±0.42 (7.2-11.53)	9.86±0.54 (7.9-12.60)	9.97±0.51 (8.5-14.00)	10.14±0.35 (8.7-12.00)	1.41	0.23	2.64	0.07	0.60
pH	6.77±0.34 (5.1-8.400)	6.75±0.42 (5.22-10.00)	7.57±0.41 (5.9-9.80)	7.45±0.52 (6.2-12.00)	7.42	2.23E-05	2.73	0.06	6.00-9.00
Dissolved Oxygen DO (mg/L)	5.65±0.54	3.26±0.43	3.02±0.44	2.56±0.35	18.66	2.10E-09	52.50	2.14E-11	5

	(2.5-7.40)	(1.53-5.60)	(1.25-5.40)	(0.93-4.50)					
Biochemical Oxygen Demand BOD (mg/L)	4.80±0.67	1.81±0.32	0.37±1.39	0.99±0.28	6.03	0.00	32.73	3.87E-09	
	(0.68-6.30)	(0.71-3.67)	(0.83-4.20)	(-0.03-2.70)					
Sulphate (mg/L)	12.20±0.10	22.37±1.18	27.04±1.74	23.02±1.10	9.61	2.11E-06	76.21	2.676E-13	
	(9.0-17.80)	(18.06-28.00)	(16.41-32.80)	(16.21-26.56)					
Phosphate (mg/L)	0.26±0.97	1.31±0.22	1.51±0.18	1.50±0.16	1.62	0.16	14.40	8.514E-06	0.90
	(0.00-0.81)	(0.52-2.49)	(0.55-2.46)	(0.52-2.30)					

Note: Values are means ± standard deviation. Maximum and minimum values in parenthesis. The F-value indicate ANOVA and P-values indicate the level of probability. Nigeria Water Quality Standard for Inland Surface Waters, Federal Environmental Protection Agency (FEPA, 1991).

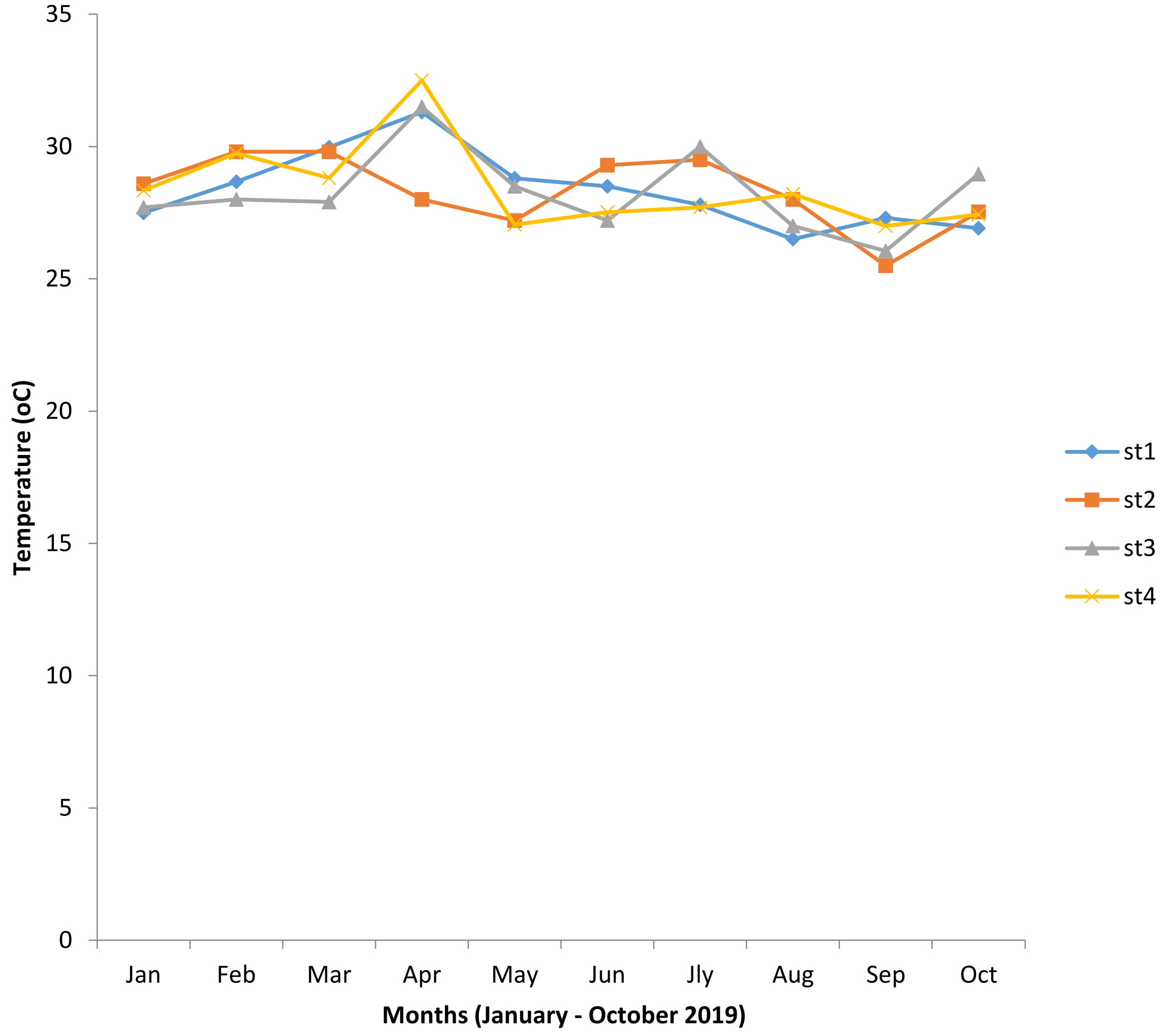


Figure 4.1 Monthly variation of Temperature in Sampling Stations of River Chanchaga.

4.1.1.2 Water depth

The spatial and temporal variation of water depth in River Chanchaga Stations 1, 2, 3 and 4 is shown in Table 4.1. The depth value ranged from 0.10 m in station 2 to 0.84 m in station 4. Depth showed no significance difference ($p < 0.05$) in the stations and months sampled. Though there was increase in the depth in August, September and October.

