MACROINVERTEBRATE DIVERSITY AND WATER QUALITY PATTERN OF A MUNICIPAL STREAM IN DOKO DISTRICT, NIGER STATE, NIGERIA

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Abstract

Macroinvertebrates organisms form significant part of an aquatic ecosystem which are of ecological and economic importance because they maintain various levels of interaction within aquatic environment. Emikpata stream in Doko district, Niger State, Nigeria is used for a variety of purposes such as irrigation, cattle drinking and domestic purposes. The macroinvertebrate diversity and water quality patterns of the stream were evaluated for a period of eight months using the standard experimental techniques. Four different study stations were selected along the course of the stream designated as Stations 1, 2, 3, 4, respectively. A total of 625 individuals from 28 species and 19 families of invertebrate were recorded. Significantly higher ($P<0.05$) macro-invertebrate abundance was recorded from dry season than in the wet season. The results of the physicochemical parameters showed that temperature (23.0 - 27.0 ^{0}C), flow velocity (0.29-0.30 m/s), conductivity (49.1 - 110.0 us/cm), dissolve oxygen (5.97 - 6.35 mg/L), total hardness (12.3-18.0 mg/L), total alkalinity (13.0-20.5 mg/l), phosphate (0.60 - 1.12 mg/L) , potassium (1.74 - 1.92 mg/L) was not significant ($P>0.05$) among the sample stations while biological oxygen demand (3.25-3.87 mg/L), pH value (6.0 - 6.32), chlorine (10.71 - 32.79 mg/L), nitrate (1.83 - 3.69 mg/L), sodium (7.24 - 9.02 mg/L), showed significant differences ($P<0.05$) between the sample station.. The CCA result showed strong relationships between species abundance and measured environmental variables. Emikpata Stream is found to be under minimum anthropogenic impact and is impaired in the downstream sections. Higher population of pollution tolerant macroinvertebrates groups and the tasting water quality of the surface water during the sampling period were implications of pollution stress caused by anthropogenic activities, decomposing domestic wastes and inorganic fertilizer washed into the stream from various nearby farms.

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CHAPTER ONE

1.0 INTRODUCTION

1.1 Background to the Study

Macroinvertebrates organisms are significant part of an aquatic ecosystem which are of ecological and economic importance because they maintain various levels of interaction within aquatic environment (Dobson *et al*., 2002). Biomonitoring of this organism may help to conserve and making management decision in an area. Macroinvertebrates have limited mobility and can stay in an area for some time without moving away easily. The type of the macroinvertebrates species obtained may be used as indicator of the status of the water quality of that environment at that location in a particular time (Arimoro and Keke 2016). Macroinvertebrates have high variability and are significant to predict the effect of short term environmental variation which are used to distinguish some characteristics of rivers and streams across the globe (Barbour *et al.,* 1999). According to Uwem and Edet (2016) substrate is among the most important factor in the distribution of macrobenthic invertebrates, although alterations in physico-chemical parameters such as temperature and salinity and food availability also play vital role in determining the extent of distribution and abundance of macrobenthic invertebrates species in aquatic ecosystem and they plays a critical role in the functioning of aquatic environment. Also, they constitute a major link in the aquatic food chain (Olomukoro *et al*., 2013; Uwem and Edet., 2016).

Freshwater pollution by human activities is becoming a matter of urgent concern threatening environmental productivity, sustainability and further social economic development in sub-Saharan Africa (Arimoro and Ikomi., 2008; Nyenje *et al.,* 2010; Arimoro and Keke., 2016). Several uses of aquatic ecosystems, includes laundry, water source for drinking, irrigation, hydropower generation as well as riparian activities on rivers' catchments such as unregulated land use and landscape alteration, have led to both biotic and physical deterioration of aquatic environment (Nyenje *et al.,* 2010). In Nigeria, land use changes on various catchments, agro-industrial activities and rapid urbanization pose threats to the well-being of aquatic environment and alters the composition and abundance of macroinvertebrates (Arimoro and Ikomi, 2008; Andem *et al*., 2014; Arimoro *et al*., 2015). Also, human population and industrial activities are increasing; hence there is greater threat of water pollution. Diverse inputs of pollutants in most metropolitan area of Nigeria include domestic, industrial waste waters and rainwater surface effluents which flows through the urban waterways primarily into the three main river systems (Ayoade and Olusegun, 2012). The spatio-temporal functional and structural compositions of macroinvertebrate assemblage in any stream system can be influenced by human activities (Arimoro and keke 2016). In the face of changing and intensifying human activity in catchments draining into the stream, there is a need to assess the current status of water quality and benthic invertebrate fauna assemblage in the river and to test protocols for future monitoring.

Most rivers in Nigeria, particularly those in urban areas are now being used for dumping both solid and liquid wastes, these high-polluting activities are now threatening the sustainability and functionality of freshwater ecosystems in Nigeria (Arimoro and Oganah, 2010). Keke *et al* (2017) reported that most the vast Nupe flood plain and it tributaries and riparian vegetation in Niger State are used for extensive fisheries activities and serve as spawning and nursery ground for a number of fish species, which depend largely on several macroinvertebrates organisms for survival. Also, they are used for irrigation of crops as well as sources of drinking water for both human and livestock.

Emere and Nasiru (2008) reported that most major cities contain a number of water ways such as drainages which are channeled directly into water bodies such as streams and rivers. Those water bodies have been subjected to increasing pollution from contaminated surface water runoff from industrial, agricultural, residential, commercial, recreational areas and institutions such as schools and hospital.

Edegbene *et al.,* (2015) revealed that River Chanchaga, in North central Nigeria is an important river flowing through several Local Government Areas in Niger State of Nigeria. It is a municipal river which is mainly used by the riparian communities and environs as source of potable water, irrigation and other domestic activities. Some stations of the river is presently faced with perturbation arising from car washing, bathing, illegal gold mining, and industrial activities at its catchment. All these anthropogenic activities affect the distribution and survival of macroinvertebrates across the river.

1.2 **Statement of the Research Problem**

Most uses of water in most part of Nigeria compromise water quality and the integrity of the aquatic ecosystems (Arimoro *et al*., 2015). With increase human activities such as industrialization and urbanization along Emikpata stream couple with other anthropogenic activities which include laundry, farming, bathing and drinking along the stream which is threatening the sustainability and integrity of biodiversity and water quality. However, since there is increase human activities on the streams thus there is need to assess the current health status of the water quality and macroinvertebrates assemblage of this streams which will serves and provide baseline information on biomonitoring guides of Emikpata stream.

1.3 Justification of the Study

The result from this study will give a base line information on the macroinvertebrate diversity and water quality pattern of Emikpata stream. It will also give us insight on the level of anthropogenic activities which may cause the change in the physico-chemical parameters. The information from the study area will also justify whether the changes in physico-chemical parameters effect the level of macroinvertebrate.

Emikpata stream in Niger State is main source of water to the nearby settlements with the increase in population of the surrounding number of villages in which the water are mostly used for domestic activities such as drinking, laundry, bathing, washing of plates and also water from this stream is used for irrigation of crops in nearby farmland. In this regards, biological monitoring as proved to be an important tool in assessing the condition of this water body. Also, biological and chemical data are essential in understanding ecosystem integrity. This study will provide baseline information on the abundance and diversity of macrobenthic invertebrates in relation to physico-chemistry of Emikpata stream in Niger State.

1.3 Aim and Objectives of the study

This study is aimed to assess the macrobenthic invertebrate assemblage and water quality status of Emikpata stream in Doko district of Niger state.

The objectives of the study are to determine the;

i Macroinvertebrate species composition and distribution in Emikpata stream.

ii. Physico-chemical parameters of Emikpata stream. .

iii. Spatio-temporal variations of macroinvertebrate assemblage and physico-chemical parameters of Emikpata stream.

CHAPTER TWO

2.0 LITERATURE REVIEW

The management of waters is of great importance for the life of our society and one of the challenges to be met by future generations. The sustainable use of water resources for their exploitation in different aspects is essential. Also, the maintenance of good water quality, both sanitary and environmental, is essential, since it depends largely on the conservation of biodiversity. Water is an important and essential substance in protoplasm and is the basis of life. Many lower organisms live in direct contact with water. In higher animals the cells are in contact with the intercellular fluid containing water. Water is found to be 50% to 97% by weight to all plants and animals and about 70% of human body (Susmita and Bhulyan 2006). Several uses of water include laundry, water source for drinking, irrigation, hydropower generation as well as riparian activities on rivers' catchments such as unregulated land use and landscape alteration, have led to both biotic and physical deterioration of aquatic environment (Nyenje *et al*., 2010).

Water pollution is an old phenomenon, the rate of industrialization and consequently, urbanization has aggravated its effect on most of the Nigeria rivers such as Ogunpa River, Oyo State as reported by Ogidiaka *et al*. (2012). Availability of safe and reliable source of water is an essential prerequisite for sustained development. Water quality assessment is of immense importance to practices involving the use of water bodies such as in the management of fisheries, water supply, pollution, irrigation and sewage reservoir and impoundment, to mention but a few. Pollution status of water bodies are usually expressed as biological and physico-chemical parameters (Adakole, 2001). Water pollution is of great consequence because both terrestrial and aquatic life may be affected; it may cause disease due to the presence of some hazardous substances that, may distort the water community, add odours and significantly hinder economic activities (Asonye *et al.,* 2007).Water pollution by human activities is becoming a matter of urgent concern threatening environmental productivity, sustainability and further social economic development (Arimoro and Ikomi., 2008; Nyenje *et al*., 2010; Arimoro and Keke., 2016). The physico-chemical properties of water quality assessment give a proper indication of the status, productivity and sustainability of a water body (Djukic *et al*., 1994). The changes in the physico-chemical characteristics like temperature, transparency and chemical elements of water such as dissolved oxygen, nitrate and phosphate provide valuable information on the quality of the water, the source(s) of the variations and their impacts on the functions and biodiversity of the reservoir. Physico-chemical properties of the water get varied season wise and in addition, anthropogenic activities such as agriculture, urbanization, domestic sewage, in the catchment area result in the deterioration of water quality (Verma *et al.*, 2012). Temperature, turbidity, nutrients, hardness, alkalinity and dissolved oxygen are some of the important factors that play a vital role for the growth of living organisms in the water body. The physical and chemical characteristics of water bodies and their immediate biotypes are one of the major factors in determining the diversity, abundance and distribution of macroinvertebrates. The water chemistry of an aquatic environment can be evaluated by the disturbance from the local surrounding land used pattern and other anthropogenic activities across the reach of the river (Edegbene *et al*., 2015).

2.1 Use of Physico-chemical Parameters to Assess Water Pollution

Water quality indicates the relation of all hydrological properties including physical, chemical and biological properties of the water body. Hence, water quality assessment involves analysis of physico-chemical, biological and microbiological parameters that reflects the biotic and abiotic status of ecosystem (Emere and Nasiru, 2009).

2.1.1 Dissolved oxygen

Higher values of dissolved oxygen indicate good aquatic life. Dissolved oxygen enters water through the air or as a plant by-product. From the air, oxygen can slowly diffuse across the water surface from the surrounding atmosphere, or be mixed in quickly through aeration, whether natural or man-made. The aeration of water can be caused by wind (creating waves), rapids, waterfalls, ground water discharge or other forms of running water. Dissolved oxygen is also produced as a waste product of photosynthesis from phytoplankton, algae, seaweed and other aquatic plants (Mustapha, 2008).

The oxygen requirements for organisms may vary and an increase or decrease which exceeds the required limit will have an adverse effect on the organism. Some organisms are very sensitive to the presence of dissolved oxygen and their absence signifies an alteration in the dissolved oxygen level. These organisms include most mayfly, stonefly, and caddisfly nymphs (Dadi- Mamud *et al.*, 2014).

2.1.2 pH

pH is defined as the intensity of the acidic or basic character of a solution at a given temperature. pH is the negative logarithm of hydrogen ion concentration (pH=-log [H+]). The pH in water samples range from 7.0 to 7.85. The pH of water is important for the biotic communities as most of the plant and animal species can survive in narrow range of pH from slightly acidic to slightly alkaline condition (Goher , 2002). The absence of some organisms like carps, suckers, snails, clams, mussels indicates that the water body is acidic hence they can only be found in water that is alkaline, that is, water with pH level of above 7.0. The pH values above 8 in natural water are produced by photosynthetic rate that demand more carbondioxide (CO_2) than quantities furnished by respiration and decomposition (Wani and Subla, 1990). The pH of water also depends on the relative quantities of calcium, carbonate and bicarbonate.

2.1.3 Biochemical oxygen demand

The biochemical oxygen demand may be defined as the oxygen required for the microorganism to performed biological decomposition of dissolved solids or organic matter in the waste water under aerobic conditions. At high BOD levels, organisms such as macro invertebrates that are more tolerant of lower dissolved oxygen (i.e. leeches and sludge worms) may appear and become numerous. Organisms that need higher oxygen levels (i.e. caddisfly larvae and mayfly nymphs) will not survive. The BOD level of polluted water may range from 4ppm and above indicating that the water is becoming polluted with organic matter which encourages the presence of bacteria to decompose them (Seema., 2015).

2.1.4 Electrical conductivity

Water capability to transmit electric current is known as electrical conductivity and serves as a tool to assess the purity of water (Murugesan *et al.*, 2006). This ability depends on the presence of ions, their total concentration, mobility, valence, relative concentrations and temperature of measurement (Shinde *et al*., 2011). The electrical conductivity ranged from 2.15 to 3.47 Ω/cm. Conductivity shows significant correlation with ten parameters such as temperature, pH value, alkalinity, total hardness, calcium, total solids, total dissolved solids, chemical oxygen demand and chloride of water (Kumar and Sinha, 2010).

2.1.5 Total dissolved solids

Solids refer to the suspended and dissolved matter in water (Nicola *et al.*, 2010). They are very useful parameters describing the chemical constituents of the water and can be considered as edaphically relation that contributes to productivity within the water body (Goher, 2002). In natural water dissolved solids are composed mainly of carbonates, bicarbonates of calcium, magnesium, sodium, potassium, iron and manganese. Indeed, high concentration of total dissolve solids enriches the nutrient status of water body which results into eutrophication of water (Mustapha., 2008). Eutrophication of water leads to the depletion of oxygen and increase in microbial activities thereby altering the abundance of macroinvertebrates such as the mayfly and the caddisfly.

2.1.6 Temperature

The temperature plays a crucial role in physico-chemical and biological behaviour of aquatic system (Dwivedi and Pandy, 2002). Temperature is one of the most important factors in the aquatic environment (Singh and Mathur, 2005). Temperature is a measure of the intensity (not the amount) of heat stored in a volume of water measured in calories and is the product of the weight of the substance (in gms), temperature (ºC) and the specific heat (Cal g - ºC-1). In general, atmospheric and water temperature depend on geographical location and meteorological conditions such as rainfall, humidity, cloud cover, wind velocity, etc. The atmospheric and water temperature go more or less hand in hand. Water temperature is of enormous significance as it regulates various abiotic characteristics and activities of an aquatic ecosystem (Singh and Mathur, 2005). Temperature is known to influence water chemistry, especially the parameters like dissolved oxygen, solubility, pH, conductivity, etc. The solubility of oxygen in water increases when water temperature decreases (Singh and Mathur, 2005). High temperature can increase solubility and thus toxicity of certain element which can cause irritation to macroinvertebrate at severe cases the organisms are altered.

2.1.7 Total hardness

The total hardness of water is not a specific constituent but is a variable and complex mixture of cations and anions. Principally the water hardness is changed by ions such as calcium and magnesium. The highest amount of total hardness in the water is as a result of the presence of high content of calcium and magnesium in addition to sulphate and nitrate which indicates pollution from sewage waste and the low amount of total hardness is due to low concentration of calcium and magnesium present in water (Abowei and Ekubo, 2011).

2.1.8 Alkalinity

Alkalinity in natural water is due to free hydroxyl ion and hydrolysis of salts formed by weak acid and strong bases and also due to salt containing carbonates and bicarbonates silicate and phosphate along with hydroxyl ion in the free states (Arimoro *et al.,* 2015). The change in alkalinity depends on carbonates and bicarbonates, which in turn depends upon release of carbondioxide (CO_2). Change in carbonates and bicarbonates also depend upon release of carbondioxide through respiration of living organisms. The presence of large amount of sewage waste and organic pollutant in water effect photosynthesis rate, which also result in death of plants and living organism. The degradation of plants, living organism and organic waste might also be one of the reasons for increase in a carbonate and bicarbonate, resulting in an increase in alkalinity level (Chaurasia and Pandey, 2007). The more alkaline in the water the more there is also a risk of ammonia toxicity which can make the water polluted.

2.1.9 Sodium

Sodium is a natural constituent of raw water, but its concentration is increased by pollution sources such as rock salt, precipitation runoff, soapy solution and detergent (Ogidiaka *et al.,* 2012). The high level of sodium is attributed to intrusion from marine ecosystem and surface run-off, as it carries the salt dissolved from the surrounding area. The addition of waste water containing soap solution and detergent from the surrounding slummy area are also responsible for the increase in sodium level in the water bodies there by making the water polluted (Mustapha, 2008).

2.2 Chlorides (Cl-)

Chloride is one of the most important parameter in assessing the water quality (Arimoro , 2009). Higher concentration of chlorides indicates higher degree of organic pollution. Concentration of chlorides (Cl) in sea water is around 20,000 mg/l, in unpolluted rivers between 2 and10 mg/l and in rain water 2 mg/l. When it is above 200mg/l, the water is unsuitable for human consumption. Maximum permissible limit with regard to chloride content in natural freshwaters according to WHO is 250 mg/l (WHO ,2011). The chloride in drinking water originates from natural sources, sewage and industrial effluents, urban runoff containing de-icing salt and saline intrusion. Presence of high chloride level is due to frequent run-off loaded with contaminated water from the surrounding slum area and evaporation of water (Verma *et al.,* 2012). The content of chloride is due to the dilution of lake water by rain.