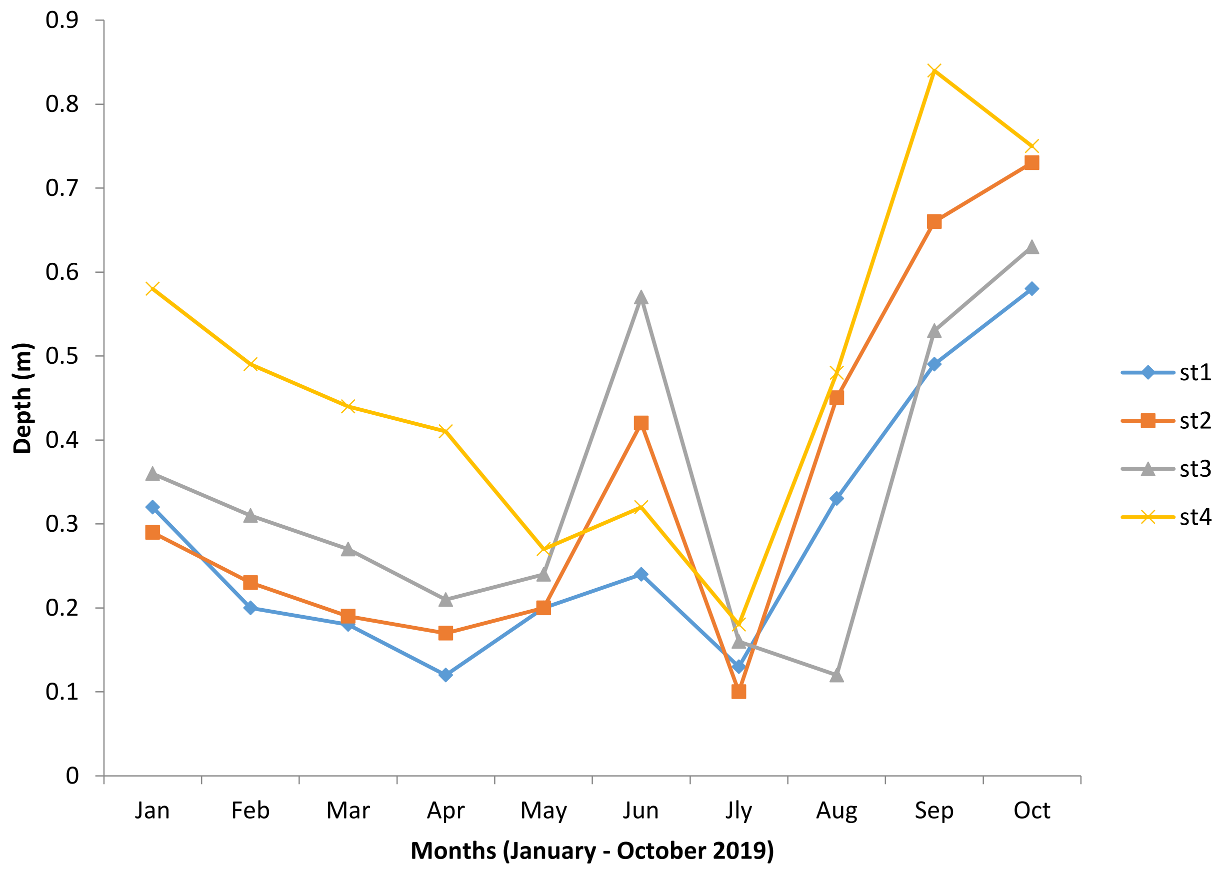


Figure 4.2 Monthly variations in water depth in Sampling Stations of River Chanchaga.

4.1.1.3 Water transparency

The spatial and temporal variation of water transparency in River Chanchaga Stations 1, 2, 3 and 4 is shown in Table 4.1. The transparency value ranged from 2.00 cm in station 2 to 28.00 cm in station 1. Transparency showed no significance difference ($p < 0.05$) among the stations and in the months sampled. Transparency was generally higher in station1, 2, and 3 compared to station 4.

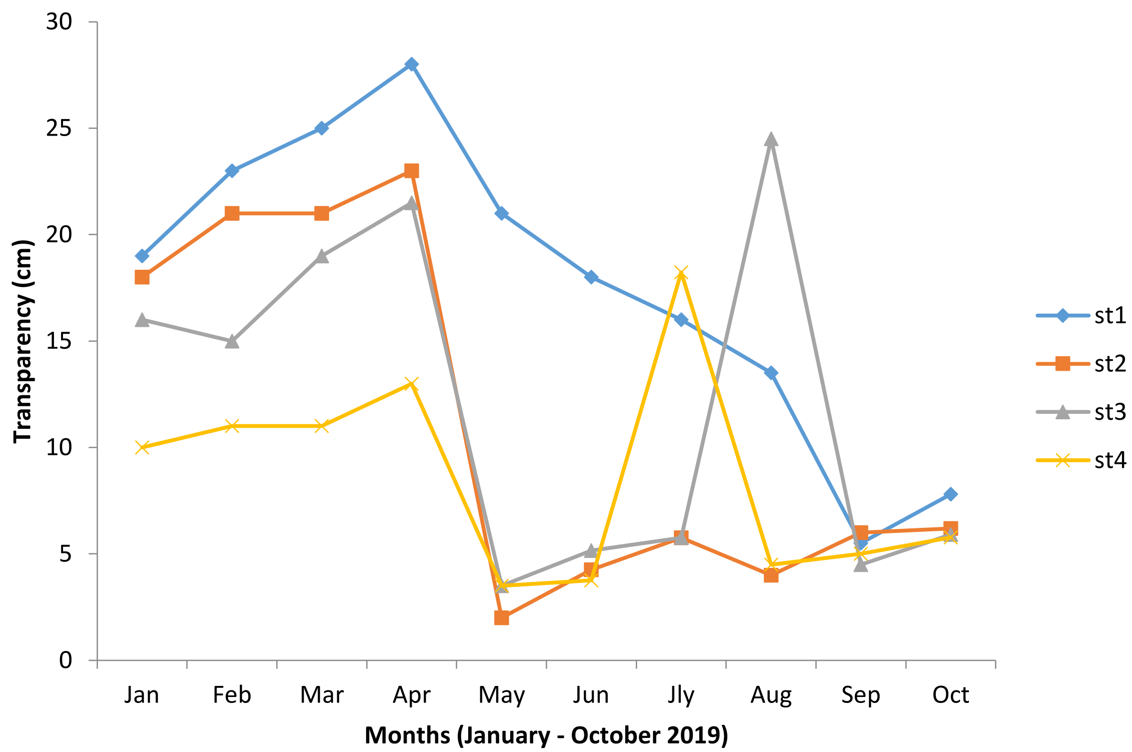


Figure 4.3 Monthly variations in water transparency in Sampling Stations of River Chanchaga.

4.1.1.4 Flow velocity

The spatial and temporal variation of water flow velocity in Chanchaga River Stations 1, 2, 3 and 4 is shown in Table 4.1. The flow velocity value ranged from 0.00 m/s in station 1 to 1.49 m/s in station 3. The flow velocity showed no significance difference ($p > 0.05$) in the months sampled but there was significant different ($p < 0.05$) in the stations sampled. The sharp variation in station 3 could be attributed to the topography and the poor vegetation cover of this station.