2.3 Macroinvertabrates as Indicators in Assessing Water Pollution

In the past, water quality was assessed using only physico-chemical parameters, but these variables only reflect punctual pollution. The use of biological indicators is more adequate to detect long-term changes in water quality, since aquatic organisms are adapted to specific environmental conditions (Uwem and Edet, 2016). If these conditions change, some organisms can disappear (intolerant) and be replaced by others (tolerant). Therefore, variations in the composition and structure of macroinvertabrates assemblages in waters can indicate possible water pollution. Macroinvertebrates can be useful indicators of water quality because these communities respond to integrated stresses over time, which reflect fluctuating environmental conditions. Community responses to various pollutants (e.g. organic, toxic, and sediment) may be assessed through interpretation of diversity, known organism tolerances, and in some cases, relative abundances and feeding types. Macroinvertebrates have different levels of tolerance for low water quality. Certain taxa or groups of organisms are known to be more or less tolerant of polluted conditions of water. The presence or absence of these organisms can be used to evaluate the level of pollution or human disturbance of water (Arimoro and Keke, 2016)

2.4 Responses of Macroinvertebrates Communities to Seasonal Changes.

Macroinvertebrates structure is affected by environmental factors such as temperature, pH, dissolved oxygen and pollution (Sharma and Rawat, 2009; Saghali *et al.*, 2013). Macroinvertebrates can be useful indicators of water quality because these communities respond to integrated stresses over time, which reflect fluctuating environmental conditions. Community responses to various pollutants (e.g. organic, toxic, and sediment) may be assessed through interpretation of diversity, known organism tolerances, and in some cases, relative abundances and feeding types. The abundance of macroinvertebrate in stream is known to be influenced by biotic conditions such as hydraulic stress, temperature and water chemistry (Nicola *et al*., 2010; Linares *et al*., 2013). The dry and rainy season variation is of a great importance in determining the ecological changes in the tropics; rainfall distribution patterns which have a great impact on both the chemistry of water as well as the population dynamics of the fauna (Linares *et al*., 2013).

Arimoro (2009) conducted a research on the ecological impact of rubber effluent on macroinvertebrate communities of the Adofi River, Niger Delta area of Nigeria. The rubber effluent impacted negatively on the sediment and water chemistry by elevating the levels of some heavy metals (Nickel (Ni), Lead (Pb), and Zinc (Zn), chemical parameters as biochemical oxygen demand (BOD_5), chemical oxygen demand (COD), conductivity and the amount of nutrients at the discharged site. A combined total of 87 macroinvertebrate taxa were recorded from the three stations of the river. The abundance and community structure showed variation between the effluent impacted site and the reference sites as most sensitive macroinvertebrate taxa were completely missing from the effluent impacted site. The preponderance of oligochaetes and some dipteran taxa associated with low dissolved oxygen levels in the impacted site bears credence to the fact that the chemical components of the rubber effluent waste water were lethal to some aquatic forms.

Arimoro *et al.* (2011) conducted a research on the spatio-temporal variation of macroinvertebrates in relation to canopy cover and other environmental factors in Eriora River, Niger Delta in which the effects and possible interactions of environmental factors and canopy cover on macro- invertebrate community structure (abundance, rich-ness, and diversity) were examined in four stations in Eriora River, southern Nigeria bimonthly from May to November 2010. The river supported diverse macroinvertebrates in which the upstream sampling stations with dense canopy cover were dominated by Decapoda, Ephemeroptera, Odonata, Gastropoda, Trichoptera, and Coleoptera while Diptera and Coleoptera were the benthic organisms found predominant at downstream stations with less canopy cover. Some caddisfly species such as *Agapetus agilis*, Trichosetodes species and the stone- fly (Neoperla) species were present upstream and were found to be potential bioindicators for a clean ecosystem. The blood worm *Chironomus* species and *Tabanus* sp. were abundant at the downstream of the river and are considered potential bioindicators for an organically degrading ecosystem. Some environmental factors varied temporally with significantly higher macroinvertebrate abundance and richness in the month of May.

The ecological integrity of upper Warri River, Niger Delta using aquatic insects as bio indicators conducted by Arimoro and Ikom, (2008) showed that the composition and density of the upper Warri River, Niger Delta, Nigeria were assessed and the influence of different physical and chemical variables on their distribution was explored at three designated stations. A total of 57 taxa were recorded with Station 2 accounting for the greatest Ephemeroptera–Plecoptera–Trichoptera (EPT) richness. Abundance of the aquatic insects was affected by the nature of the substrate, macrophytes and canopy cover at the various stations examined. Generally, pollution tolerant insect taxa such as chironomids and culicids larvae were only sporadically present.

Arimoro *et al.* (2011) also reported on the variations in macrobenthic community structure in time and space along a pollution gradient were examined in a small Niger Delta creek. Salinity fluctuated between fresh and mesohaline conditions with values ranging from 0.4 to 5.2, and conductivity ranged from 16.9 to 36.0 μS cm–1. The upper creek was relatively free of gross pollution, with high dissolved oxygen and low nutrient and salinity levels. At its lower end, BOD_5 was relatively high and nutrient levels were high, indicating substantial organic input. The middle and upper creek were dominated by *Naboandelus africanus*, *Appasus* sp., *Laccotrephes* sp., *Plea* sp. (Hemiptera) and *Georissus* sp. (Coleoptera). Sensitive taxa such as *Neoperla* sp. (Plecoptera), *Ecnomus* sp. (Trichoptera) and *Ephoron* sp. (Ephemeroptera) were restricted to the upper creek.

At the impaired site *Neritina* sp. (Mollusca), *Sesarma* sp. (Decapoda), *Nereis* sp. (Polychaeta) and *Chironomus* sp. (Diptera) dominated the assemblage.

Keke *et al.* (2017) reported on the intensity of human-induced impacts on the distribution and diversity of macroinvertebrates and water quality of Gbako River, North Central, Nigeria, Four study stations were selected along the river course (upper reaches of less human impacts through mid-reaches with relative high human impacts to lower reaches of less human impacts), designated as Stations 1, 2, 3, and 4. Water temperature (23.10–30.00 C), flow velocity (0.10–2.40 m/s), conductivity (32.00–110.00 S/cm), and alkalinity (7.50–10.50 mg/L) were similar in all the stations sampled. However, BOD (2.20–6.00 mg/L) and nitrates (0.50–1.67 mg/L) were significantly higher ($p<0.05$) in Station 3. A total of 676 individuals from 41 invertebrate taxa in 27 families from nine orders were collected from the four stations during the study. Aquatic insects represented 85.4 % of the taxa and 76.6 % of all individuals collected. The rest of the fauna was composed of Mollusca, Crustacea, and Gastropoda. Ten macroinvertebrate taxa, *Philaccolus, Pseudocloeon, Bugilliesia, Calopteryx, Coenagrion, Brachythemis leucostica, Gomphus, Hydrometra, Sphaerudx, and Potadoma* species, were found in all the four sampled stations. The overall 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 when compared with the less disturbed stations 1 and 4.

Furthermore, the marginally high nutrient levels (phosphate and nitrate) obtained at these stations are an indication that the water body is becoming stressed with organic input and increasing levels of anthropogenic activities. The canonical correspondent analysis (CCA) ordination revealed strong relation- ships between species abundances and measured environ- mental variables. The low relative abundance of

Ephemeroptera–Plecoptera–Tricoptera (EPT) taxa indicated that the environmental conditions were relatively stressed, along the whole stations. However, the abundance of mayflies (Ephemeroptera), Coleoptera (Gyrinus, Dytiscus), and Anisoptera in all the sites studied is an indication that the sites are relatively free from gross pollution, especially at the upper reaches.

Arimoro and Muller (2009) also reported in is study that the faunistic composition and spatiotemporal variations in density and diversity in River Orogodo (Southern Nigeria) was investigated at five ecologically distinct stations over a 12-month period. The mayfly nymph community responses to environmental variables were evaluated by means of biological measures and multivariate analysis (redundancy analysis [RDA]). Thirteen morphologically distinct taxa belonging to six families were identified. The dominant taxa were Afrobaetodes pusillus (23.1%), Baetis sp. (13.7%), and Caenis cibaria (11.4%). The density of Ephemeroptera differed significantly ($p < 0.05$) both in space and time. Diversity was influenced by substrate heterogene- ity which in turn was influenced by catchment processes such as flooding and anthropogenic activities especially abattoir effluent. Based on the RDA ordination and relative abundance data, Baetis sp. dominated at impacted stations while a more equitable distribution of species were observed in less disturbed sites. Water velocity, canopy cover, nature of bottom sediments, and the amount of dissolved oxygen also accounted for the variations in Ephemeroptera densities at the different stations. Shannon diversity, taxa richness, and evenness were lowest in Station 3.

Arimoro *et al.* (2015) reported on the study which evaluated the impact of anthropogenic influences on the Ogba River using water chemistry and macroinvertebrate data sets obtained over a period of 6 months between January and June 2012. Four stations, stations 1–4, characterised by various human activities were chosen along the river. Organic wastes from domestic and industrial sources were the major point sources of pollutants. Station 2 where the municipal wastewater drains into the river had elevated values off low velocity, BOD_5, sulphate, phosphate, nitrate and sodium. Based on the canonical correspondence analysis (CCA), 5-day biochemical oxygen demand (BOD_5), sulphate, nitrate and phosphate were the main factors that help to shape the macroinvertebrate assemblage structure of the Ogba River. Macroinvertebrates clustered strongly by stations than by seasons indicating that water quality differences between the stations were responsible for the observed differences in the biotic assemblage. The preponderance of naidid oligochaetes, baetid nymphs and certain tolerant dipteran taxa including chironomids and ceratopogonids at all four stations was an indication that the entire water body was stressed. The odonates were the single most abundant taxa in which their dominance could be attributed to the vegetative nature of the stream, favouring odonate colonisation. Overall, the responses of macroinvertebrates to stress were reflected by the different assemblage structures recorded at the four study stations. Substrate and microhabitat obliteration and poor water quality appeared to be the factors responsible for the observed assemblage structure in the Ogba River.

Zhang *et al.* (2016) recorded a total of 104 taxa; *Bellamya aeruginosa* had the highest fre- quency of occurrence (71 out of 93 sites), followed by *Limnodrilus hoffmeisteri* (49) and *Corbicula fluminea* (42). Oligochaeta was the most abundant taxonomic group, accounting for 89.42% of total macroinvertebrate abundance. Benthic communities were mainly characterized by pollution- tolerant taxa, such as *L. hoffmeisteri* (Oligochaeta), *B. aeruginosa* (Gastropoda), and *Polypedilum scalaenum* (Chironomidae), indicating severe anthropogenic disturbance and habitat degradation. The macroinvertebrate diversity decreased from the western hills to the eastern plains aquatic ecoregions; the Shannon-Wiener and Margalef indices differed significantly between the two ecoregions. The abundances (%) of gathering collectors increased from upstream to down- stream, but scrapers showed the opposite trend, consistent with the river continuum concept. Community structure and spatial patterns of macroinvertebrates in the Lake Taihu Basin were strongly correlated with habitat diversity, nutrient loads, and aquatic vegetation coverage. These results provide valuable information for effective management practices of biodiversity conservation in stream and river ecosystems of the Lake Taihu Basin.

According to a research work carried out by Aganmwonyi and Iriabgonse (2015) on the survey of the impact of cattle grazing on macro invertebrate fauna of Ovia River was carried out between January and June 2004. Macro invertebrate and water samples were collected from three sampling locations; Station I (new grazing area for cattle), Station II (initial grazing area) and Station III (control location). A total of 33 taxa of macro invertebrates with 831 individuals were encountered in the study.

Zabbey and Hart (2016) reported environmental forcing of intertidal benthic macro fauna of woji Creek in the Niger Delta where demands for such data is pressing due to impending pollution. We present a rare case of available pre-spill data of how distribution and abundance of macro benthic in fauna were structured by some physical and chemical variables of interstitial water in woji Creek, lower eastern Niger Delta, Nigeria, before two major oil spills impacted the creek in 2008. Monthly composite samples of macrobenthos and interstitial water in four soft-bottom unvegetated intertidal flats were analysed for one year. Thirty-six taxa, twenty-two families and four classes of macro zoobenthos were recorded. The bivalves Lorepis aberrans, Macoma innominata, Senilia senilis, and polychaetes Nereis diversicolor, N. virens, N. pelagic and

Clymenella torquata were eurizonal in distribution and abundant, attaining sub-dominant and dominant status at the sites.

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Description of the Study area

The study was carried out on in Emikpata stream, Doko district of Niger State, North Central Nigeria (Figure 3.1). The town lies within the latitude of 090 03’ 8N and 09006’40” N and longitude of 06001’0” E and 06002’42” E. It is in guinea savannah region characterized by wet and dry seasons. The wet season starts from April to October while the dry season is from November to March. Sampling stations were selected based on the level of activities of the riparian users. For the purpose of this study, the study areas were divided into four stations (Emi – Bako, Kuchi gbako, Gadza, Amgbasa) and each station is 6KM away from each another.

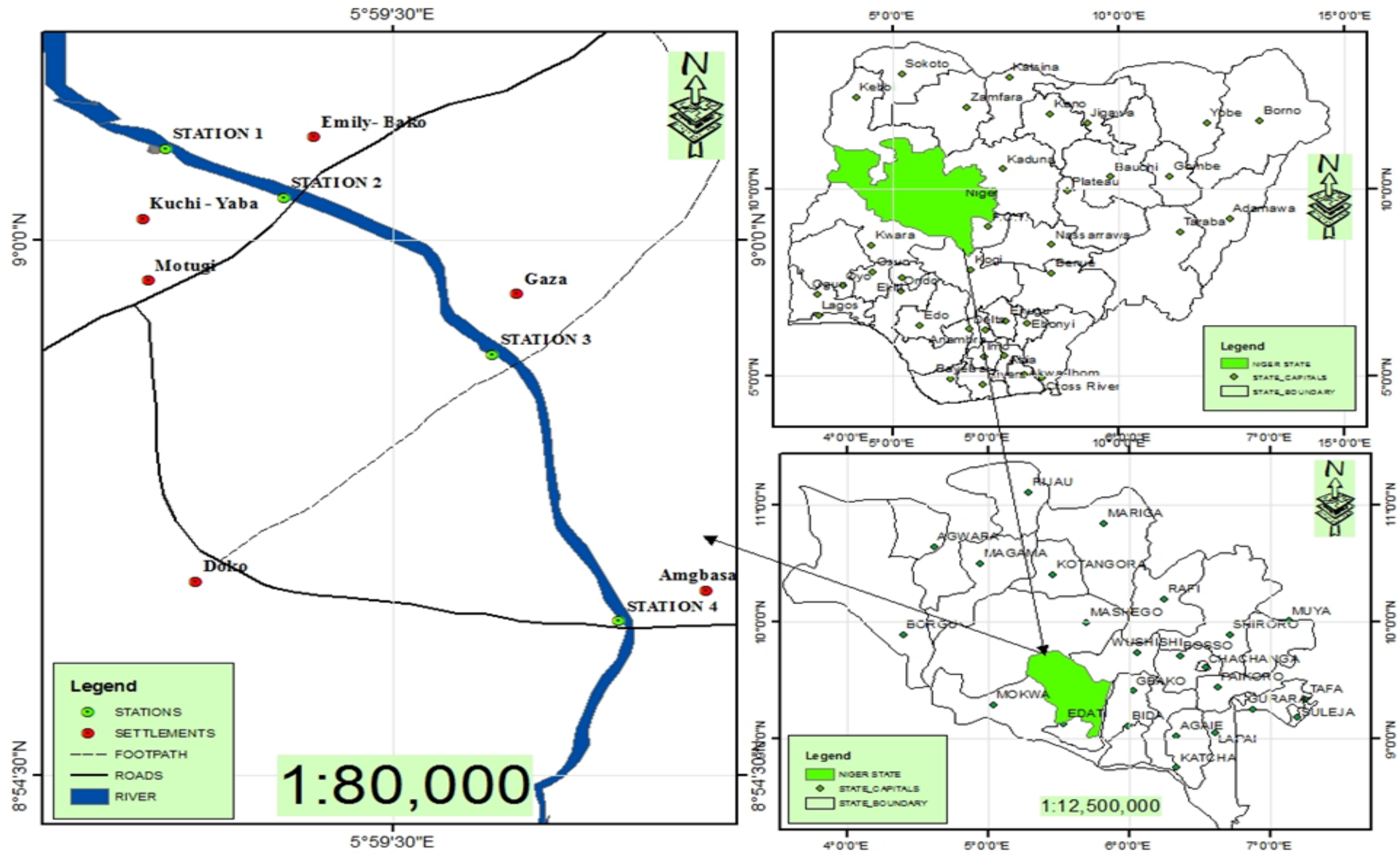

Fig 3.1 Map of the study area of Emikpata stream, Doko district of Niger State.

3.2 Sampling stations

Station 1, Emikpata stream. This station was located very close to Emi Bako village close to it catchment in Doko district. The vegetation cover is thick riparian (with few mangoes trees nearby). The vegetation consists mainly of nymphae species. This station is has no human activities.

Plate 3.2.1 Station 1 Emi bako of Emikpata stream in Doko Niger State.

Source; Field photograph (2018)

Station 2 Emikpata stream: This station was located under a motorable bridge between Kuchi Yaba. The vegetation cover is very few riparian and has trees covering the surrounding. The vegetation consists mainly of nymphae species. Washing of clothes, washing of plates and other human activities take place here.

Plate 3.2.2 ; Station 2, Kuchi gbako bridge of Emikpata stream in Doko, Niger State.

Source: Field photograph (2018)

Station 3, Emikpata stream. This station is 6km away from Station 2 (Gaza). It was located in an open place with a lot of vegetative cover. In these station there is less human activities here but a lot of animals like grazing animal drink water there and also used for the irrigation of vegetables.

Plate 3.2.3; Station 3 Gaza village of Emikpata stream in Doko, Niger State.

Source: Field photograph (2018)

Station 4 Emikpata stream. This station is located 6km away from Station 3 (Amgbasa). This station has few vegetation cover with macrophytes. This station was relatively free from human activities except farming due to its location in the outskirt of the town.

Plate 3.2.4; Station 4 Amgbasa village bridge of Emikpata Stream in Doko, Niger State.

Source: Field photograph (2018)

3.3 Water Quality Sampling Techniques:

Water samples for physico-chemical parameters were collected monthly for a period of six months (July 2018 to February 2019) from four selected sampling stations in the Emikpata stream. Sampling period covers both the dry and wet seasons. The following physical and chemical parameters were determined

3.3.1 Temperature

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

3.3.2. Depth

The depth of the streams was measured by using a wooden meter rule stick. The rod was lowered below the water body at a selected point. Readings were taken to estimate the mean depth (Edegnene *et al.*, 2015)

3.3.3. Flow velocity

Flow velocity was determined by marking two points along the watercourse by fixing two long stick to the bottom of the stream. A floating object (tennis ball) was placed at one point. A stopwatch was used to record the time it took the floating object to be transported between the two stick points (Edegnene *et al.*, 2015 and Arimoro *et al.*, 2015)

Thus velocity (ms-1) = distance (m) / time taken (s)

3.3.4. pH (Hydrogen ions concentration)

The pH was measured by using a multipurpose switch meter (Hanna HI 991300/1) the device would be switched to pH mode and calibrated after which the device would be inserted into the water sample at 5cm below the surface water and allowed for some minutes to stabilized. The reading was taken and noted (APHA, 2012).

3.3.5. Electrical conductivity

Conductivity was measured using a portable switch gear electrolysis conductivity meter (Hanna HI 991300/1). The meter was set to the zero point and the sproule electrolytic conductivity was rinsed with the sample water. The water sample was poured into the sprouled and the knob was pressed and would be recorded accordingly (APHA, 2012).

3.3.6. Turbidity

Turbidity was measured by using a portable multipurpose machine (Hanna HI 991300/1). The meter was switched to turbidity mode and calibrated, after which the device was inserted into the water sample at 5cm below the surface water and allowed for some minutes to stabilize. The reading was taken and noted (APHA, 2012).

3.3.7. Dissolved oxygen (DO)

The dissolve oxygen DO samples were collected in duplicates from all the sampling stations using 250ml sampling bottles. Where the lighter bottles were used for DO. The bottles were first rinsed with the sample water before collection which were carefully done by immersing the bottle under the water surface and the bottled were allowed to over flow so as to avoid air bubbles inside. The DO bottles were fixed immediately at the sites.

The sample for DO concentration were fixed by adding 2ml of Winkler solution A (which is 40-50% Manganeous sulphate) and also 2ml of Winkler solution B (which is alkaline iodide solution) on the surface of the sample. The bottles were fixed by inversion (shaking severally up and down) and the samples were allowed to settle before been transported back to the laboratory for titration. In the laboratory 2ml of concentrated H_2SO4 were added and shaken as to dissolve the precipitate formed, after which 100ml of the sample were measured in a clean conical flask and were titrated with 0.025N sodium thiosulphate solution until a pale yellow or straw coloured solution were observed. Two drops of freshly prepared 1% starch solution was added into the solution as an indicator. The indicator immediately changed the colour from pale yellow to pale-black. Titration continued until the blue-black colour changed to colourless or disappeared. The volume of the titrant (sodium thiosulphate) were recorded and the dissolved oxygen concentration was expressed in Mg/L using the formula:

DO (mg/l) = $\frac{8 \ x \ 100 \ x \ N \ X \ V}{V}$

Where V= volume of water sample used for titration

v= volume of titrant (sodium thiosulphate)

N= Normality of titrant

3.3.8 Biological oxygen demand (BOD)

Biological oxygen demand sample were collected in duplicates from all the sampling stations using 250ml sampling bottles. The BOD determination were wrapped with aluminium foil and place in a black polythene bag to avoid light and then taken to laboratory where they are incubated at 20^0C for 5days in a dark coloured amber bottles. The BOD samples were allowed to stay for 5days after which the water were fixed and analyzed in the same method as that of DO. Afterwards, the BOD concentration was calculated using the formula (APHA, 2012).

BOD (mg/l) = D1-D2

Where D1= dissolved oxygen calculated in the lighter bottle

D2= dissolved oxygen calculated in the wrapped incubated bottled

3.3.9. Total Alkalinity

Total alkalinity was determined by measuring 100ml of water sample in a conical flask. A few drops of phenolphthalein indicator were added and there will be no colour change. Then add a few drop (about 2-4ml) of methyl orange indicator were added and yellow colouration developed. It was then titrated with 0.1NHCL until the yellow colour changed to the first color (APHA, 2012). The end point was recorded and total alkalinity were also calculated as

Total alkalinity = Volume of 0.1NHCL used × 100 / Volume of water used.   .

3.3.10. Nitrates-Nitrogen (NO3-N)

One hundred (100ml) of the water sample were poured into a 250ml of Erlenimyer flask. Then 2ml of phenol disulphuric acid was added immediately to the residue and stirred. It was then left for about 10 minutes. After about 10-15, minutes distilled water was added, stirred slowly and allowed to cool. Five to ten (5-10)ml of strong ammonia solution was added and yellow colour appeared. It was stirred again and allowed to settle. The absorbance was measured using 410nm in UV spectrophotometer and distilled water was used as the blank sample. It was calculated using NO3-N = reading from curve × 1000×D / ml of sample where D is the dilution factor

3.3.11. Phosphate- Phosphorus (PO4-P)

One hundred (100)ml of the water sample was measured into 250ml conical flask then 1 ml of denigers reagent was added, followed by 5 drops of stannous chloride ($SnCl_2$). A blue mixture was observed. The absorbance was measured at 690nm using a spectrophotometer and distilled water as blank. The PO4-P was determined using APHA (2012);

PO4-P= reading from curve × 1000×D / ml of sample

where D is the dilution factor

3.3.12 Sodium (Na) and Potassium (K)

About 10ml of the water sample was measured in a galas cubicle. The flame spectrophotometer was calibrated using distilled water as blank. The calibrated wire was immersed into the water sample and allowed for some minutes to stabilize. The reading was taken and noted (APHA 2012).

3.3.13 Total hardness

The water sample was thoroughly shaken and 25ml was taken and diluted to 50ml with distilled water. 2ml of phosphate buffer solution was added to bring the pH of the water sample to 10. Three drops of ferrochrome black indicator was also added. This was titrated with 0.01mol/L EDTA to a blue colour end point. Hardness was then calculated in line with APHA (2012) method.

3.3.14 Chlorine

The water sample was thoroughly shaken and 25ml was taken and diluted to 50ml with distilled water. It measured by titrating 50ml of the sample with standardized silver nitrate solution using potassium chromate solution in water as an indicator. The latter indicator is an adsorption indicator while the former makes a red colour compound with silver as soon as the chloride are precipitated from the solution and the measure is taking (APHA, 2012).

3.4 Macroinvertebrates sampling;

Kick samples of Macroinvertebrates were collected monthly (July 2018 to February 2019) with a D-frame net (250µm mesh) within an approximately 50-m wide portion of the river. Samples was taken from different substrata (vegetation, sand, and gravel biotypes). Samples collected from the net were preserved in 70 % ethanol. In the laboratory, samples were washed in a 250µm mesh sieve to remove substrates and macroinvertebrates taxa were picked out with the aid of forceps and were observed using a stereoscopic microscope (Olinpus). Sorted Macroinvertebrates were also identified to lowest taxonomic rank using the taxonomic list of species known to be available in Africa (Umar *et al.*, 2013)

3.5 Data Analysis

The mean range and standard deviation of each physico-chemical characteristic were calculated per station. Also, biological indices such as taxa richness and evenness (E) abundance, number of taxa, diversity index and dominance were computed using paleontological statistics software tool pack (PAST) by using ANOVA (analyses of variance), Canonical correspondence analysis (CCA). Both the physico-chemical characteristics and benthic fauna were also compared by using one-way analysis of variance (ANOVA).

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

4.1 Result

The result of Physicochemical parameters on the Emikpata Stream over a period of eight months (July 2018 to February 2019) were presented in Table 4.1. In the Emikpata Stream, the depth, pH, chlorine, nitrate and sodium differed significantly ($P<0.05$) among all the sampling stations as indicated by ANOVA. There were no significant differences ($P>0.05$) in temperature, flow velocity, DO, BOD_5, conductivity, total hardness, alkalinity, phosphate and potassium among the sampling stations of the stream.

Table 4.1. Mean summary of Physicochemical parameters of sampling stations in Emikpata stream, Doko district of Niger State.

Parameters	Stations				Probablities		WHO	NIS
	1	**2**	**3**	**4**	**Stations**	**Months**		
Temperature (mg/l)	23±0.94	23.42±1.13	27±1.09	24±1.04	0.361	1.74E-08	30-32	_
	(19.6-26.2)	(19.4-27.3)	(19.6-26.8)	(19.5-26.9)				
Depth (cm)	20.96±2.55*	23.1±1.98	23.26±2.17	24.1±1.55	0.024	4.08E-10	_	_
	(10.6-28.6)	(15.3-28.2)	(12.5-29.1)	(16.5-29.2)				
Flow velocity (m/s)	0.286±0.01	0.287±0.01	0.300±0.01	0.292±0.01	0.737	0.0308	_	_
	(0.22-0.359)	(0.238-0.338)	(0.268-0.354)	(0.250-0.32)				
DO (mg/l)	6.35±o.42	6.17±0.29	5.97±0.43	6.15±0.42	0.806	0.007	4	4
	(5-8)	(5-8)	(4-8)	(5-8)				
BOD (mg/l)	3.65±0.32	3.87±0.22	3.62±0.18	3.25±0.31	0.254	0.015	6	6
	(3-5)	(3-5)	(3-4)	(2-5)				
Ph	6.32±0.09	6.0±0.10*	6.1±0.09	6.2±0.15	0.002	1.33E-07	6.5-8.5	6.5-8.5
	(5.95-6.75)	(5..46-6.4)	(5.8-6.5)	(5.4-6.71)				
Conductivity (µ/Sc)	49.1±3.47	65.0±5.15	110±7.46	108±13.35	0.136	7.35E-06	1000	1000
	(35-62)	(48-85)	(85-144)	(55-151)				
Total Hardness (mg/l)	12.3±1.25	12.3±1.85	17.1±1.43	18.0±1.63	0.054	0.084	150	150

	(7-18)	(7-22)	(10-22)	(13-25)				
Total alkalinity(mg/l)	13.0±0.90	15.0±1.60	20.5±0.90	20.0±0.53	0.812	0.001	100	100
	(10-18)	(10-22)	(18-26)	(18-22)				
Chlorine (mg/l)	11.04±0.33	32.79±0.96*	13.35±1.37	10.71±0.45	1.33E-15	0.044	250	_
	(9.9-12.68)	(29.4-37.24)	(9.8-20.14)	(8.8-12.6)				
Nitrate (mg/l)	1.83±0.15	3.69±0.54*	2.43±0.41	2.41±0.10	0.0003	0.0017	50	_
	(1.3-2.62)	(2.32-6.85)	(1.53-5.25)	(2.18-3.11)				
Phosphate (mg/l)	0.60±0.04	0.90±0.09	1.12±0.14	1.01±0.12	0.092	0.185	5	_
	(0.46-0.86)	(0.61-1.31)	(0.77-1.85)	(0.6-1.51)				
Sodium (mg/l)	8.89±0.72	7.24±0.62*	9.02±0.90	8.03±0.70	0.003	1.94E-07	50	_
	(6.28_11.2)	(5.81-10.3)	(6.35-13.3)	(6.39-10.5)				
Pottasium (mg/l)	1.74±0.34	1.81±0.37	1.92±0.47	1.90±0.35	0.479	4.08E-13	1.00	_
	(0.98-3.6)	(11.1-3.9)	(0.95-4.77)	(0.90-3.96)				

Values followed by the same superscript alphabates in the row are not significantly different (P>0.05) by Duncan multiple range test * World health organization (WHO, 2011), Nigeria industrial standard (NIS, 2015)

4.1.1 Temperature of stream

Emikpata Stream Station 1 recorded low temperature in the month of July, 2018 (25.1), increased gradually August, 2018 (26.4) and September, 2018 (27.3) before steadily decreasing from October, 2018 (26.5) to January, 2019 (20.0) before a slight increase in the month of February, 2019 (24.7). Station 2 record the high temperature in July, 2018 (27.3), decreased in August, 2018 (26.8) and increase September, 2018 (28.1), before decrease in October, 2018 (26.7) and November, 2018 (20.2), also a slight increase in December, 2018 (23.6) and low in January, 2019 (22.2), February, 2019 (21.3). Station 3 also recorded low temperature in July, 2018 (26.4), increased gradually from August, 2018 (27.1) to October, 2018 (28.0) and a short fall in November, 2018 (22.8) and December, 2018 (21.2) before a slight rise in January, 2019 (27.0) and a fall in February, 2019 (24.7). Station 4 recorded low temperature in July, 2018 (26.1) before a gradual increase in the month of August, 2018 (27.4) to October, 2018 (28.2) and a decrease in November, 2018 (22.0), but slight increase in December, 2018 (25.4) and January,2019 (26.7) before a slight decrease in February, 2019 (20.5). There were no significant differences in the temperature between the four stations ($P>0.05$).

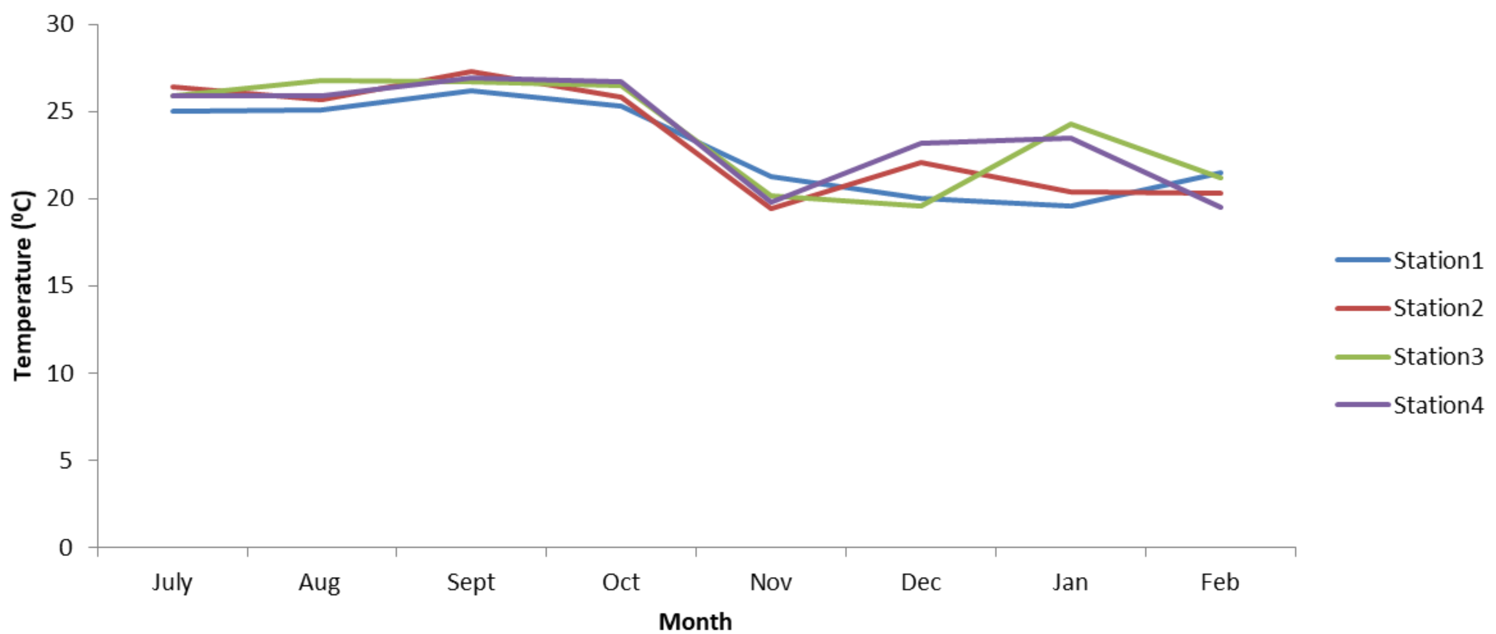

Figure 4.1.1: Spatio-temporal variation of Temperature in the sampling stations of Emikpata stream Doko district of Niger State.

4.1.2 Depth of stream

Station 1 recorded the lowest depth in July, 2018 (27) and August, 2018 (25) before a steady increase in September, 2018 (29) and a fall in the month of October, 2018 (28) to February, 2019 (15). Station 2 recorded low depth in July, 2018 (29) and a steady decrease in August, 2018 (29), to October, 2018 (28), but a decrease from November, 2018 (28.) to February, 2019 (19). Station 3 recorded low depth in July, 2018 (28) and increase steadily in August, 2018 (29), before a steady decrease in September, 2018 (29), to December, 2018 (22) before a rise in January, 2019 (23) and high fall in February, 2019 (16). Station 4 recorded the highest depth in July, 2018 (29) and decrease in August, 2018 (25) before a rise in September, 2018 (30) and decrease in October, 2018 (29) to November, 2018 (24), further rise in December, 2018 (26) and steady fall in January, 2019 (23) to February, 2019 (17). There were significant difference between station 1 and three other stations ($P>0.05$).