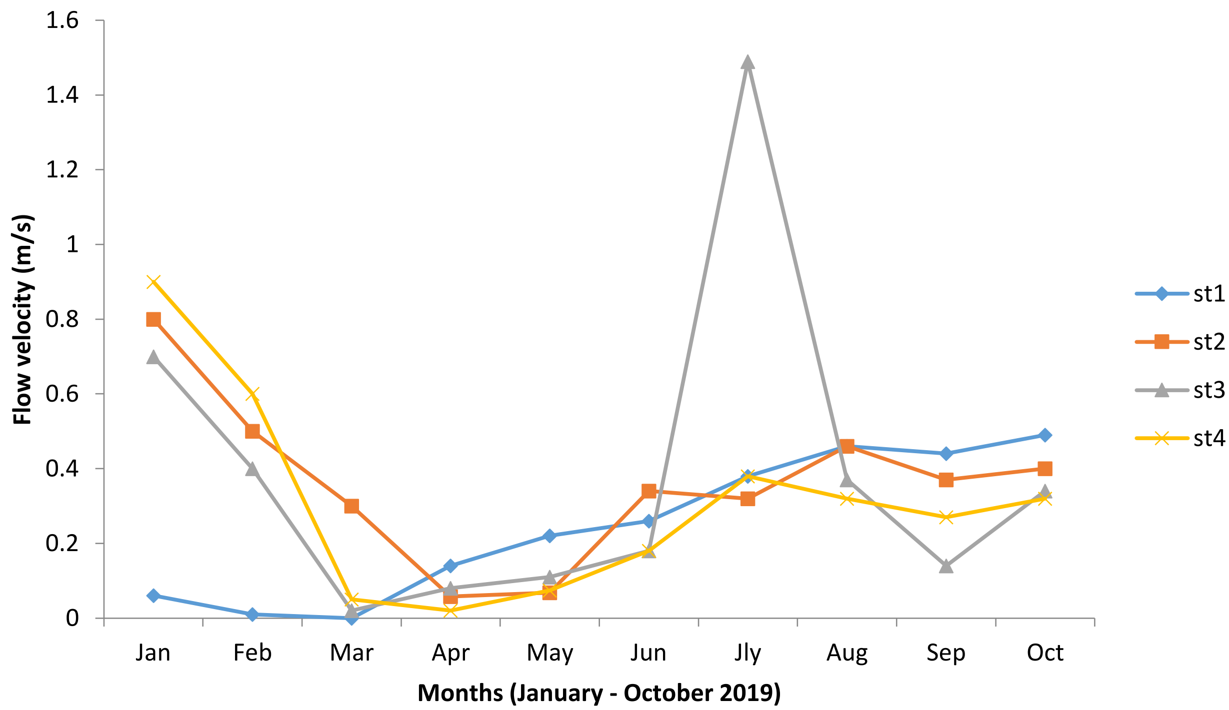


Figure 4.4 Monthly variations in flow velocity in Sampling Stations of River Chanchaga.

4.1.1.5 Electrical conductivity

The spatial and temporal variation of water Conductivity in River Chanchaga Stations 1, 2, 3 and 4 is shown in Table 4.1. The Conductivity value ranged from 7.2µ/cm in station 1 to 14.0µ/cm in station 3. The Conductivity showed significance difference ($p<0.05$) in the months and stations sampled.

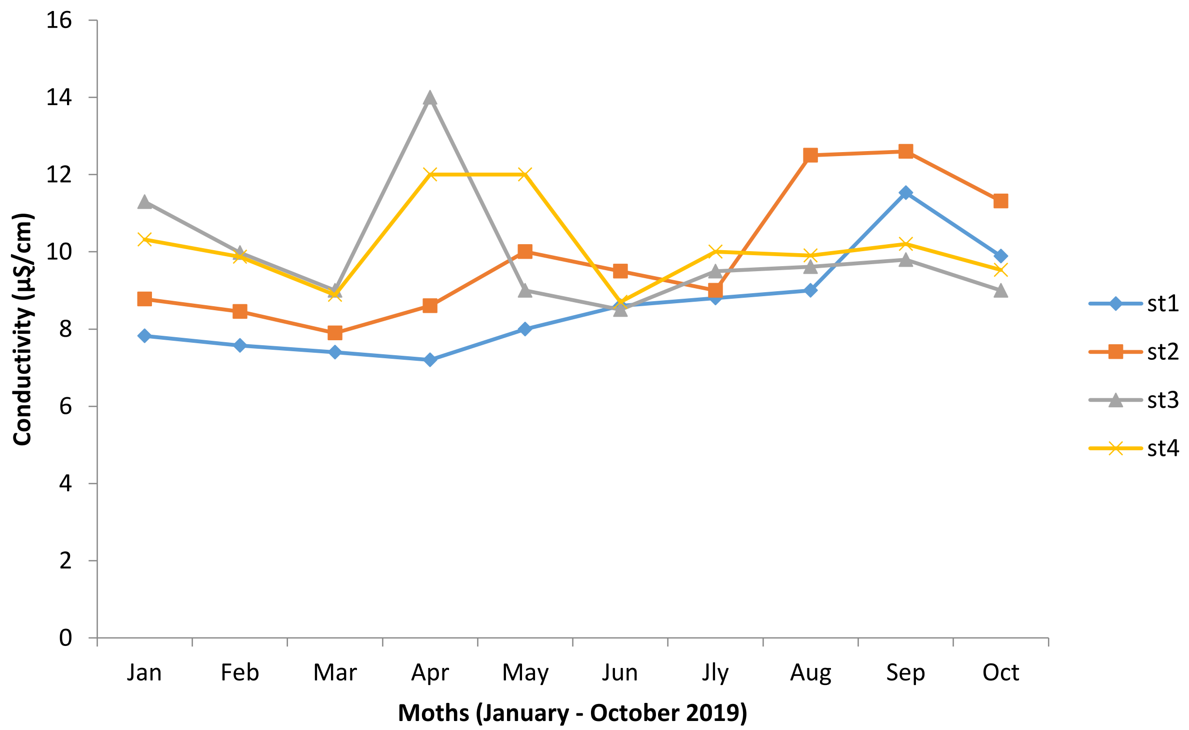


Figure 4.5 Monthly variations in Electrical Conductivity in Sampling Stations of River Chanchaga.

4.1.1.6 Water pH

The spatial and temporal variation of water pH in Chanchaga River Stations 1, 2, 3 and 4 is shown in Table 4.1. The pH value ranged from 5.10 in station 1 to 12.00 in station 4. The pH showed no significance difference ($p > 0.05$) in the months while there was significant different ($p < 0.05$) in the stations sampled.

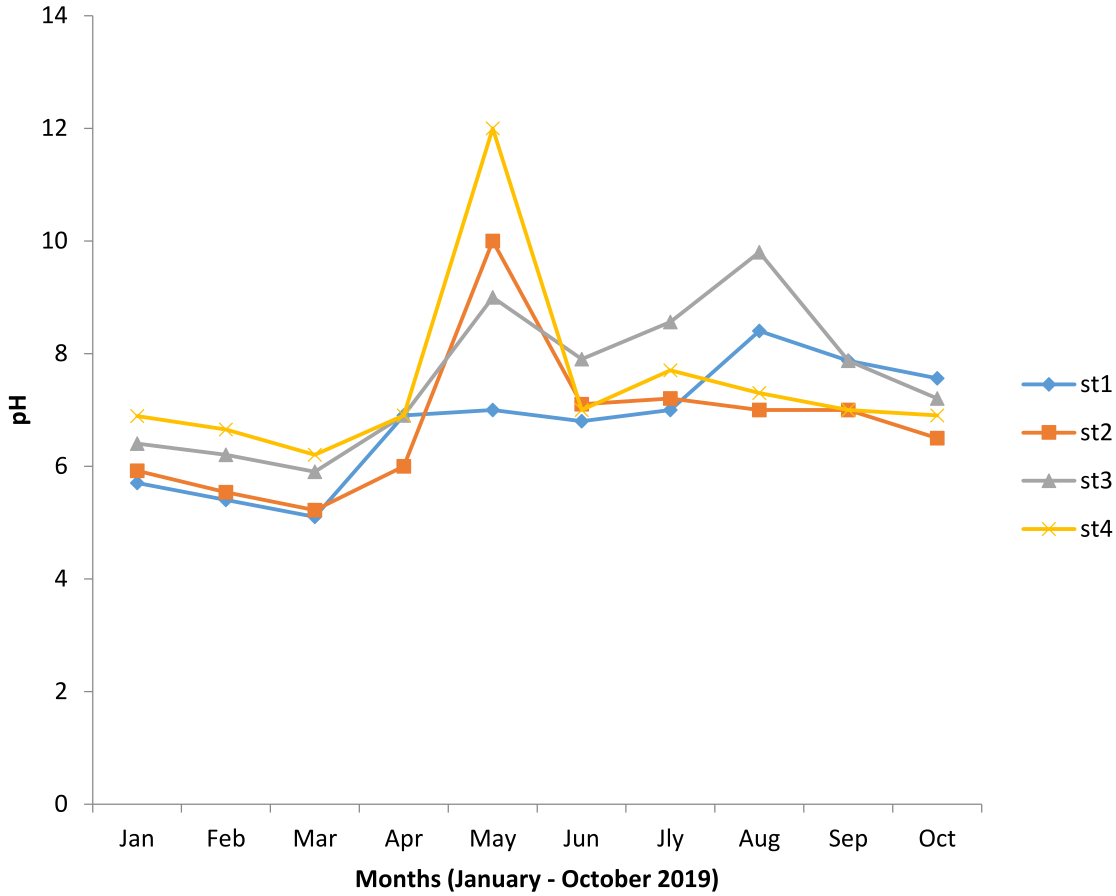


Figure 4.6 Monthly variations in pH in Sampling Stations of River Chanchaga.