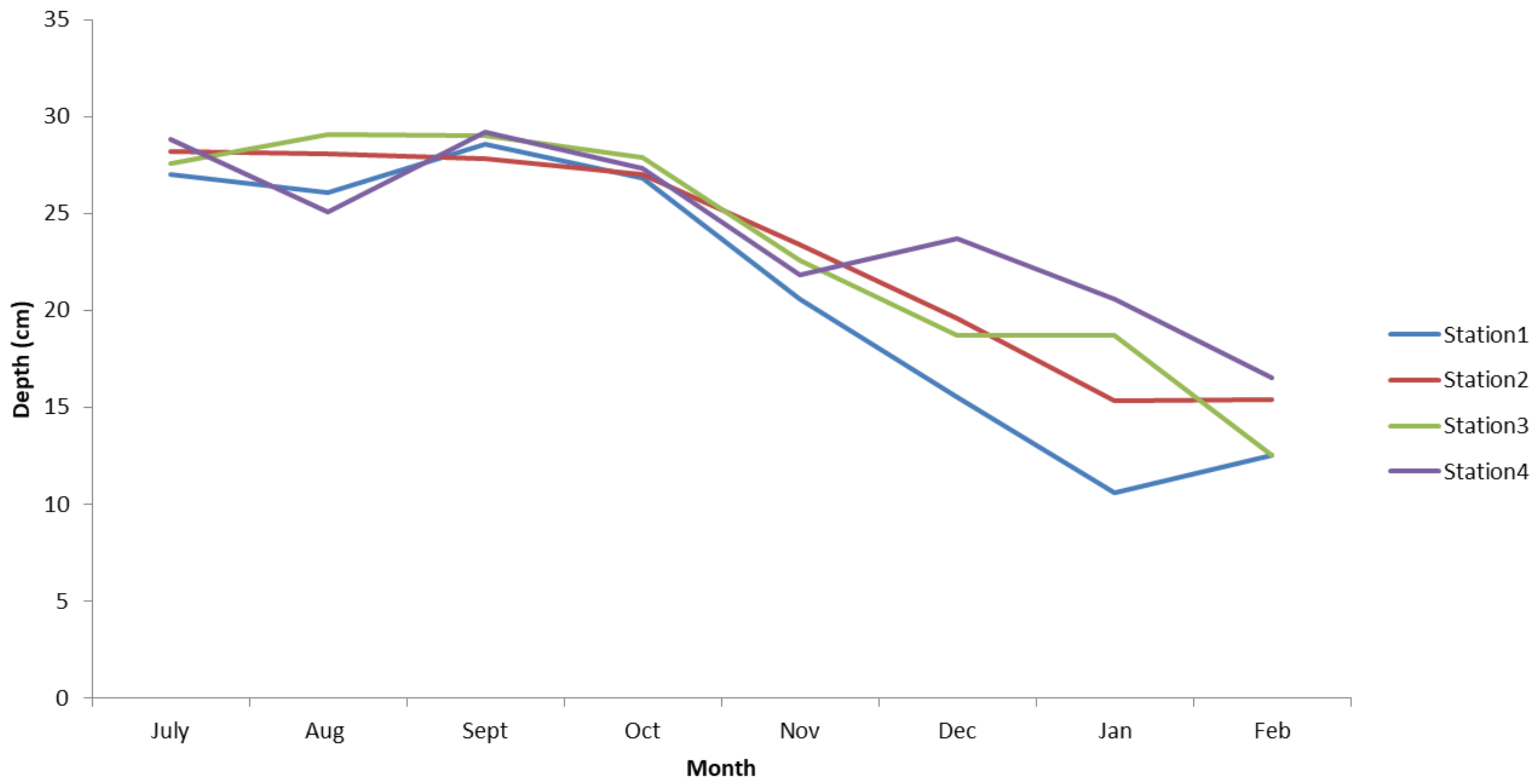

Figure 4.1.2: Spatio-temporal variation of Depth in the sampling stations of Emikpata stream Doko district of Niger State

4.1.3 Flow Velocity of stream

Emikpata Stream Station 1 recorded the lowest flow velocity in July, 2018 (0.31) and increase in August, 2018 (0.33) before a steady decrease in September, 2018 (0.31) and an increase in the month of October, 2018 (0.37), and a gradual fall from November, 2018 (0.33) to February, 2018 (0.25). Station 2 recorded low flow velocity in July, 2018 (0.32), a decrease in August, 2018 (0.24), and an increase in September, 2018 (0.27) and October, 2018 (0.34) but a slight fall from November, 2018 (0.31) to February, 2019 (0.25). Station 3 recorded low flow velocity in July, 2018 (0.29) and increased steadily in August, 2018 (0.30), before a steady decrease in September, 2018 (0.29), but an increase in October, 2018 (0.32) and November, 2018 (0.35) and a sharp fall in December, 2018 (0.27) before a rise in January, 2019 (0.31) and high fall in February, 2019 (0.29). Station 4 recorded the highest flow velocity in July, 2018 (0.30) and decrease in August, 2018 (0.24) before a rise from September, 2018 (0.30) to December, 2018 ((0.33) and steady fall in January, 2019 (0.30) and a rise February, 2019 (0.34). There were no significant differences in the flow velocity between the four stations (P>0.05).

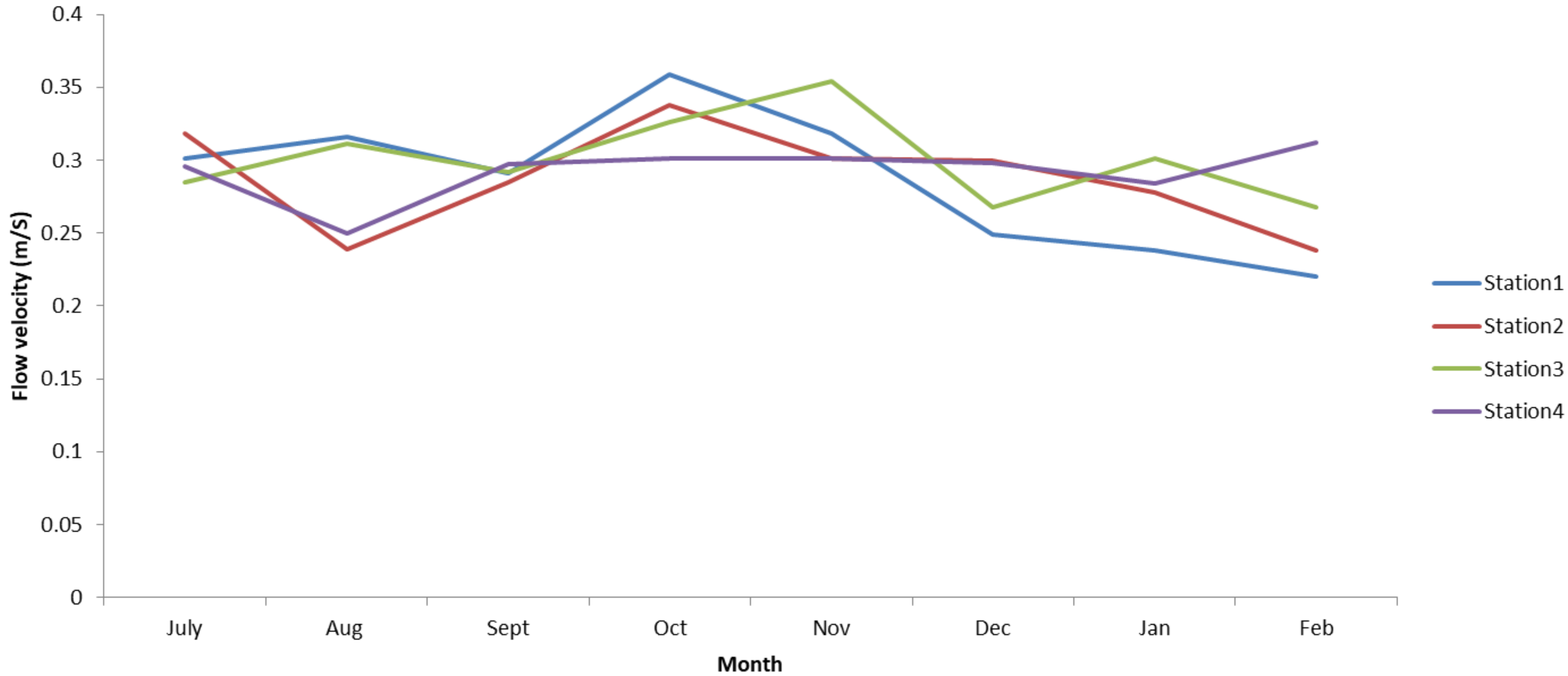

Figure 4.1.3: Spatio-temporal variation of Flow velocity in the sampling stations of Emikpata stream Doko district of Niger State

4.1.4 pH of stream

Emikpata Stream Station 1 recorded high pH in July, 2018 (5.94) followed by a subsequent increase steadily in all the remaining months (figure 4.1.4). Station 2 recorded low pH in July, 2018 (5.46) but increase in August, 2018 (5.85), September, 2018 (5.88), October, 2018 (5.96), November, 2018 (6.11) and December, 2018 (6.40) before a slight fall in January, 2019 (6.10) and increase in February, 2019 (6.31). Station 3 recorded pH in July, 2018 (5.80) and a steady increase in August, 2018 (5.88), September, 2018 (6.01), October, 2018 (6.22), November, 2018 (6.18), December, 2018 (6.38) and January, 2019 (6.51) before a fall in February, 2019 (6.44). Station 4 also recorded low pH in July, 2018 (5.40) and steady increase in August, 2018 (6.10) and September, 2018 (6.40) before a little fall in October, 2018 (6.14) and November, 2018 (6.20) followed by a gradual increase in December, 2018 (6.45), January, 2019 (6.65) and February, 2019 (6.71). There were significant differences between station 2 and three other stations ($P>0.05$).

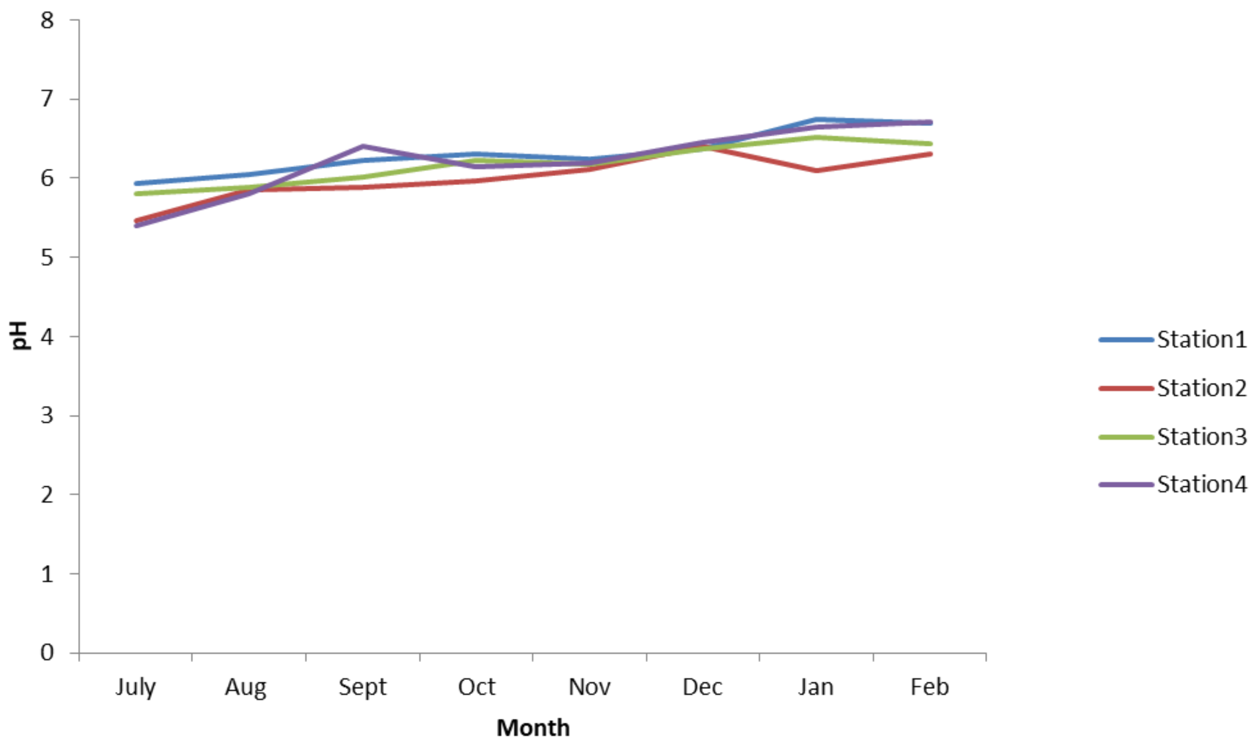

Figure 4.1.4: Spatio-temporal variation of pH in the sampling stations of Emikpata stream Doko district of Niger State.

4.1.5 Dissolved oxygen of stream

Emikpata Stream Station 1 recorded low dissolved oxygen in July, 2018 (5.0) and increased steadily in August, 2018 (5.8), September, 2018 (7.0) and a stable increase in October, 2018 (6.0), November, 2018 (6.0), December, 2018 (8.0), January, 2019 (8.0), February, 2019 (5.0). Station 2 recorded high DO in July, 2018 (6.0) and a steady increase the following months and a gradual decreased in January, 2019 (6.0) and February, 2019 (5.0). Station 3 recorded low DO in July, 2018 (6.0) and a gradual increase in August, 2018 (6.0) and September, 2018 (7.0) before slight drop in October, 2018 (4.00) and gradual increased in November, 2018 (4.8), December, 2018 (6.0), January, 2019 (8.0) and a drop in February, 2019 (6.0). Station 4 also recorded low DO in July, 2018 (5.4) and slight increase in August, 2018 (6.0), September, 2018 (5.8) before a slight drop in October, 2018 (5.0) before a steady increased in November, 2018 (6.0), December, 2018 (8.0), January, 2019 (8.0) and a fall in February, 2019 (5.0). There were no significant difference in dissolve oxygen between the four stations ($P>0.05$).

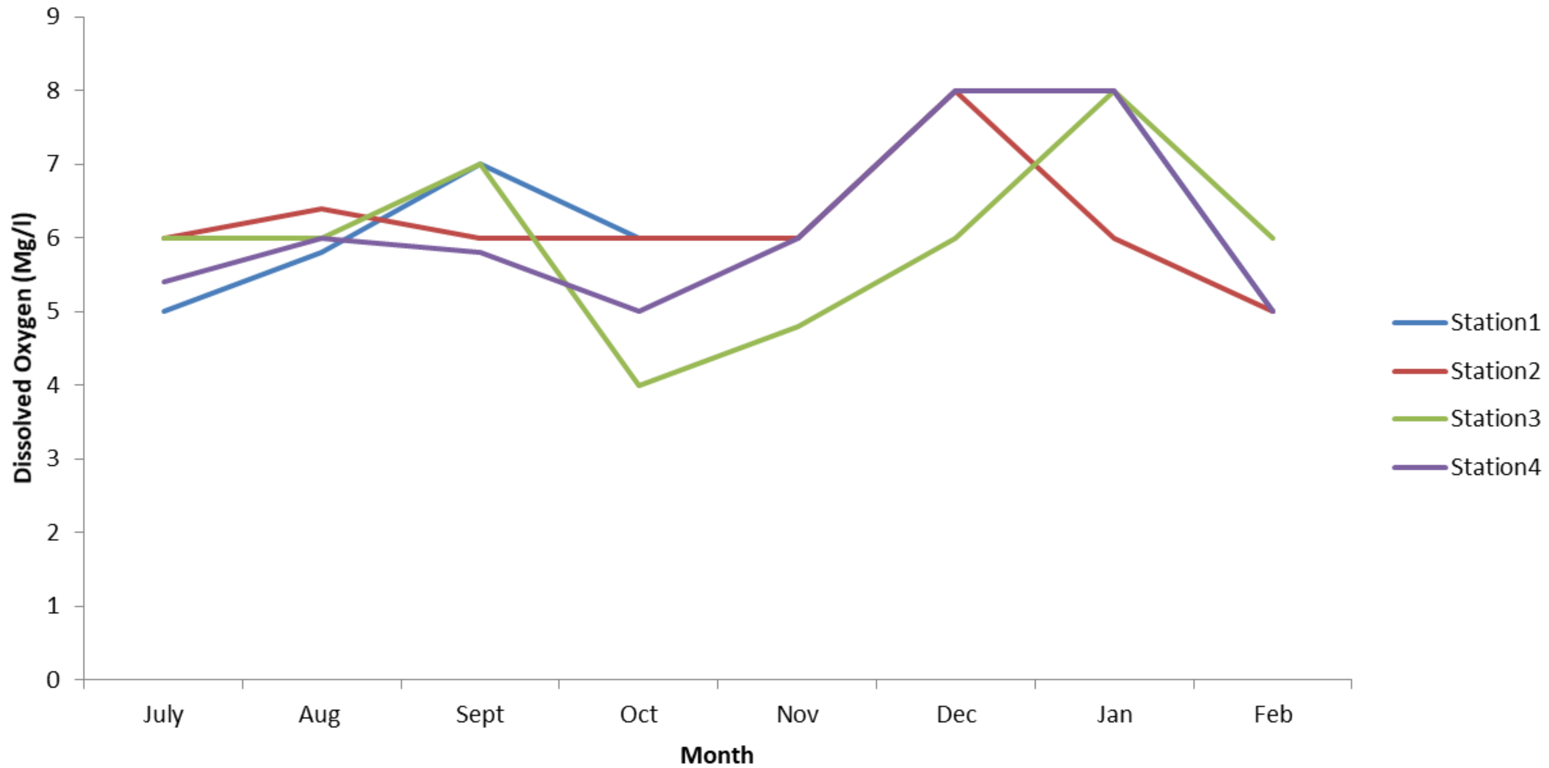

Figure 4.1.5: Spatio-temporal variation of Dissolved Oxygen in the sampling stations of Emikpata stream Doko district of Niger State

4.1.6 Biochemical oxygen demand (BOD) of stream

Emikpata Stream Station 1 recorded low BOD in July, 2018 (3.0), August, 2018 (3.0), September, 2018 (3.0), October, 2018 (3.0), before a gradual increase in November, 2018 (4.0), December, 2018 (5.0), January, 2019 (5.0) and a decreased in February, 2019 (3.0). Station 2 recorded the high BOD in July, 2018 (4.0), a slight increase in August, 2018 (5.0) and a fall in September, 2018 (4.0), October, 2018 (4.0), November, 2018 (3.0), December, 2018 (4.0), January, 2019 (4.0) and February, 2019 (3.0). Station 3 also recorded low BOD and a decreased in all the months. Station 4 also recorded low BOD in July, 2018 (3.0) followed by a rise in August, 2018 (4.0) and September, 2018 (4.0) before a drop in October, 2018 (3.0) November, 2018 (3.0). A gradual increase in December, 2018 (5.0) and fall in January, 2019 (3.0), February, 2019 (2.0). There were no significant differences in biochemical oxygen demand between the four stations ($P>0.05$).

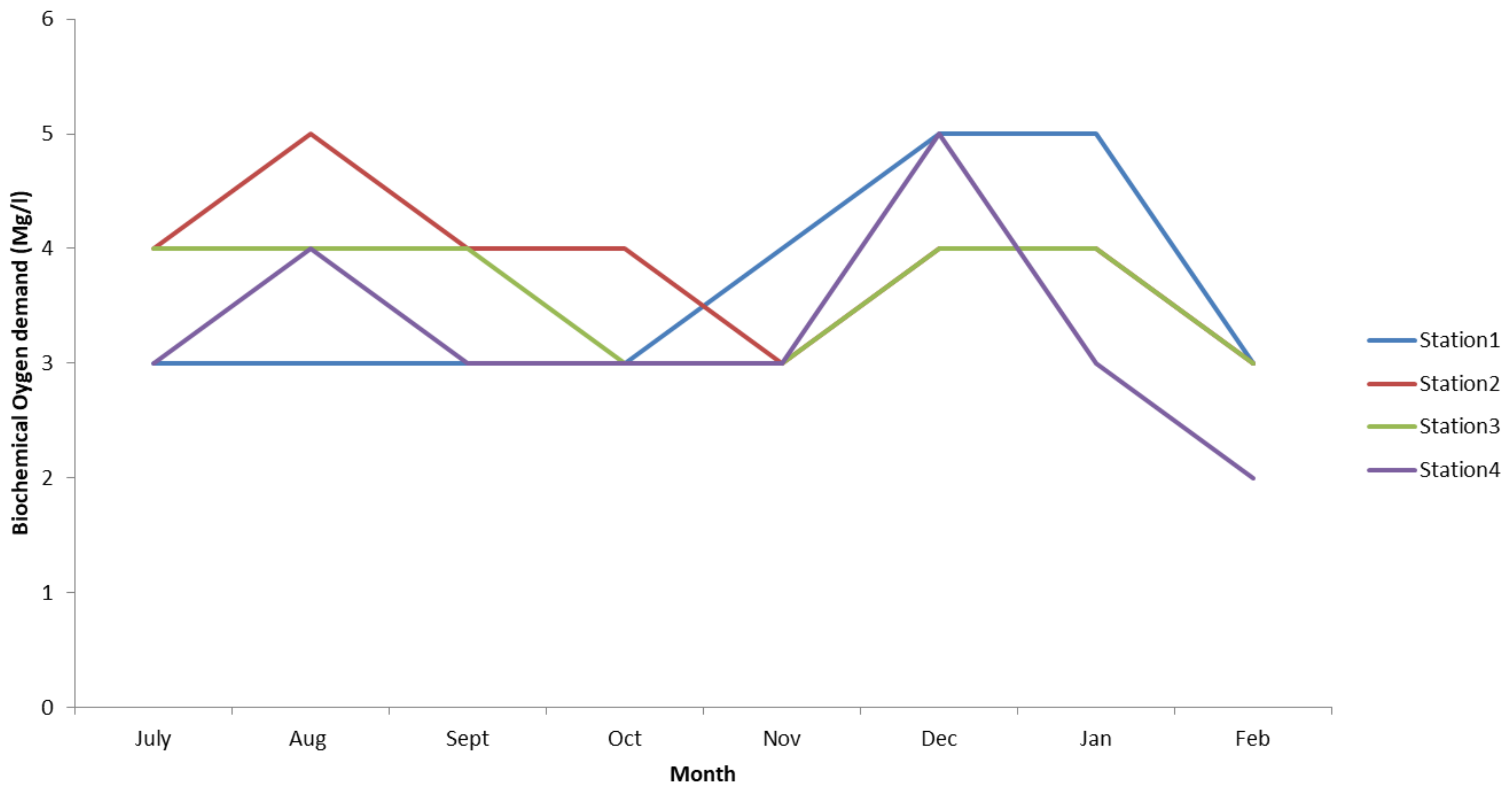

Figure 4.1.6: Spatio-temporal variation of Biochemical Oxygen Demand in the sampling stations of Emikpata stream Doko district of Niger State.

4.1.7 Electrical conductivity of stream

Emikpata Stream Station 1 recorded low conductivity in July, 2018 (35) and gradually increased from August, 2018 (51) to November, 2018 (62) and slight decreased from December, 2018 (49) to January, 2019 (38) and increased in February, 2019 (43) (figure 4.1.7). Station 2 recorded low conductivity in July, 2018 (48) and gradual increased in conductivity from August, 2018 (48) to February, 2019 (85). Station 3 recorded low conductivity in July, 2018 (96), slight increase in August, 2018 (128), September, 2018 (144) before a decrease from November, 2018 (118) to January, 2019 (85) and an increase in February, 2019 (88). Station 4 recorded high conductivity in July, 2018 (97), August, 2018 (149), September, 2018 (151) and a gradual decreased from October, 2018 (138) before a slight decrease in January, 2019 (55) and a rise in February, 2019 (61). There were no significant differences in conductivity between the four stations ($P>0.05$).

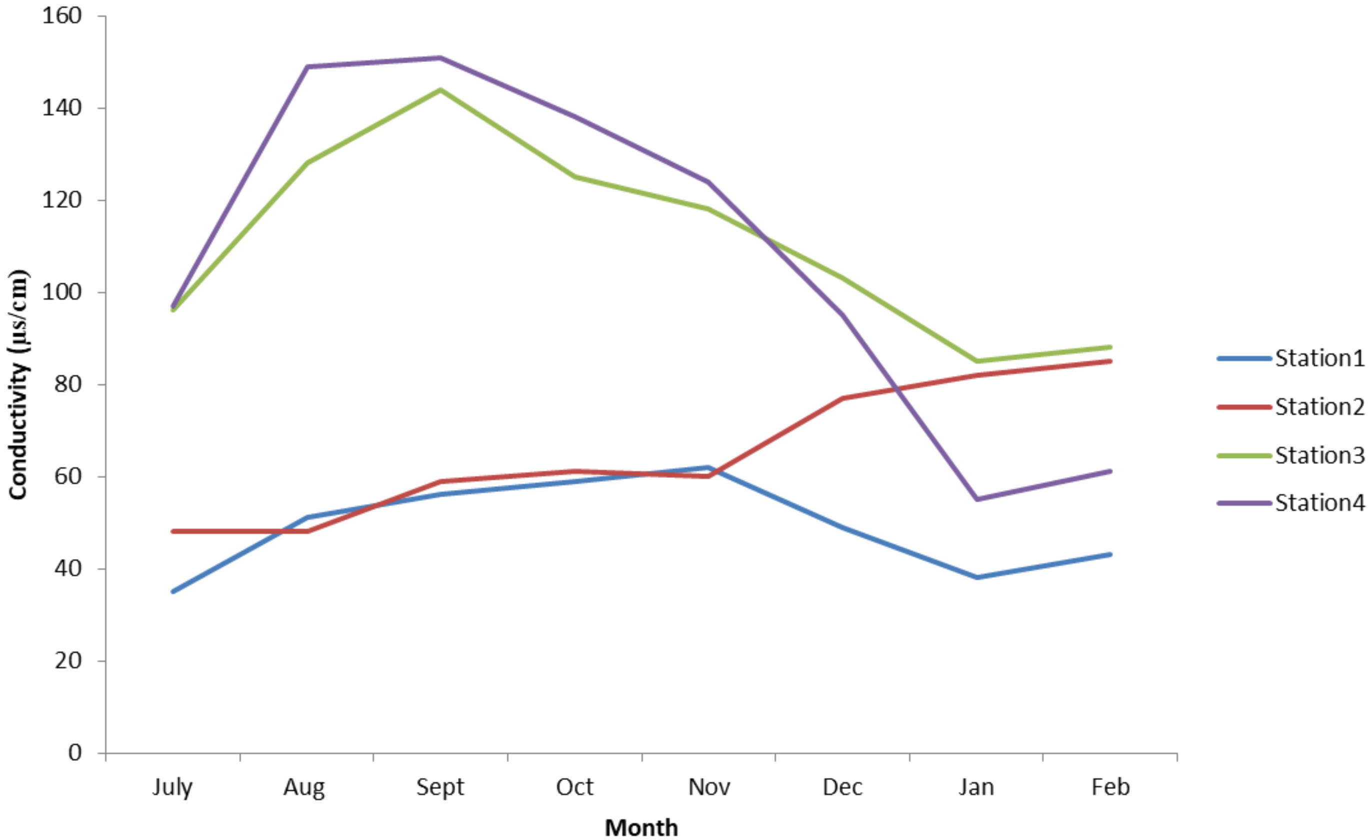

Figure 4.1.7: Spatio- temporal variation of electrical conductivity in the sampling stations of Emikpata stream Doko district of Niger State.

4.1.8 Total hardness of stream

Emikpata Stream Station 1 recorded low hardness in July, 2018 (7.0) and a gradual increased throughout from August, 2018 (10) to February, 2019 (18). Station 2 recorded low hardness in July, 2018 (8) and August, 2018 (7) but a slight increase from September, 2018 (10) to February, 2019 (22). Station 3 recorded low hardness in July, 2018 (10), and slightly increase in August, 2018 (18) and September, 2018 (22) but a slight decline in October, 2018 (20) and an increase in November, 2018 (22) before a decrease in December, 2018 (14) and a gradual increase in January, 2019 (15) and February, 2019 (18). Station 4 recorded high hardness in July, 2018 (13) to September, 2018 (24) before a drop in October, 2018 (20) and slight increase in November, 2018 (24). A drastically drop in December, 2018 (14) before a slight increase in January, 2019 (14) and February, 2019 (18). There were no significant differences in the total hardness between the four stations ($P>0.05$).

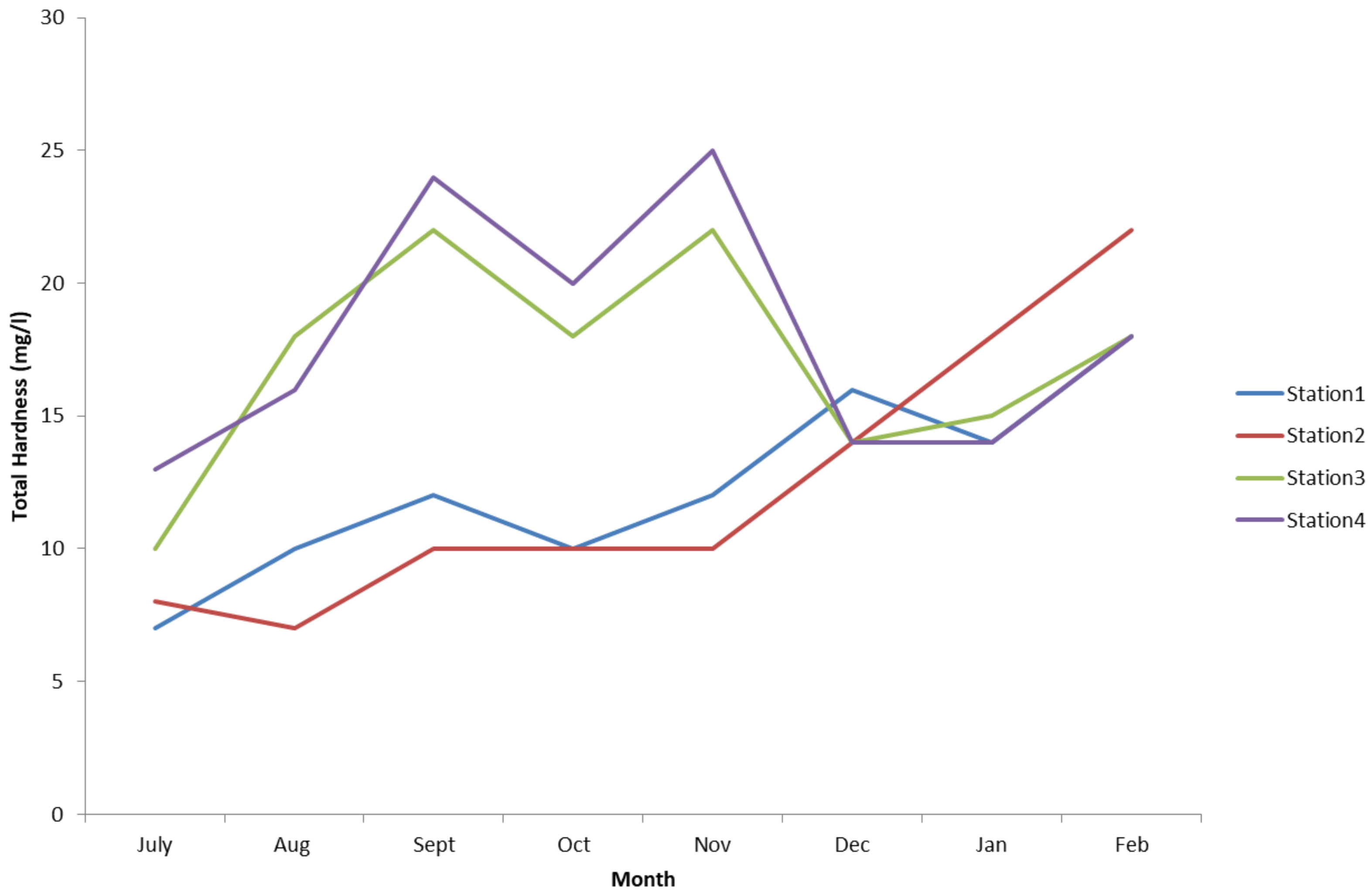

Figure 4.1.8: Spatio- temporal variation of Total Hardness in the sampling stations of Emikpata stream Doko district of Niger State.

4.1.9 Total alkalinity of stream

Emikpata Stream Station 1 recorded low alkalinity in July, 2018 (11) and August, 2018 (11) before a slight increase in September, 2018 (14) to November, 2018 (14) before a drop in December, 2018 (12) to January, 2019 (10) and slight increase in February, 2019 (12). Station 2 recorded low alkalinity between July, 2018 (14) and August, 2018 (10) before a gradual increase from September, 2018 (14) to February, 2019 (16). Station 3 recorded low alkalinity in July, 2018 (20) before a gradual increased from August, 2018 (22) to September, 2018 (26) and slight fall from October, 2018 (20) to February, 2019 (14). Station 4 recorded the highest in July, 2018 (22), a slight drop in August, 2018 (20) and September, 2018 (20) but a slight increase in October, 2018 (22) and a gradual decreased from November, 2018 (20) up to February, 2019 (14). There were no significant differences in the total alkalinity between the four stations ($P>0.05$).

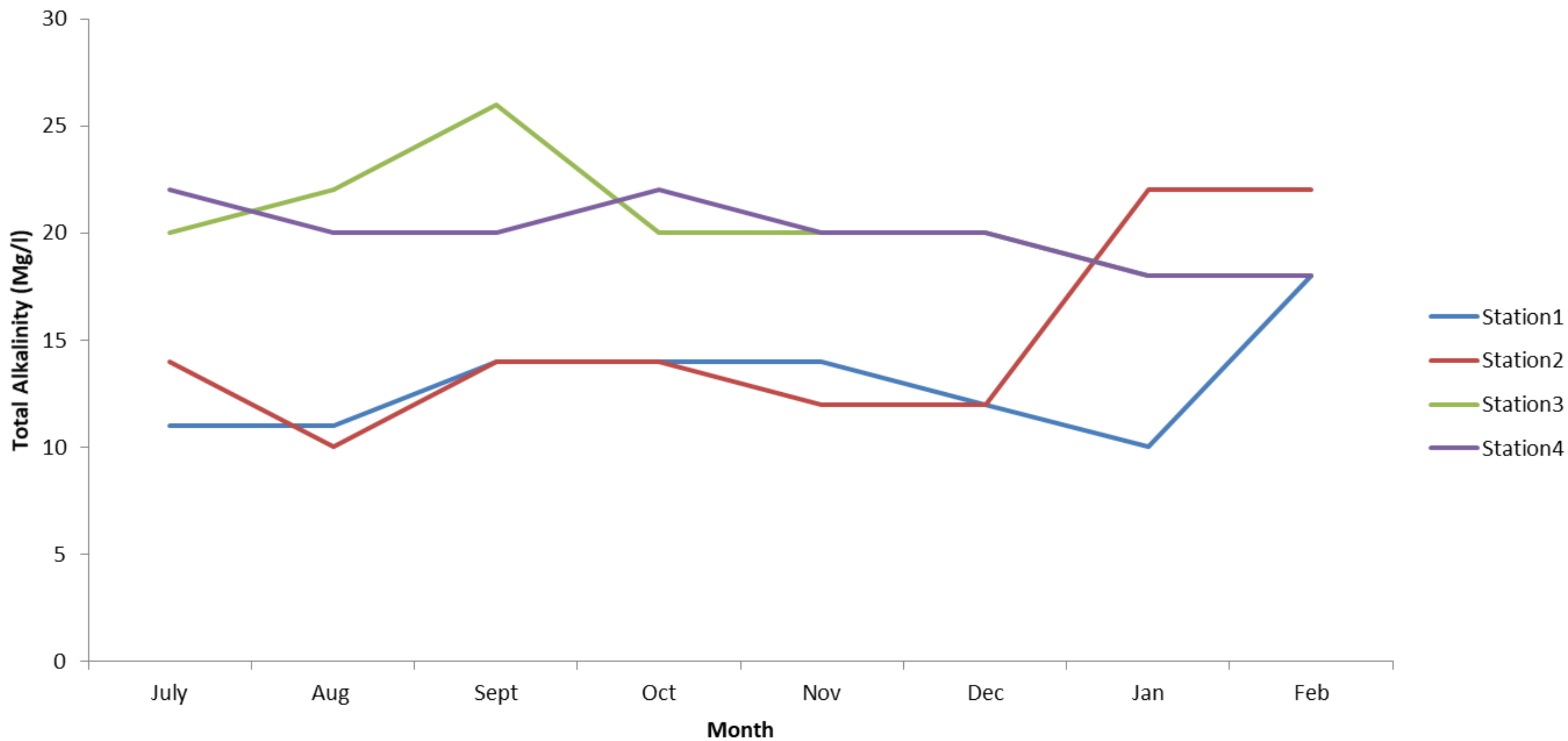

Figure 4.1.9: Spatio- temporal variation of Total alkalinity in the sampling stations of Emikpata stream Doko district of Niger State.

4.1.10 Chlorine of stream

Emikpata Stream Station 1 recorded low chlorine in July, 2018 (10.7) and slight increase from August, 2018 (10.8) to December, 2018 (10.6) before a decrease in January, 2019 (12.2) and February, 2019 (12.68). Station 2 recorded high chlorine in July, 2018 (29.4) and start to increase from August, 2018 (31.3) to February, 2019 (36.0). Station 3 recorded low chlorine in July, 2018 (9.8) and a slight increase in August, 2018 (10.8) to February, 2019 (20.1). Station 4 also recorded low chlorine in July, 2018 (9.8) and a slight increase in August, 2018 (9.8) to November, 2018 (12.6) before a drop in December, 2018 (10.9) to January, 2019 (8.8) and an increased in February, 2019 (10.2). There were significant differences between in station 2 and three other stations ($P>0.05$).