4.1.1.7 Dissolved oxygen (DO)

The spatial and temporal variation of DO in River Chanchaga Stations 1, 2, 3 and 4 is shown in Table 4.1. The DO (mg/L) value ranged from 0.93 mg/L in station 3 to 7.40 mg/L in station 1. The DO value showed no significance difference ($p > 0.05$) in the months and stations sampled. Station

1 recorded higher value in dissolved oxygen throughout the sampling period compared to stations 2, 3 and 4.

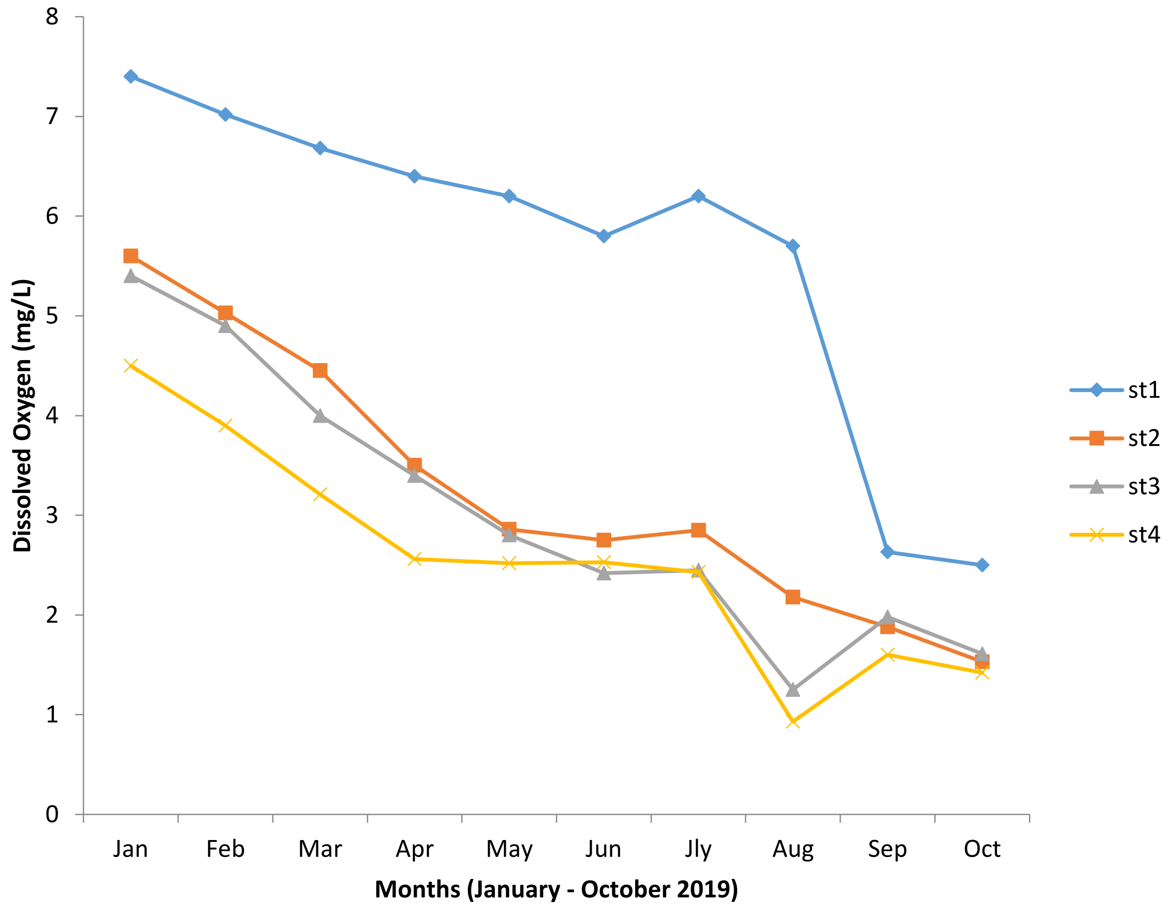


Figure 4.7 Monthly variations in DO(mg/L) in Sampling Stations of River Chanchaga.

4.1.1.8 Biochemical oxygen demand (BOD)

The spatial and temporal variation of BOD in River Chanchaga Stations 1, 2, 3 and 4 is shown in Table 4.1. The BOD (mg/L) value ranged from -0.03 mg/L in station 4 to 6.30 mg/L in station 1.

BOD showed no significance difference ($p > 0.05$) in the months and stations sampled. Station 4 recorded higher value in biological oxygen demand throughout the sampling period compared to stations 1, 2 and 3.

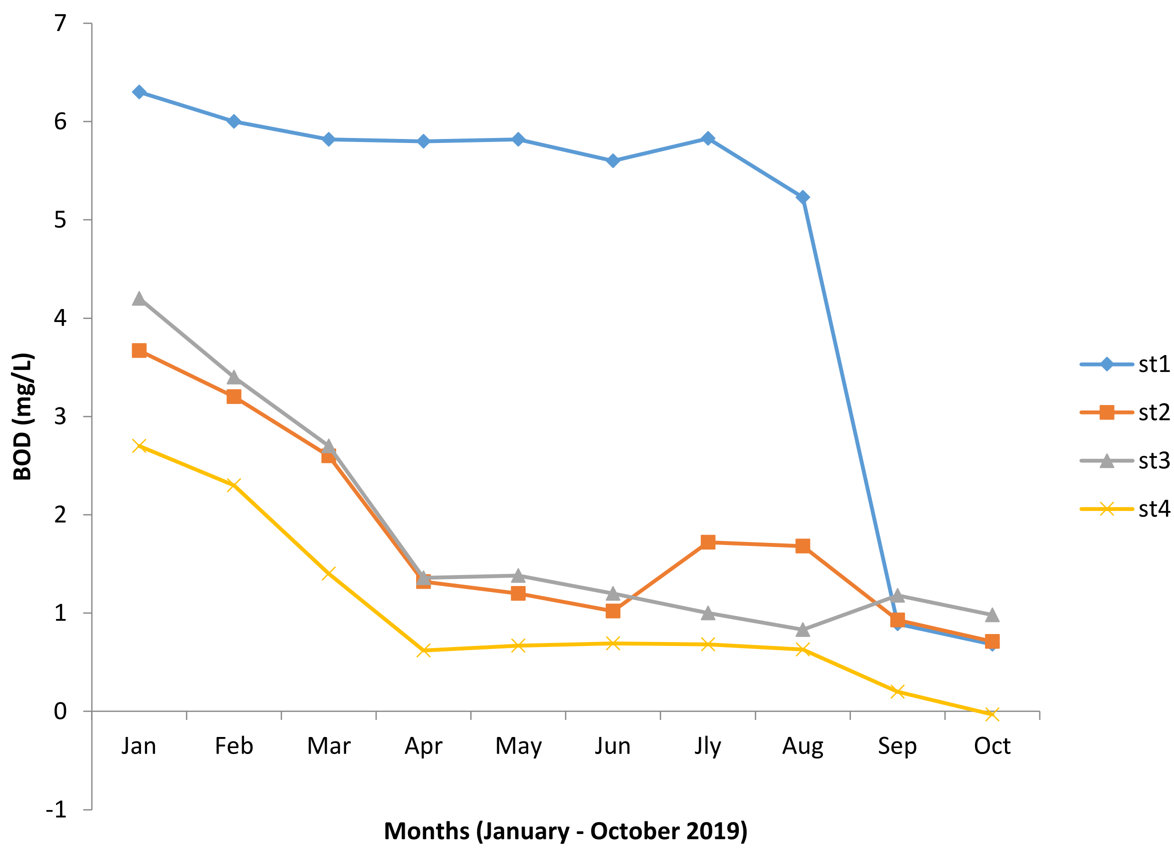


Figure 4.8 Monthly variations in BOD (mg/L) in Sampling Stations of River Chanchaga.