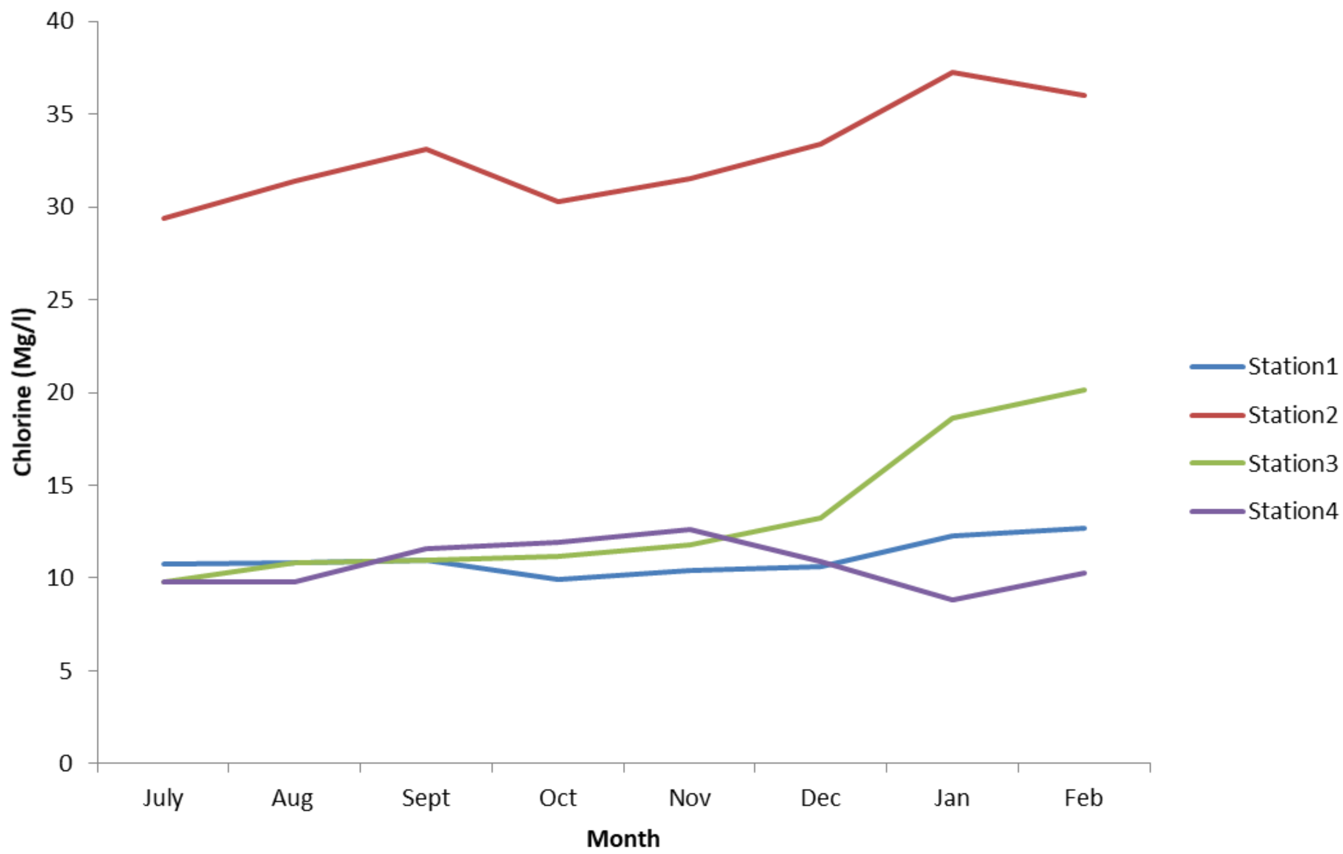

Figure 4.10: Spatio- temporal variation of Chlorine in the sampling stations of Emikpata stream Doko district of Niger State.

4.1.11 Nitrate of stream

Emikpata Stream Station 1 recorded high nitrate in July, 2018 (1.8) and a slight decreased from August, 2018 (1.8) to October, 2018 (1.3) and a slight rise from November, 2018 (1.4) to January, 2019 (2.6) before a drop in February, 2019 (2.1). Station 2 recorded high nitrate in July, 2018 (4.2) and a slight rise in August, 2018 (4.6) and a gradual drop from September, 2018 (3.4) to December, 2018 (2.3) and a drastic rise in January, 2019 (6.8) and a high drop in February, 2019 (2.3). Station 3 also recorded low nitrate in July, 2018 (2.0) and a slight increase in August, 2018 (2.1) and slight decreased in September, 2018 (1.9) to October, 2018 (1.5) before a slight increase from November, 2018 (1.7) to January, 2019 (5.2) and drastic drop in February, 2019 (2.6). Station 4 recorded low nitrate in July, 2018 (2.2) and slight increase in August, 2018 (2.4) before a slight drop from September, 2018 (2.2) to November, 2018 (2.2) and a rise from December, 2018 (2.4) to January, 2019 (3.11) and slight drop in February, 2019 (2.4). There were significant differences between station 2 and three other stations ($P<0.05$).

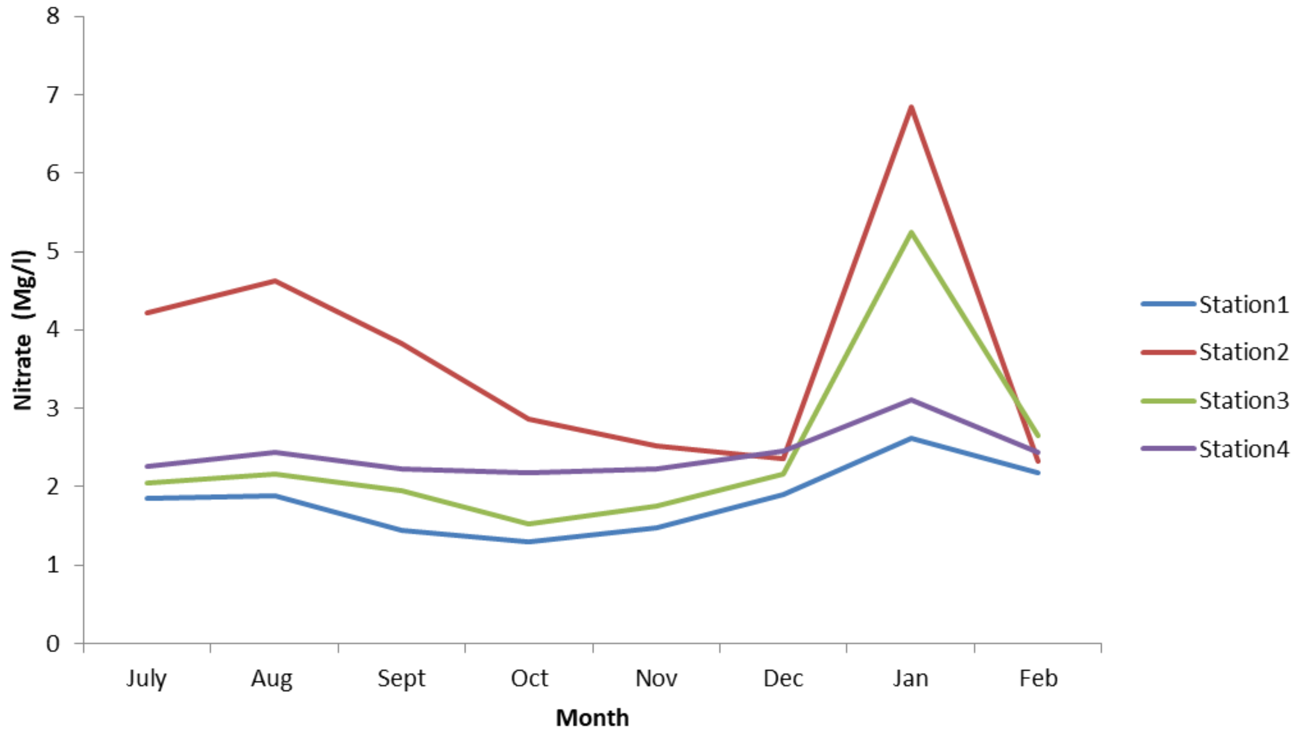

Figure 4.1.11: Spatio- temporal variation of Nitrate in the sampling stations of Emikpata stream Doko district of Niger State.

4.1.12 Phosphate of stream

Emikpata Stream Station 1 recorded low phosphate in July, 2018 (0.51) before a rise in August, 2018 (0.66) and slight decreased in September, 2018 (0.62) to October, 2018 (0.48) and gradual increased in November, 2018 (0.61) to December, 2018 (0.65) and drop in February, 2019 (0.60). Station 2 record low phosphate in July, 2018 (0.72), slight increase in August, 2018 (1.04) and September, 2018 (1.31) before a gradual drop in October, 2018 (1.22) to February, 2019 (0.61). Station 3 record high phosphate in July, 2018 (1.85) and slight decreased from August, 2018 (1.28) to October, 2018 (0.77) and a gradual increased from November, 2018 (0.85) to January, 2019 (1.58) and a slight fall in February, 2019 (0.80). Station 4 also recorded low phosphate in July, 2018 (1.39) and slight increase in August, 2018 (1.51) and gradual decreased from September, 2018 (1.24) to February, 2019 (0.60). There were no significant difference in the phosphate between the four stations ($P>0.05$).

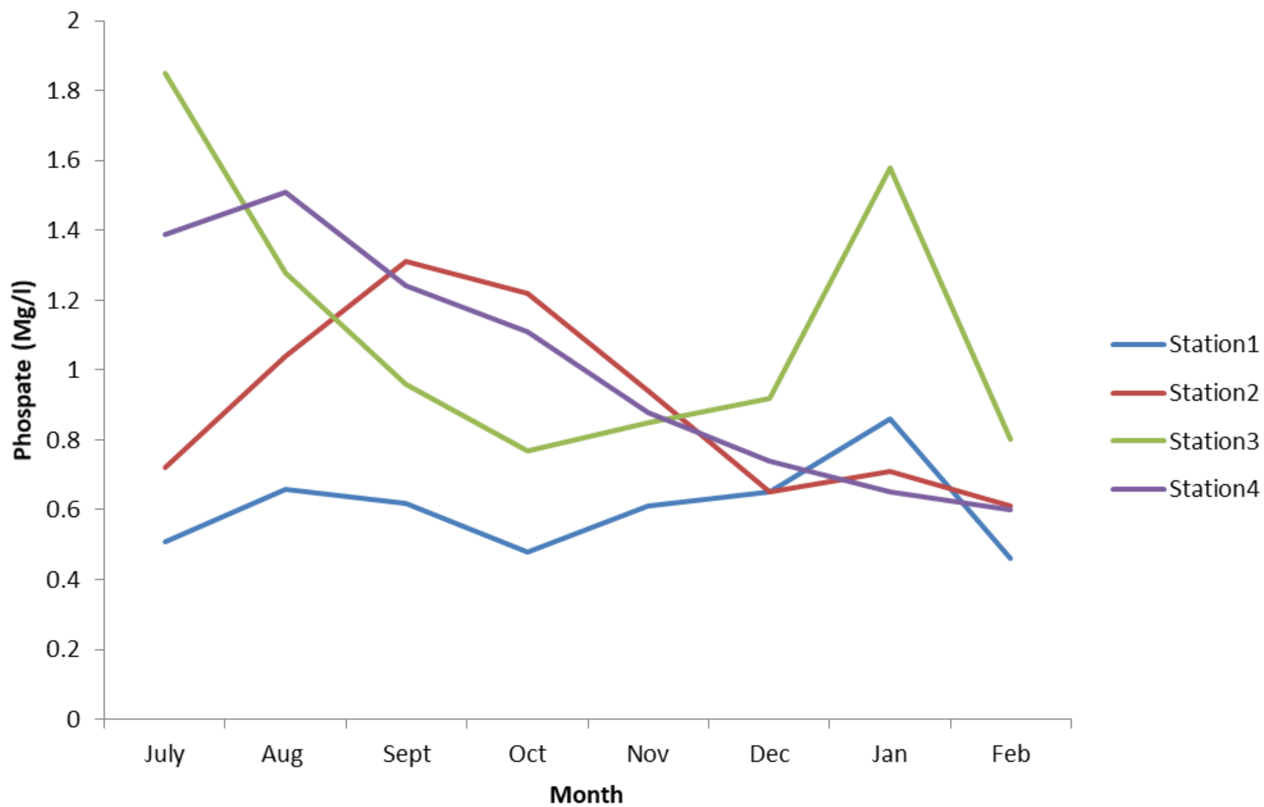

Figure 4.1.12: Spatio- temporal variation of Phosphate in the sampling stations of Emikpata stream Doko district of Niger State.

4.1.13 Sodium of stream

Station 1 recorded low sodium in July, 2018 (6.28) and an increase from August, 2018 (6.45) to January, 2019 (11.20) but a drastical drop February, 2019 (10.83). Station 2 record low sodium in July, 2018 (5.98) and gradual increased in August, 2018 (6.22) to September, 2018 (6.51) before a drop in October, 2018 (5.81) and steady rise from November, 2018 (6.20) to February, 2019 (10.30). Station 3 recorded high sodium in July, 2018 (7.16) and an increased in August, 2018 (8.55) before a drop from September, 2018 (7.84) to October, 2018 (6.35) and gradual increased from November, 2018 (6.75) to February, 2019 (11.90). Station 4 record low sodium in July, 2018 (6.53) but a gradual decrease from August, 2018 (6.39) and an increase in September, 2018 (7.08) before a slight decreased from October, 2018 (6.62) to November, 2018 (6.40) and a gradual increased from December, 2018 (10.42) but a decrease in February, 2019 (10.30). There were significant differences in Station 2 and three other stations ($P<0.05$).

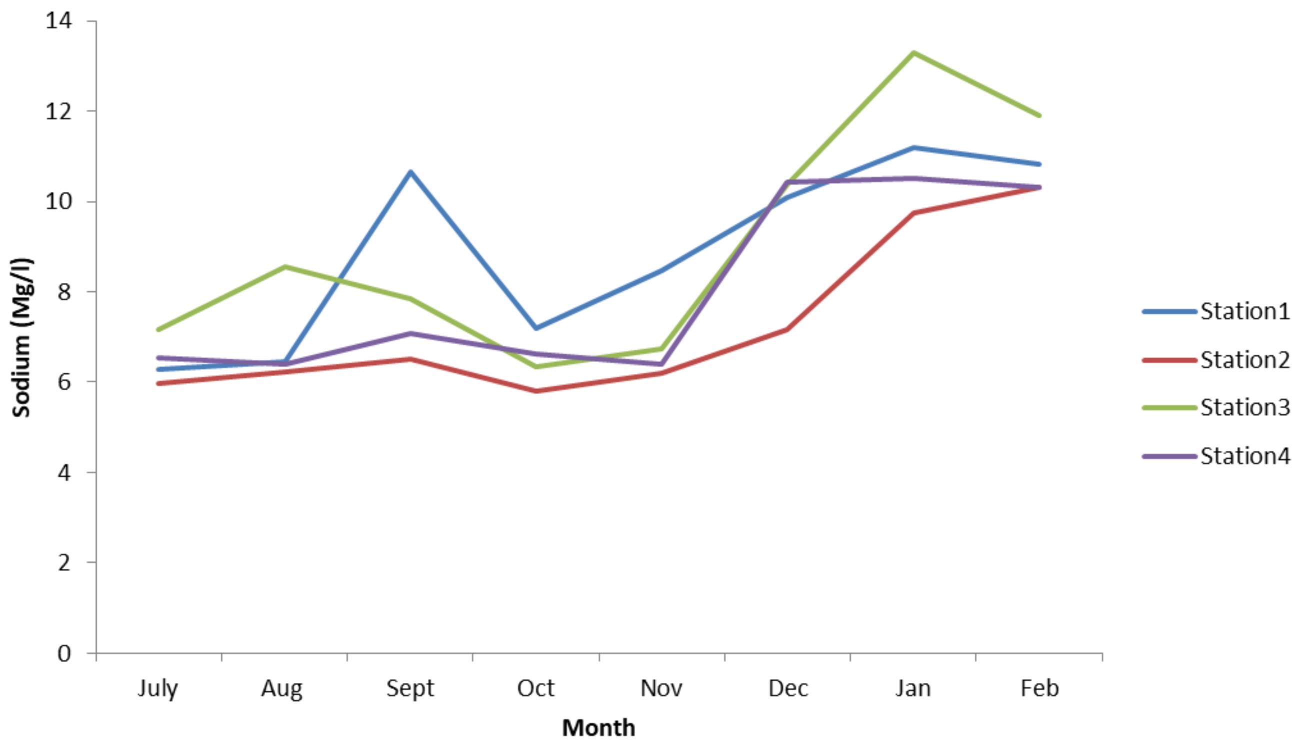

Figure 4.1.13: Spatio-temporal variation of Sodium in the sampling stations of Emikpata stream Doko district of Niger State

4.1.14 Potassium of stream

Emikpata Stream showed Station 1 record high potassium in July, 2018 (1.33), a slight decreased in August, 2018 (0.98) before a steady increased from September, 2018 (1.22) to January, 2019 (3.60) and a drop in February, 2019 (2.96). Station 2 record low potassium in July, 2018 (1.19) but a gradual increased from August, 2018 (1.25) and maintain similar trend up to January, 2019 (3.90) and slight decrease in February, 2019 (3.03). Station 3 record high potassium in July, 2018 (1.51) but a slight decreased from August, 2018 (1.30) to September, 2018 (0.95) before a steady increase from October, 2018 (1.20) to January, 2019 (4.77) and a drop in February, 2019 (3.18). Station 4 also record low potassium in July, 2018 (1.39) but a slight increase from August, 2018 (1.60) to September, 2018 (1.75) and a slight decrease from October, 2018 (1.45) to November, 2018 (0.90) before a gradual increase from December, 2018 (1.41), January, 2019 (3.90) and a fall in February, 2019 (2.80). There were no significant difference in potassium between the four stations ($P>0.05$).