4.1.1.9 Sulphate content

The spatial and temporal variation of Sulphate in River Chanchaga Stations 1, 2, 3 and 4 is shown in Table 4.1. The Sulphate (mg/L) value ranged from 9.00 mg/L in station 1 to 32.80 mg/L in station 3. Sulphate showed no significance difference ($p > 0.05$) in the months and stations sampled. Sulphate was higher in station 3 while station 1 recorded the least value.

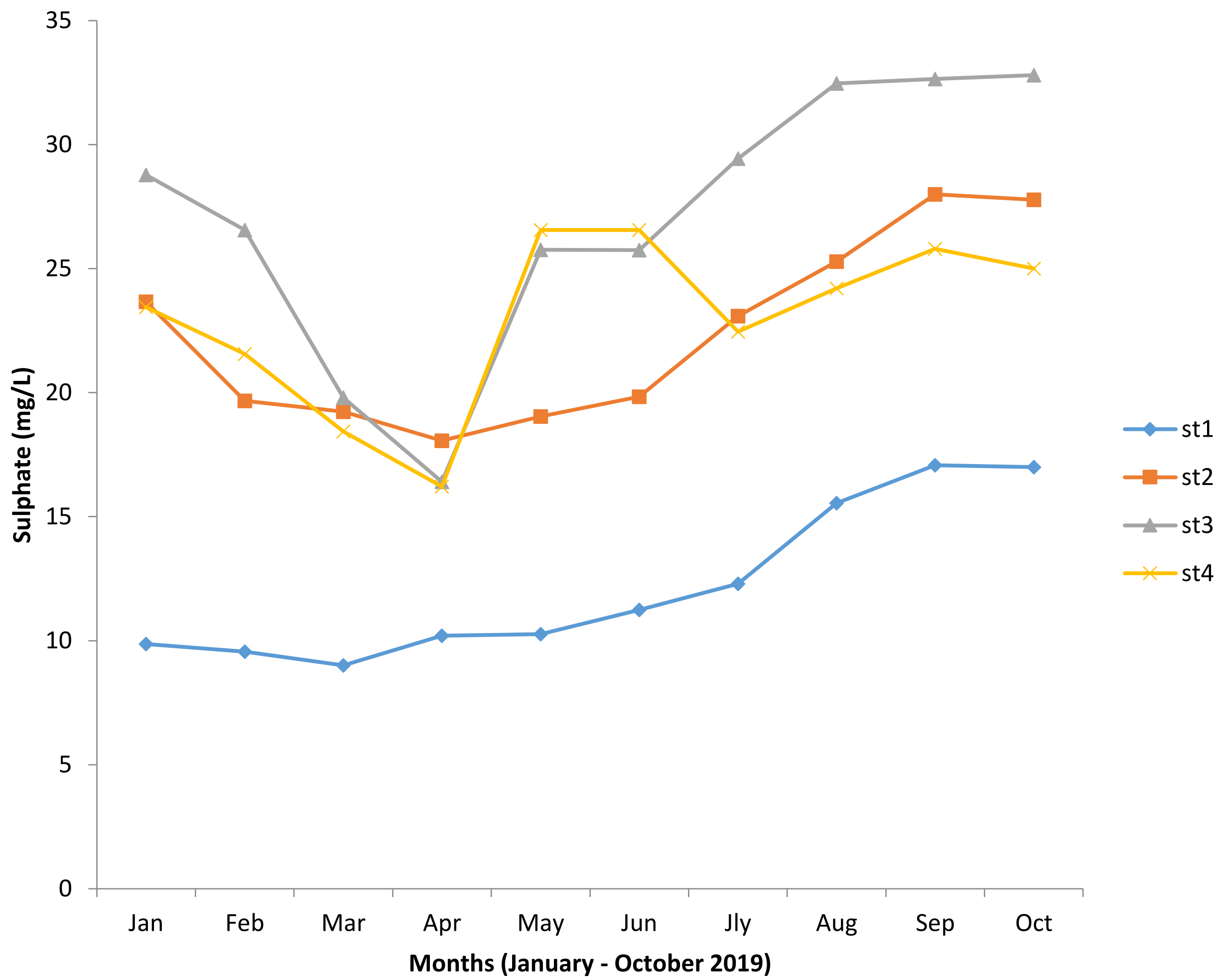


Figure 4.9 Monthly variations in Sulphate content (mg/L) in Sampling Stations of Chanchaga River.

4.1.1.10 Phosphate content

The spatial and temporal variation of Phosphate in River Chanchaga Stations 1, 2, 3 and 4 is shown in Table 4.1. The Phosphate (mg/L) value ranged from 0.0000l mg/L in station 1 to 2.49 mg/L in station 2. Phosphate showed significance difference ($p < 0.05$) in the months while there was significant difference ($p > 0.05$) in the stations sampled.