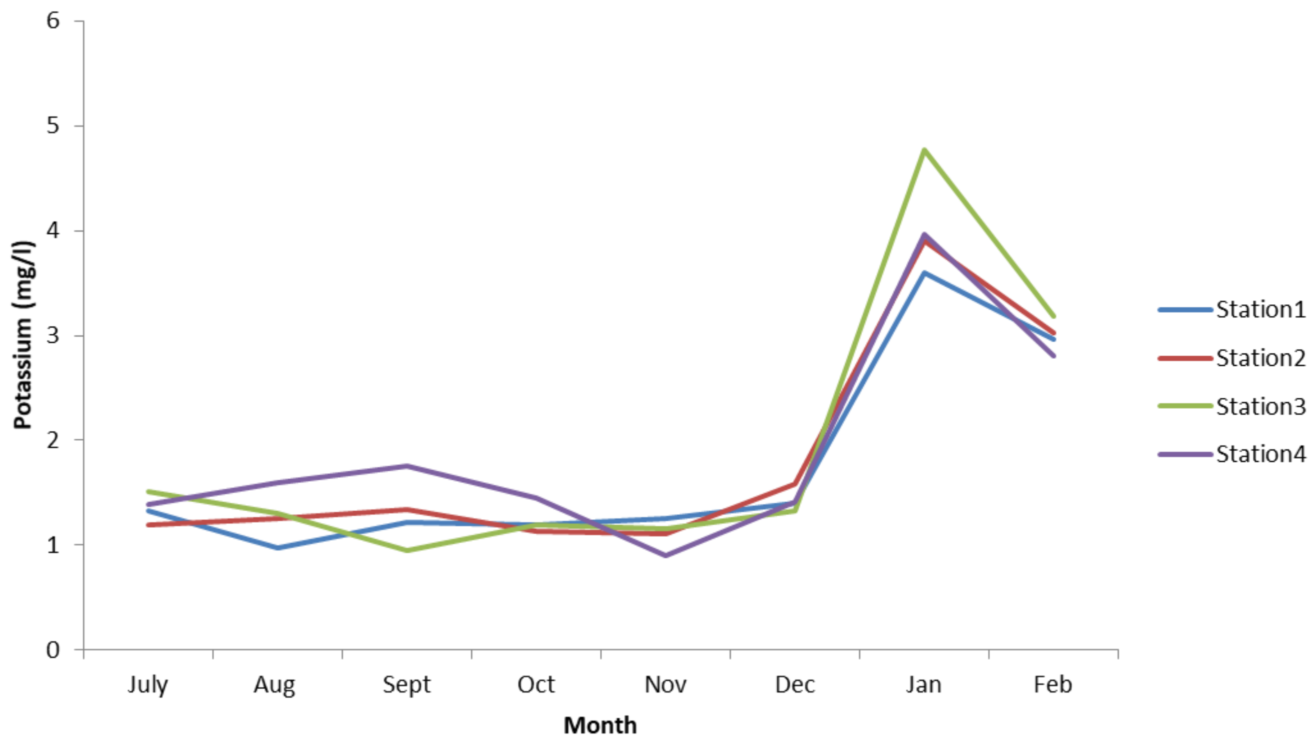

Figure 4.1.14: Spatio-temporal variation of Potasium in the sampling stations of Emikpata stream Doko district of Niger State

4.2 Macroinvertebrate assemblages of sampling stations in Emikpata stream.

A total of 625 individuals from 28 species and 19 families (Baetidae, Dystcidae, Hydrophilidae, Coegnoridae, Plactinemidae, Gomphidae, Aeshnidae, Cordillidae, Libelluubidae, Nepidae, Hydrometridae, Naucoridae, Notonectidae, Gerridae, Chironomidae, Unionidae, Physidae, Lumbricoides, Caridianae) of macro invertebrates were recorded during the study period in Emikipata stream. The number of recovered macro invertebrate group in each station showed that 114 (18.28%), 175 (28.00%), 139 (22.24%) and 197 (31.52%) for Stations 1,2,3 and 4 respectively. Station 4 recorded the highest percentage of macroinvertebrates followed by Stations 2,3 and the lowest percentage of macroinvertebrates is Station 1. The number of recovered macroinvertebrates per group shows that Odonata (231), Ephermicroptera (114), Hempitera (99) and Coleoptera (84) recorded the highest while Diptera (55), Oligochaeta (28), Decapoda (7) and Mollusca (7) where the least. Upon all the percentage of individual macro invertebrate in the stations of the stream showed that there were significant differences ($P<0.05$) in the number of individual per sampling stations (Table 4.2).

From table 4.3, the diversity indices including abundance number of Taxa, Shannon – wimpier diversity, evenness and Margaret's indices calculated for each station of the stream the highest number of species (197) was recorded in Station 4, Station 2 recorded the second highest (175), 139 in Station 3 and 114 in Station 1 respectively. Simpson and Shannon indices were the same with the highest recorded in Station 4 (0.9404) and lowest in Station 1 (0.09044). Station 4 (0.7294) recorded the highest evenness index while Station 1 (0.7023) recorded the least. Evenness indexs showed significant difference among sampling stations ($P<0.05$). Margelef's index was recorded highest (5.111) in Station 4 and followed by Station 2 (5.034), Station 3 (4.256) and lowest is Station 1 (3.589).

Table 4.2 Macroinvertebrate assemblage of sampling stations in Emikpata stream, Doko district of Niger State.

Order	Family	Species	Station1	Station2	Station3	Station4
Ephemeroptera	Baetidae	*Bugillesia* sp	14	10	8	11
		Chloen sp	15	35	11	10
Coleoptera	Dystcidae	*Phylodyte* sp	0	1	0	1
	Hydrophilidae	*Crenis digesta*	3	10	16	8
		Hydrophilus sp	2	9	13	6
		Hyphydrus sp	1	0	1	1
		Culymbetes Sculptilis	0	5	3	4
Odonata	Coegnoridae	*Coenagrion* sp	13	15	6	25
		Pseudoigrian sp	14	17	15	14
	Plactinemidae	*Mesocnemis* sp	8	6	4	7
	Gomphidae	*Ophiogomphus* sp	0	2	4	6
	Aeshnidae	*Aeshna* sp	2	7	6	10
	Cordillidae	*Epitheca* sp	1	5	4	7
	Libellubidae	*Libellula* sp	5	1	0	3
		Zyxomma sp	2	1	1	3
		Brachythermis sp	5	2	3	7
Hempitera	Nepidae	*Ranatra* sp	3	1	0	4
		Laccocotrophes sp	7	13	12	16
	Hydrometridae	*Hydrometra* sp	0	1	2	16

	Naucoridae	*Macrocroris* sp	0	1	2	1
		Naucoris sp	0	1	0	1
	Notonectidae	*Notonecta* sp	1	3	3	4
	Gerridae	*Gerris* sp	2	1	1	3
Diptera	Chironomidae	*Chironomus* sp	16	10	17	12
Mollusca	Unionidae	*Unio mancus*	0	2	1	2
	Physidae	*Physa* sp	0	1	0	1
Oligochaeta	Lumbricoides	*Lumbricoides* sp	0	10	6	12
Decapoda	Caridianae	*Caridina gabonensis*	0	5	0	2
Total			**114**	**175**	**139**	**197**

Table 4.3. Diversity indices of recovered macroinvertebrate of Emikpata stream Doko district of Niger state.

Diversity indices	**Station 1**	**Station 2**	**Station 3**	**Station 4**
Total Individuals	114	175	139	197
Taxa Richness	18	27	22	28
Simpson Dominance index	0.9044	0.9158	0.9243	0.9404
Shannon index (H)	2.537	2.797	2.77	3.017

Evenness e^H/S	0.7023	0.6071	0.7254	0.7294
Margalef index	3.589	5.034	4.256	5.111

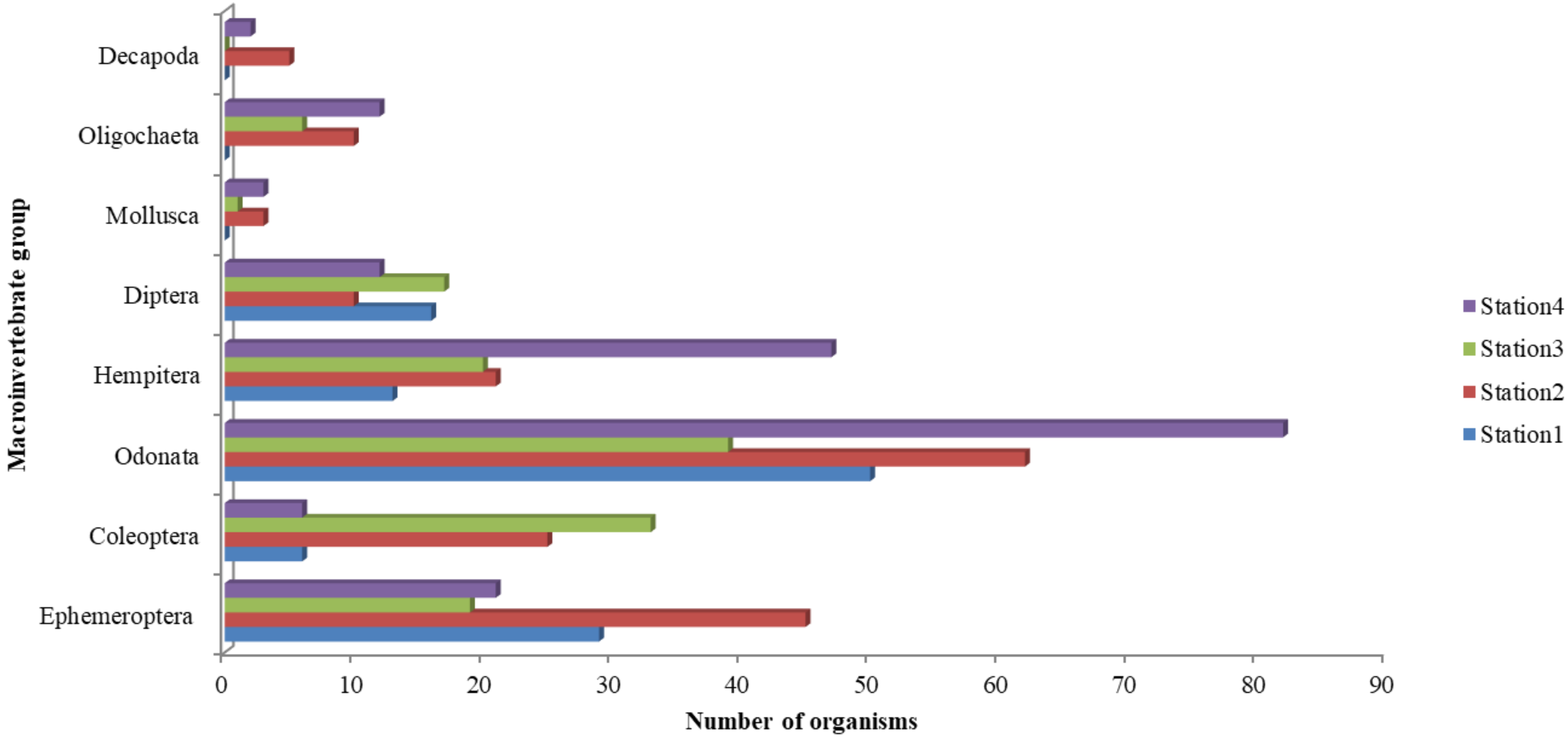

Figure 4.2: Number of recovered macroinvertebrate group in each sampling station.

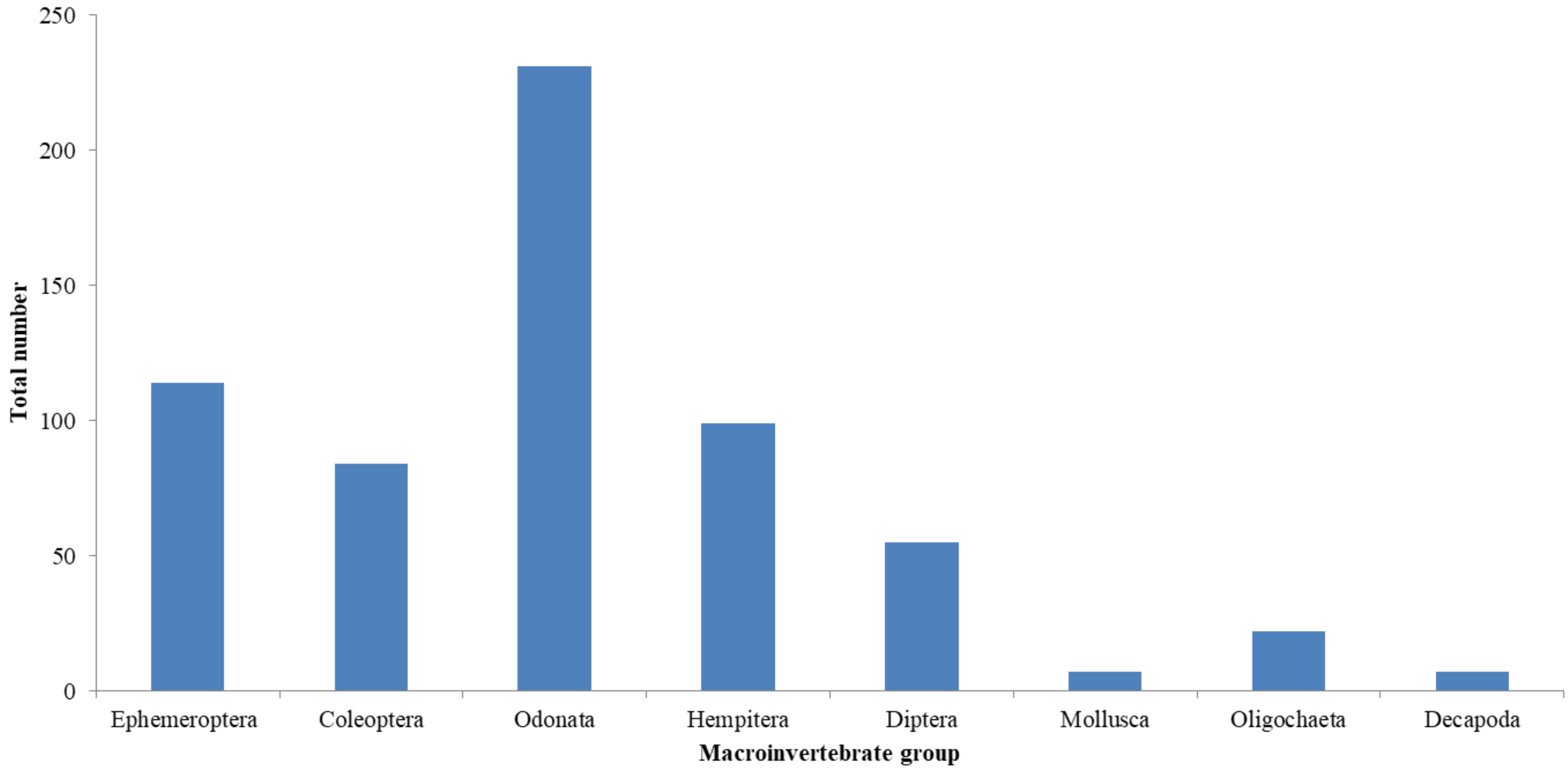
250
200
150
100
50
0
Total number
Ephemeroptera
Coleoptera
Odonata
Hempitera
Diptera
Mollusca
Oligochaeta
Decapoda
Macroinvertebrate group

Figure 4.3: Number of recovered macroinvertebrate per group

4.3 Seasonal assemblage of macroinvertebrate per station.

The total number (386) and percentage (61.76%) individuals of macroinvertebrate recorded during the study period in Emikpata stream were recorded in dry season (November to February 2019) and 38.24% (239 individuals) were recorded in the rainy season (July to October 2018). From the stream higher abundance were recorded in the dry season than the wet season.

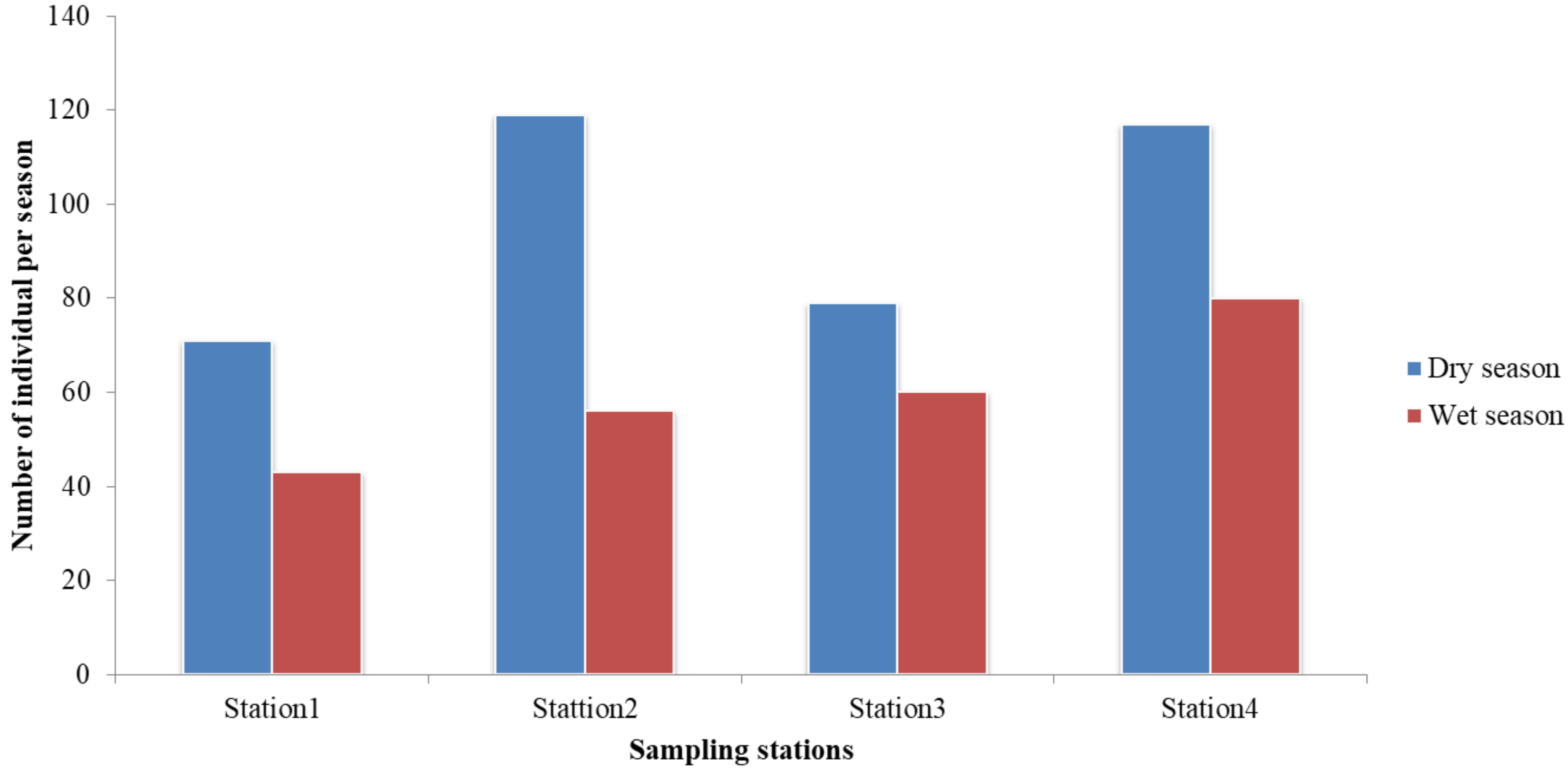

Figure 4.3: Seasonal assemblage of macroinvertebrates per station

4.4 Relationship between Macroinvertebrate and measured physico-chemical parameters.

In Emikpata stream canonical correlation analysis (CCA) tri-plot showed a relationship between the measured environmental variables and species abundance. The Axis 1 of CCA accounted for 39.7% of variation in data set. Organization in axis I was mostly affected by BOD, DO and pH. CCA axis 2 account for 36.76% of variation in data set. Organisms in axis 2 were affected by chlorine, nitrate, flow velocity, phosphate, depth, conductivity and total handness as shown in table 4.5. Organisms associated with axis 1 of CCA are Chlo (Chloen Sp), Psen (*Psendoigriam* Sp), Chir (*Chironomus* sp), Bug (*Bugillesia* Sp), meso (*Mesocriemis* Sp), Hyph (*Hyphydrus* sp), Coen (*Coenagrion* sp), Brac (*Brachythermis* sp), Zyxo (*Zyxomma* sp), Gerr (*Gerris* sp), Rana (*Ranatra* sp), Libe (*Libellula* Sp). Organism associated with axis 2 of the CCA are Phy (*Phylodyte* Sp), Crenis (*Crenis digester* Sp), Hydro (*Hydrophilin* Sp) Culy (*Culymbeters Sculptilis*), Ophio (*Ophiogomplins* sp), Aes (*Aeshna* sp), Epi (*Epitheca* sp) Lacco (*Laccocotrophes* sp), Hydro (*Hydrometra* sp), macro (*Macrocroris* sp), Nau (*Naucoris* sp), Noto (*Notonecta* sp), Unio (*Unio Mancus* sp), Phy (*Physa* sp), Lumb (*Lumbrocoides* sp), Cari (*Caridina gabonesis* sp).