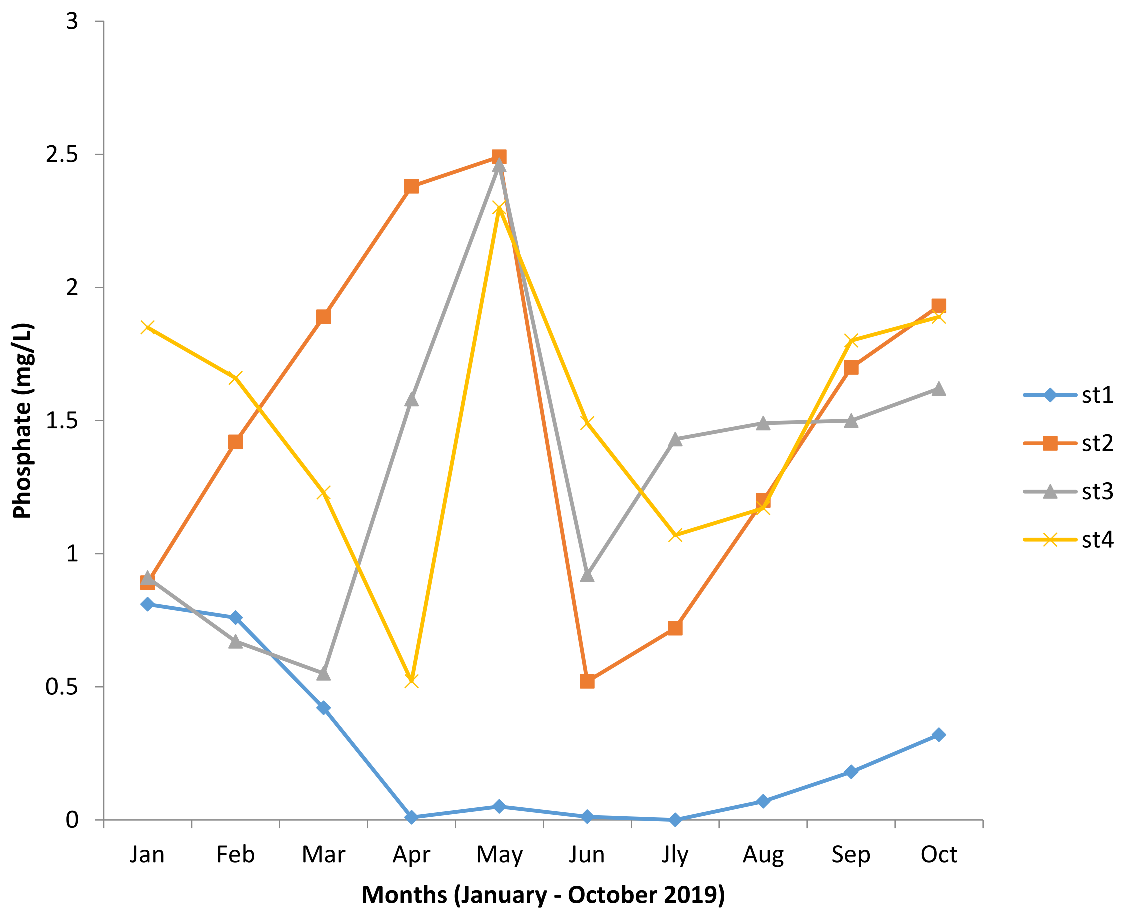


Figure 4.10 Monthly variations in Phosphate (mgL^{-1}) in Sampling Stations of River Chanchaga.

4.1.2 The Abundance, Distribution, Composition and Diversity of Macroinvertebrate and Spatial and Temporal Variations in River Chanchaga, Niger State

4.1.3 Macroinvertebrates assemblages

A total of 2707 individuals from 25 families belonging to 11 orders of macroinvertebrates were recorded during the study period in River Chanchaga (Table 4.2). A total of 180(6.6 %), 165(6.10 %), 437(16.14 %) and 1925(71.11 %) individuals were recorded for Stations 1, 2, 3and 4 respectively. The percentage distribution and abundance of taxonomic level reveal that Odonata, Mollusca and Ephemeroptera were the most common groups encountered in all the sampling stations while Decapoda, Crustacean, oligochaetes, Dipterans, Plecoptera and Coleoptera were sparingly distributed in all the sampling stations.

Table 4.2 Distribution and Abundance of Macroinvertebrates in River Chanchaga Minna, Niger State

Order	**Family**	**Taxa/Species**	**Station**			
			1	2	3	4
Mollusca	Corbuculidae		0	3	1	0
	Planorbidae		0	0	1	0
	Thiaridae	*Potadoma moerchi*	0	8	116	162 0
		Melanoides tuberculate	0	4	5	109
	Unionidae	*Neritina* sp	0	0	158	5
Decapoda	Atyidae	*Caridina* sp	33	12	3	1
Crustacean	Potamonautidae		0	1	34	0
Oligochaeta	Naididae	*Dero* sp	0	0	1	0
	Hirudinae	*Hirudo* sp	1	1	0	5
Diptera	Chironomidae	*Chironomus* sp.	3	7	15	18
Ephemeroptera	Baetidae	*Bugillesia* sp.	16	11	1	13
		Cloeon sp.	46	8	0	16
	Isonychidae		23	5	3	4
Coleoptera	Dysticidae	*Phylodyte* sp.	0	1	0	11
	Hydrophilidae	*Crenis* sp.	5	22	10	8
		Hydrophilus sp.	1	13	11	3

Order	Family	Taxa/species	Station 1	Station 2	Station 3	Station 4
	Psephenidae		0	3	0	1
Plecoptera	Perlidae		6	2	0	0
	Pteronarcydidae		2	0	1	0
Odonata	Coegnoridae	*Coenagrian* sp.	2	4	6	10
		Pseudogrian sp.	4	7	4	0
	Plactinecmidae	*Mesocnemis* sp.	8	7	11	8
	Gomphidae	*Ophiogomphus* sp.	29	2	5	23
	Aeshnidae	*Aeshna* sp.	35	9	12	23
	Libellubidae	*Libellula* sp.	7	0	0	19
Hemiptera	Nepidae	*Ranatra* sp.	0	1	3	2
		Lacocotrephes sp.	1	9	6	4
	Hydrometridae	*Hydrometra* sp.	0	3	0	0

	Naucoridae	*Macrocoris* sp.	0	2	4	3
	Apataniidae		2	0	0	0
Total			**180**	**165**	**437**	1925

4.1.4 Some of the encountered macroinvertebrate groups River Chanchaga Minna, Niger State

Order Hemiptera

Plate I: ***Laccoccotrephes*** **sp**.

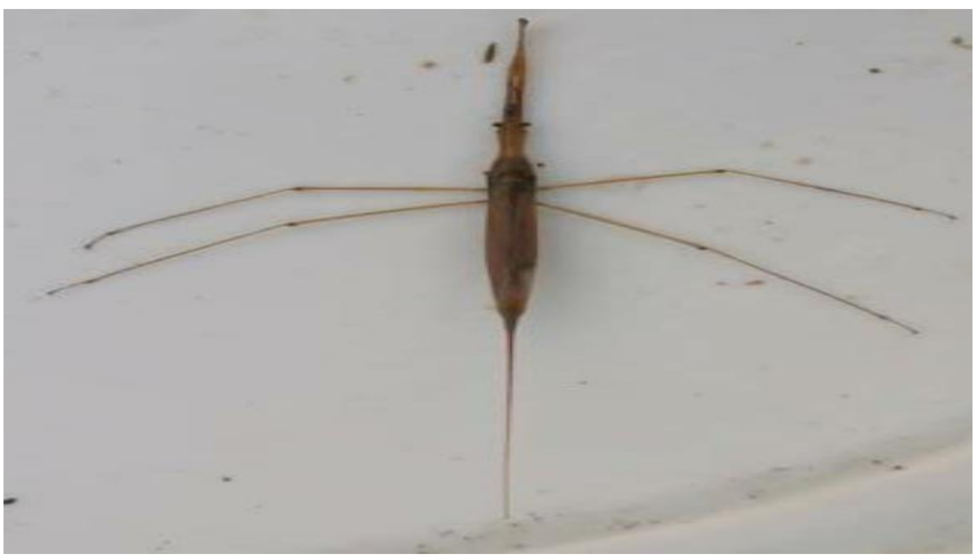


Plate II: ***Ranatra*** **sp**

Order Ephemeroptera

Plate III: ***Bugillesia* sp.**

Plate IV: ***Isonychchia* sp**.

Order Coleoptera

Plate V: ***Hydrophilus* sp.**

Plate VI: ***Orectochilus* sp**

Order Odonata

Plate VII: ***Coenagrian* sp**.

Plate VIII: ***Ophiogomphus* sp**.

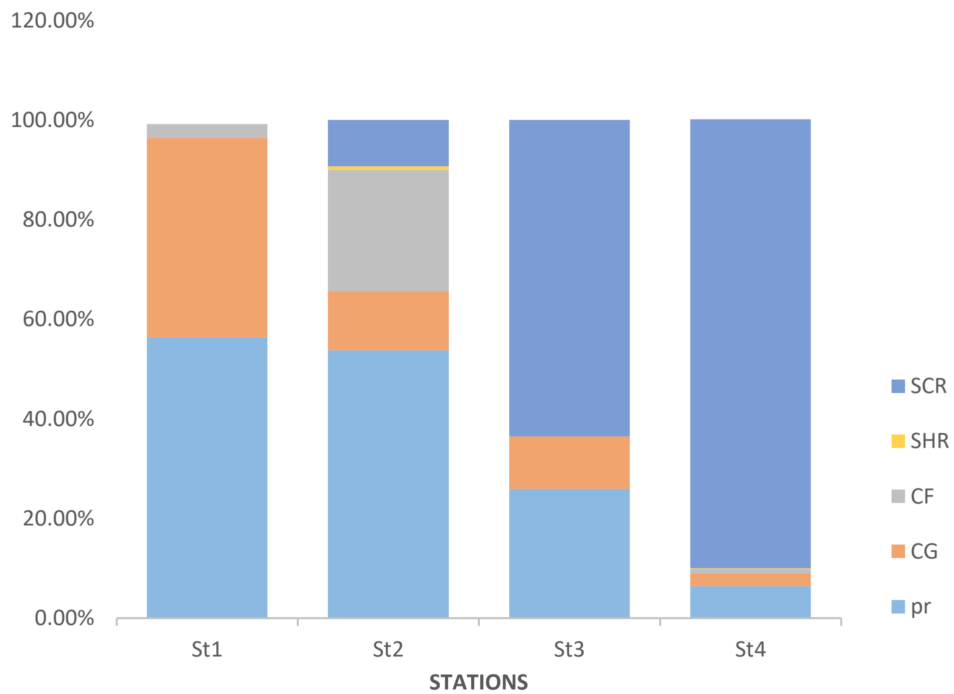
Order oligocheate

Plate IX: ***Hirudina*** **sp.**

Order Plecoptera

Plate X: ***Plecoptera***

4.1.5 Relative abundance of macroinvertebrate functional feeding groups of river Chanchaga Minna, based on percentage density



Key

Scrapper

Shredders

Collector Filterer

Coll. Gatherer

Predators

Figure 4.11

Relative abundance of Macroinvertebrate Functional feeding groups of River Chanchaga Minna, based on percentage density

4.1.6 Diversity, evenness, dominance and similarities indices of macroinvertebrate of River Chanchaga in Minna.

Summary of biological indices including abundance, number of Taxa, Shannon-Weiner diversity, evenness and Margalef's indices calculated for each station of the river are shown in Table 4.3. The highest number of species (24) was recorded in Station 2, while 17, 21 and 23 species were recorded in Station 1, 3 and 4 respectively. Number of individuals was highest in Station 4 (1925), followed by Station 3(437), while 180 and 165 individuals were recorded in station 1 and station

2 respectively. Simpson index was highest at Station 2 (0.9121) followed by 0.8553 in Station 1 while 0.7838, and 0.2848 were recorded in Station 3 and 4 respectively. Shannon index recorded in Stations 1, 2, 3, and 4 were 2.227, 2.763, 2.08 and 0.086 respectively. Station 2 (0.6606) recorded highest Evenness index, while Station 1(0.5455), Station 3(0.3481) and station 4 recorded 0.1066.

Table 4.3 Diversity indices of the recovered benthic macroinvertebrates of River Chanchaga Minna, Niger State

	Station 1	Station 2	Station 3	Station 4
Taxa_S	17	24	23	21
Individuals	179	160	434	1921
Dominance_D	0.1447	0.08789	0.2162	0.7152
Simpson_1-D	0.8553	0.9121	0.7838	0.2848
Shannon_H	2.227	2.763	2.08	0.806
Evenness_e^H/S	0.5455	0.6606	0.3481	0.1066

Margalef	3.084	4.532	3.623	2.645

Table 4.4 Taxa recorded from River Chanchaga Minna with allocation to functional feeding groups

Order	Family	FFG
Mollusca	Corbuculidae	*Cf*
	Planorbidae	*SCR*
	Thiaridae	*Sc*
	Unionidae	*CF*
Decapoda	Atyidae	*CF,CG,PR.*
Crustacean	Potamonautidae	*SHR*
Oligochaeta	Naididae	*CG*
	Hirudinae	*PR*
Diptera	Chironomidae	*CG,FT,PR*
Ephemeroptera	Baetidae	*CG*

	Isonychidae	*CF,PR*
Coleoptera	Dysticidae	*PR*
	Hydrophilidae	*CF*
	Psephenidae	*SCR(L) ADULT NONFEEDING*
Plecoptera	Perlidae	*PR*
	Pteronarcydidae	*SHR*
Odonata	Coegnoridae	*PR*
	Plactinecmidae	*PR,SHR,SCR*
	Gomphidae	*PR*
	Aeshnidae	*PR*
	Libellubidae	*PR*
Hemiptera	Nepidae	*PR*
	Hydrometridae	*PR*
	Naucoridae	*PR*
Tricoptera	Apataniidae	*SCR*

Keys: CF: Collector Filterers, CG: Collector Gatherer SCR: Scrapper, SHR: Shredder, PR: Predator

4.2 Discussion

The water quality of a river is controlled by its physical, chemical and biological factors, all of which interact with one another to influence its productivity (Akponine and Ugwumba, 2014).

4.2.1 Physicochemical parameters of river chanchaga

The high values of dissolved oxygen (DO), and transparency and low values of sulphate, phosphate and conductivity in station 1 is an indication of low interference with the water at the head water, while the high values in sulphate, phosphate, conductivity and low values in DO and transparency are indications of the deterioration of the river at station 3 and 4. This work is in conformity with the work of Arimoro (2007), who investigated the functional feeding groups of macroinvertebrates of Orogbodo River in Southern Nigeria. Similar trend was observed by Zabbey and Hart (2006) in their work on Woji Creek in the Niger Delta where organic wastes are constantly discharged into the stream.

The temperature level at station 4 was slightly higher than the other sites, this may be due to the lack of marginal vegetation, heat generated in the area as a result of the effluent from the fish farm and the high degree of decomposition of organic wastes from faecal droppings of the cattle around the location. This is in contrast with the level of temperature at station 1 which have high amount of vegetation cover.

The mean Phosphate value ranged from 1.31 and 1.51 mg/L for stations 1, 2 and 3. High phosphate value observed in this study could be as a result of different human activities around the water body and surface run-off (Ibrahim *et al.,* 2009). This finding is in consonance with the findings of Arimoro *et al.* (2015) who recorded phosphate range of 0.10-1.14 mg/L in Ogba River, Niger Delta Nigeria. Similarly Arimoro and Keke (2016) observed phosphate ranging between 0.06-1.40 mg/L from Gbako River Nort central Nigeria. This work is in conformity with the work of Edegbene *et* *al*. (2015) who reported a much higher phosphate (value) from River Chanchaga Niger State, Nigeria. This finding shows contrast with the work of Okayi *et al*. (2011) who reported low phosphate level in River Benue with a range of 0.07-0.17 mg/L. Phosphate is one of the limiting factors of environmental variables because when used up aquatic environment can be unproductive (Arimoro *et al*., 2015).

Mean Electrical Conductivity range recorded during in this study was between 8.58µS/cm in station 1 and 10.14 µS/cm in station 4. The conductivity increases across the stations from station 1 to station 4, This could be as a result of increase in the level of sodium ions, calcium ions and chloride, This finding is in contrast with the work of Keke *et al.* (2015) who reported a high conductivity value range of 32.00-72.00 µS/cm from surface water of downstream Kaduna River, Zungeru. Similar studies recorded a higher conductivity value range of 284-330 µS/cm obtained from Tropical River in Southern Nigeria (Ayoade and Olusegun, 2012).

Mean dissolved oxygen (DO) values ranged from 2.56 mg/L to 5.65 mg/L in all the stations. This is an indication of well ventilated and oxygenated water body throughout the study period which include both dry and wet season. Dissolved oxygen value recorded in the wet season were higher than in the dry season. This could be as a result of increased volume of water in raining season and lower temperature (Raji *et al.* 2015). Dadi-Mahmud *et al*. (2014) recorded DO range of 2.0-7.2 mg/L in River Ndakotsu Lapai, Niger state Nigeria. This findings is in consonance with Dimowo (2013), who reported DO range of 2.9-7.7 mg/L in his work on River Ogun Southwestern Nigeria. Similarly Keke *et al*. (2015) also reported a DO range of 3.5-8.2 mg/L from surface water of Kaduna River Zungeru Niger state, Nigeria. Other related works include that of Arimoro and Keke (2016) who recorded dissolved oxygen range of 3.10-50 mg/L in Gbako River North central Nigeria. This finding was in contrast with the finding of Emere and Nasiru (2009) who reported lower DO values of 0.5-3 60mg/l from a stream in Kaduna, Nigeria. Similarly, Edegbene *et al*. (2015) reported a DO values of 0.93-3.5 mg/L from River Chanchaga, Niger State, Nigeria.

In this study, depth varied between 0.10 m in station 2 to 0.84 m in station 4. This depth is an indication of a shallow stream. There was drastic increase in depth during the wet seasons as a result of runoff of rainfall. This finding is in comformity with the works of Arimoro and Ikomi (2008), Edegbene *et al*. (2015), and Arimoro and Keke (2016). However, it is in contrast with the work of Ndana (2017) who recorded a lowest depth of 1.5 cm and highest depth of 22.7 cm from his work on Landzun River, Bida, Niger state. Similarly, Ayoade and Olusegun (2012) reported a depth range of 6.56-12.9 cm from a Tropical stream in South Nigerian.

Flow Velocity is the speed with which the water flows. In this study, that the flow velocity ranged from 0.00 m/s in station 1 and 1.49 in station 3. The poor flow velocity recorded in station 1 could be attributed to the seasonal fluctuation that leads to the decrease in the volume of water, High flow regime recorded in station 3 was due to the steep topography of the stream, and this decreased down the stream as a result of the increase in the volume of water and the presence of riparian vegetations. This finding is in consonance with the work of Arimoro *et al.* (2015) from Ogba River, Arimoro and Keke (2016) from River Gbako, North Central Nigeria, Dadi-Mamud *et al*. (2014) from River Ndakotsu, Lapai, Niger state and Ndana (2017) from Landzun River.

4.2.2 Macroinvertebrates

A total of 2,707individuals from 25 families belonging to 11 orders of macroinvertebrates were recorded during the study period in River Chanchaga. The relatively high abundance of macroinvertebrate individuals and diversity in this study could be attributed to the nature of the habitat, which includes the vegetation, substrate type, the vegetation cover (Arimoro *et al*., 2015).

Nutrient availability, nature of vegetation, canopy cover, and sandy substrate could be attributed for favoring diverse groups of macroinvertebrates (Arimoro *et. al*., 2015).

In this study Ephemeroptera was only represented by the Baetidae and Isonychidae families. Two species of Baetidae family were encountered, *Bugillesia* sp. and *Cloeon* sp. Abundance of Ephemeroptera in this study was higher at station 1, the head water, where the rate of pollution is less. The abundance reduces in Stations 2, 3 and 4 as a result of their sensitivity to pollution caused by antropogenic activities and the deteriorated state of the stream by the riparian users (Arimoro and Ikomi, 2008). The findings from station 1(headwater) is consistent with the work of Arimoro and Keke (2016) who reported high abundance of Ephemeroptera in River Gbako, North central Nigeria. Similar finding was reported by Arimoro *et al.*, (2015) from River Ogbako, Niger Delta Nigeria. Edegbene *et. al.* (2015) reported low diversity and abundance of Ephemeroptera from his study in River Chanchaga, Niger State. The low abundance of Ephemeroptera in station 2, 3 and 4 are in conformity with the work of Emere and Nasiru (2009) who also reported low abundance of Ephemeroptera group in Urbanized stream, Kaduna Nigeria. The low abundance of Ephemeroptera and absence of Plecoptera and Trichoptera in sampling Stations 2, 3 and 4 is an indication of gross pollution due to anthropogenic activities at these stations. Many studies have reported higher abundance and diversity of these groups of macroinvertebrates to clean and pollution free water bodies (Arimoro and Ikomi, 2008; Odume *et. al.*, 2012; Arimoro and Keke, 2016).

Hemiptera, (bugs) were also found in both Stations 2 and 3. Their diversity and abundance in both stations were as a result of the vegetation cover and the bottom sediment of the river that favored their colonization. They were represented by families such as Nepidae; *Ranatra* sp, and *Lacocotrephes* sp. In Stations 2 and 3, Naucoridae and Hydrometridae were found only in station

2. Similar studies reported most of the above hemipterans from their works on Nigeria Freshwater (Arimoro and Ikomi, 2008; Emere and Nasiru, 2009; Arimoro *et. al*., 2015; Arimoro and Keke, 2016; Ndana, 2017). Favorable environment variables such as substrate type, vegetation covers are the factors responsible for increased species richness and diversity of subtropical African waters (Arimoro *et. al.*, 2015).

4.2.3 Macroinvertebrate functional feeding group

The shredders and predators were found to be abundant in station 1 and 2, this could be attributed to the dense vegetation cover along this stations. The work is in conformity with the prediction of the River Continuum Concept which states that shredders will decrease in abundance from headwater to the mouth and that collector-gatherers, collector filterers and scrappers will increase downstream (vannote *et al.*,1980. Other work in this regard include that of Greathous and Catherine recorded that Habitat-weighted biomass of both collector–gatherers and collector–filterers decreased along the Río Mameyes continuum, from values much above the Coweeta Creek regression at high-elevation sites to values comparable to the Coweeta Creek continuum at low elevation sites. For shredders, habitat-weighted biomass showed a marginally significant trend of decreasing along the Río Mameyes continuum and was generally much lower than shredder biomass in the Coweeta Creek continuum

CHAPTER FIVE

5.0 CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion.

Several years back, the assessment of water quality was purely base on physicochemical parameters but such measurement cannot provide information on ecological integrity of the of the water bodies because of the effect of pollution on aquatic biodiversity. The advantage of using Macroinvertebrate Functional feeding groups over physicochemical parameters is to evaluate water quality status is that it evaluate water quality over a period of time, while physicochemical parameters tests give information only precisely for that moment when sample is taken.

River Chanchaga is an important source of water for Domestic and industrial activities of the riparian users. Poor management of this water bodies has led to the degradation of its uniqueness, thus there is need to provide efficient measures to protect and manage this freshwater resources, for sustainability and conservation of water quality and aquatic biodiversity. The physicochemical parameters measured during the study period revealed strongly that the surface water was fairly polluted.

5.2 Recommendations.

1. This study serves as a baseline survey therefore, there is need for more intensive study on the entire length of both streams to fully understand the general species composition and distribution along the streams.

2. There is also urgent need to reduce anthropogenic activities, channeling of drainage and dumping of waste into our water bodies so as to reduced erosion and contamination of our water bodies. Also restoration of aquatic ecology particularly at areas which are dominated by Human settlements, is highly recommended, large groups of macroinvertebrates were recorded even due to the stress by human activities, with the exception of plecoptera and trichoptera.

3. Adequate measures have to be taken to reduce the negative impacts of man on Nigerian water. Laws should be enforced by regulation agencies governing water bodies so as to protect aquatic biodiversity.

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