Table 4.5. Canonical Correlation Analysis (CCA) of the physico-chemical parameters of emikpata stream.

	Axis 1	**Axis 2**
Eigen value	0.09465	0.08765
%	39.7	36.76
P	0.5743	0.9109
Temperature	-0.8793	-0.1581
Depth	-0.9659	-0.1636
Flow velocity	-0.6147	0.18468
DO	0.84233	-0.3652
BOD	0.25491	0.88617
pH	0.73139	-0.6479
Conductivity	-0.8115	-0.1989
Total hardness	-0.6673	-0.4188
Total alkalinity	-0.8155	-0.17
Chlorine	-0.2588	0.61715
Nitrate	-0.5503	0.50463
Phosphate_	-0.9478	0.1449

CCA tri-plot shows a relationship between the measure environmental variables and species abundance. Organisms associated with Axis 1 of CCA are Chlo (*Chloen* Sp), Psen (*Psendoigriam* Sp), Chir (*Chironomus* sp), Bug (*Bugillesia* Sp), meso (*Mesocriemis* Sp), Hyph (*Hyphydrus* sp), Coen (*Coenagrion* sp), Brac (*Brachythermis* sp), Zyxo (*Zyxomma* sp), Gerr (*Gerris* sp), Rana (*Ranatra* sp), Libe (*Libellula* Sp). Organism associated with axis 2 of the CCA are Phy (*Phylodyte* Sp), Crenis (*Crenis digester* Sp), Hydro (*Hydrophilin* Sp) Culy (*Culymbeters Sculptilis*), Ophio (*Ophiogomplins* sp), Aes (*Aeshna* sp), Epi (*Epitheca* sp) Lacco (*Laccocotrophes* sp), Hydro (*Hydrometra* sp), macro (*Macrocroris* sp), Nau (*Naucoris* sp), Noto (*Notonecta* sp), Unio (*Unio Mancus* sp), Phy (*Physa* sp), Lumb (*Lumbrocoides* sp) Cari (*Caridina gabonesis* sp) Figure 4.5.

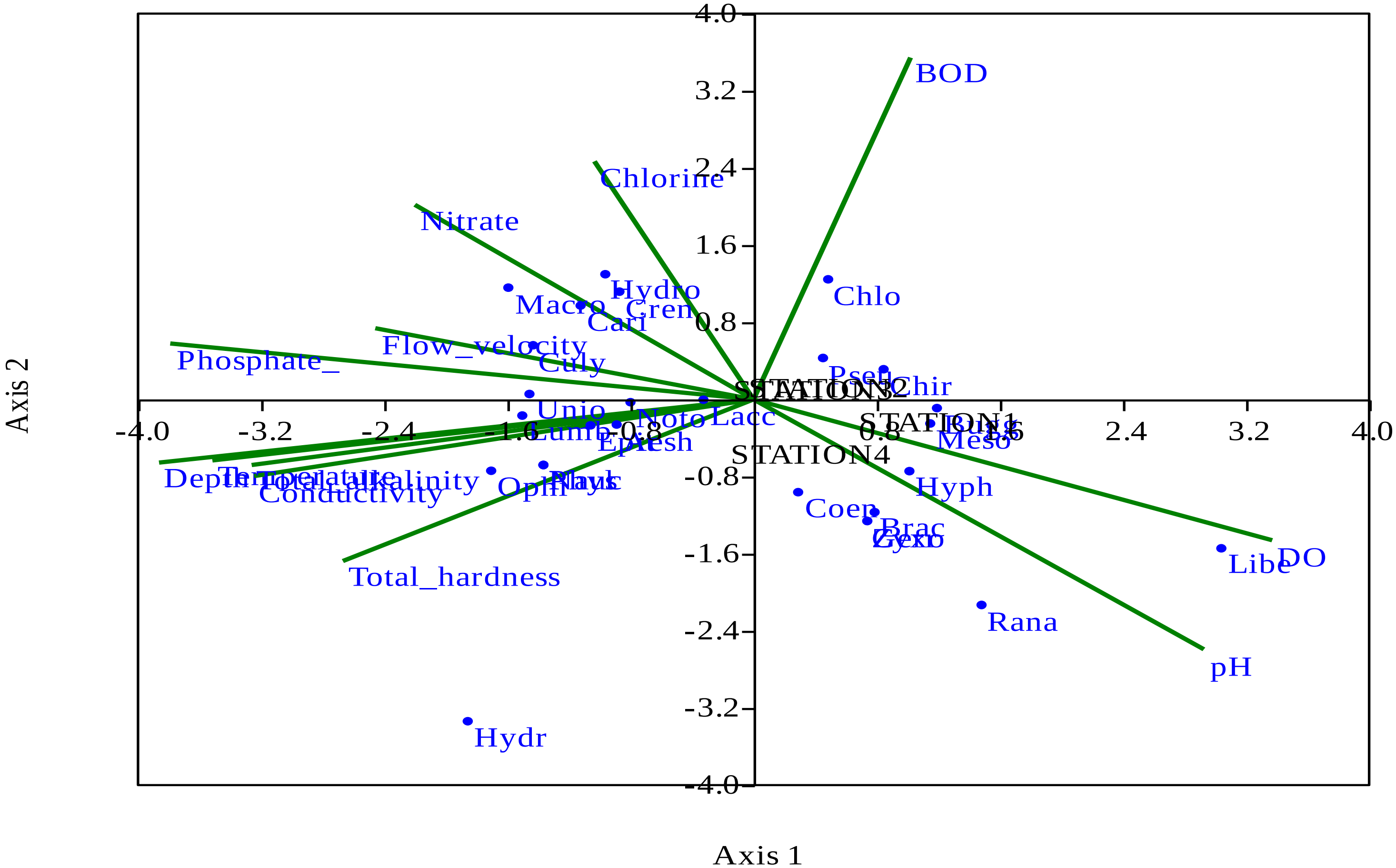

Figure 4.5, Canonical Correlation Analysis (CCA) between macroinvertebrate and environmental variables.

4.5 Discussion

4.5.1 Physico-chemical parameters

The quality of a given water body is determined by its physical, chemical and biological characteristics. They interact with one another to influence aquatic productivity (Keke *et al*., 2017). The water chemistry of aquatic environment can be influenced by different sources which include natural and anthropogenic sources. To protect our water resources, it is important to determine the factors that positively or negatively impact them. Emikpata stream is an important source of water for domestic activities for the community. Most water bodies in Nigeria have been compromised in physical, chemical and biotic characteristic because of discharges of organic and inorganic wastes from anthropogenic activities around our freshwater bodies (Arimoro and Ikomi, 2008). The physico-chemical characteristics of the stream show some variations between sampling stations and sampling periods. Depth, pH, chlorine, nitrate and sodium were statistically significant among the sampling stations ($p<0.05$). All the physico-chemical parameters measured in the stream were statistically significant ($p<0.05$) among sampling months. Water level and physico-chemical characteristics of aquatic ecosystem are usually influenced by pattern of rainfall (Mustapha, 2008). Temperature is one of the important environmental variables because it governs all the physical, chemical, biochemical and biological properties of aquatic ecosystem (Chukwuemeka *et al.*, 2014). Temperature also regulates the physiological, behavior and distribution of aquatic organism (Mustapha, 2008). From this study the mean temperature ranges between 23.0 and 27.0ºC. The medium temperature and pH obtained from this study could be as a result of sample collection time, the nature of vegetation around the stream and also the environmental condition at that particular time.

The depth range (20.96±2.55 to 24.1±1.55) and flow (0.286±0.01 to 0.300±0.01) rate increased slightly during rainy season. This could be as a result of increased in volume of water as a result of rain and wind blowing across the streams which were absence during dry season. High flow rate were observed in stream and flow regimes increased down the stream, this could be attributed to the depth of the sampling stations of the stream and high values were recorded in rainy season than in the dry season, this could be as a result of increased in the water volume as a result of rain and wind blowing across the streams which was absence during dry season (Arimoro *et al.,* 2015). The recorded Dissolved oxygen and BOD_5 might be as indication of moderately clean water (Emere and Nasiru, 2009; Arimoro and Keke, 2016). This finding was an indication of oxygenated water. Chukwuemeka *et al.,* (2014) reported that BOD value ranged of 3-5mg/l is fairly clean water. Dadi-Mahmud *et al*., (2014) recorded DO range from 2.0-7.2mg/l in River Ndakotsu, Lapai, Niger State, Nigeria. Other related works include the work of Arimoro and Keke (2016) who recorded dissolved oxygen range from 3.10-5.0mg/l in Gbako River, North central, Nigeria. Similarly Arimoro and Keke (2016) reported a BOD range of 2.20-6.0mg/l from their works in Gbako River, North Central, Nigeria. The DO is higher to that of the WHO (2011) range of (4.0) and lower BOD_5 range of (6.0). The study showed higher DO and BOD_5 values in rainy season than in dry season as a result of influx of organic matters into the stream though surface run off and erosion (Mustapha, 2008; Abowei and Ekubo, 2011).

Medium pH values obtained in this study could be as a result of surface run off or decay of organic matters in the water (Mustapha, 2008). This finding was in conformity with Arimoro and Keke (2016) who reported pH range of 6.10 to 7.70 from Gbako River, North Central, Nigeria. Similarly the work of Raji *et al.,* (2015) who recorded a similar higher pH value ranged (6.24-8.50) and in line with WHO (2011) range (6.5-9.5). This finding is in contrast with Edegbene *et al*., (2015), who reported pH range of 7.04 to7.90 from Chanchaga River, Niger State, Nigeria.

The observed lower conductivity value in the dry season than in rainy season indicatied that the sampling station might contain more amount of suspended and dissolved solid materials, which increased the concentration of cations such as calcium, magnesium and sulphate (Mustapha, 2008; Arimoro *et al.,* 2015). Conductivity values obtained in this study were in agreement with 32.00-110 µS/cm obtained from River Gbako, North central, Nigeria. (Arimoro and Keke, 2016).

The recorded low values of total hardness and alkalinity in dry season and high values in raining season, could be due to increase volume of water in rainy season and surface run off into the stream which increased amount of suspended and dissolved solid materials in the stream (Mustapha, 2008). Suspended and dissolved solid materials increased the concentration of cations such as calcium, magnesium and sulphate in our water bodies (Mustapha, 2008). This finding were in conformity with the work of Ibemenuga and Nzekwe, (2017) who reported alkalinity of 7.65-21.13mg/l in rainforest water freshwater ecosystem of southern Nigeria. Keke *et al*. (2015) reported a lower alkalinity ranged of 8.00-16.00mg/l from downstream Kaduna River, Zungeru, Niger State.

High chlorine, nitrate, phosphate, sodium and potassium values recorded during the study period were indicators of different anthropogenic activities around the stream. The influx run-offs from surrounding farm lands in some reaches of the stream are likely responsible for the perceived deterioration of the water quality. High nitrate and phosphate contents could be as a result of different anthropogenic activities and surface run off from farms and decomposition of organic matters into the water (Ibrahim *et al*., 2009). Phosphate and nitrate are one of the limiting factors of environmental variables because when used up, aquatic environment becomes unproductive (Arimoro *et al*., 2015). Nitrate and phosphate are associated with algae growth and eutrophication.

4.5.2 Macroinvertebrate groups assemblage and distribution

A total of 625 individuals from 28 species comprising the macroinvertebrate assemblage was low compared to other studies from Northern Nigeria (Emere and Nasiru, 2009; Dadi-Mamud *et al.,* 2014). The abundance and diversity of macroinvertebrate could be due to habitat type, substrate type and vegetation cover. Nutrient availability and nature of habitat also favour the abundance and distribution of macroinvertebrates (Arimoro and Keke, 2016). Taxonomic breakdown of macroinvertebrates from the stream showed the dominance of Odonata, Hemiptera, Ephemeroptera and Coleoptera. These groups except Ephemeroptera belong to pollution tolerant class in water body (Arimoro and Ikomi, 2008; Emere and Nasiru, 2009). These groups are moderately tolerant of pollution and their presence could be attributed to the vegetation cover and bottom sediment of the stream enhancing their colonization (Edengbene, 2015).

The high abundance of Odonata and Hemiptera were found in the streams, there diversity and abundance were as a result of the vegetation cover and the bottom sediment of the streams favoring their colonization. Similar studies have also reported the presence of Odonata and Hemipterans from their works on Nigeria Freshwater (Emere and Nasiru, 2009; Arimoro *et. al*., 2015; Arimoro and Keke, 2016). Favourable 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).

Coleopterans were also encountered and some of the groups were recorded in abundance. They are found across areas which have more nutrient content, the area which are moderately polluted**.** Emere and Nasiru (2009) reported that Coleopterans are associated to organically polluted waters bodies because of the nature of their exoskeleton and their ability to renew oxygen supply directly from the environment and thus remain unaffected by oxygen depleting waste.This findings was consistent with work of Arimoro and Keke (2016) who reported that, the abundance of some Coleopteran groups is an indication of fairly clean water environment (gross pollution free). Andem *et al., (*2014), and Arimoro and Ikomi (2008) also share similar view.

The presence of Ephemeroptera species are indication of clean water quality and were recorded during the rainy season months. This could be as a result of influx of rain leading to dilution in the water which enhanced the water quality (Arimoro and Ikomi, 2008; Arimoro and Keke, 2016). Low abundance of Ephemeroptera in the study area might be as a result of their sensitivity to polluted environment and the deteriorated state of some sampling stations by the riparian users (Arimoro and Ikomi, 2008). Using the EPT index, Plecoptera and Tricoptera were absent throughout the study period. Arimoro *et al.* (2015) also reported the scarcity of Plecoptera in tropical African streams. Similar finding was reported by Arimoro *et al.* (2015) from River Ogba, Niger Delta, Nigeria, Edegbene *et al.* (2015) reported low diversity and abundance of EPT from their study in River Chanchaga, Niger State. Emere and Nasiru, (2009) also reported low abundance of Ephemeroptera group in urbanized stream in Kaduna, Nigeria. The low abundance of Ephemeroptera and absence of Plecoptera and Trichoptera in sampling stations of the streams was an indication of gross pollution due to anthropogenic activities in the stations. Many studies have reported higher abundance and diversity of this group of macroinvertebrate to clean and pollution free water bodies (Odume *et. al.,* 2012; Arimoro and Keke 2016).

Few presence of Decapoda, Oligochates, Mollusc and Diptera was an indication of pollution due to presence of organic waste in the stream (Edegbene *et al.,* 2015). They are very tolerant of pollution and are mostly found in polluted environment. This finding was in conformity with the works of Emere and Nasiru, 2009; who reported various type of Oligochaetes, Decapodes, Mollusc and Diptera from their works on different streams in Nigeria.

This study showed that there was spatial and temporal variation in macroinvertebrate abundance in the stream. High abundance of macroinvertebrates was encountered in dry season than in the wet season. This could be as a result of the increase in water volume during wet season, increase flow rate and surface run off from surroundings environment which must have erupted the habitat structure doing the wet season. Higher abundance of macroinvertebrates was recorded in dry season in many streams in Nigeria (Arimoro and Ikomi, 2008; Keke *et al.,* 2017)

4.5.3 Relationship of macroinvertebrates with physico-chemical parameters.

There was a positive correlation between macroinvertebrates species and measured physicochemical parameters in the streams. The scarcity of Ephemeroptera, absence of Trichoptera and Plecoptera in the stream signifies the deterioration of biotic and overall ecological status of the stream. Several researchers have reported the absence or low abundance of this group in Nigerian water bodies (Arimoro *et al* 2015; Edegbene *et al* 2015; Arimoro and Keke 2016). Species richness, diversity and evenness indices of sampling stations of the stream during the sampling period reflected the water quality condition of each stream. For over a period of time, there has been an increasing activity around our water bodies which is due to increased anthropogenic activities. Anthropogenic activity has negative impacts on the stream which affects water quality and distribution of aquatic organisms in the stream.

CHAPTER FIVE

5.0 CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

Emikpata Stream is found to be under minimum anthropogenic impact and is impaired in the downstream sections. The physico-chemical characteristic of the stream showed some variations between sampling stations and sampling periods. Depth, pH, chlorine, nitrate and sodium were statistically significant among the sampling stations ($p<0.05$). Taxonomic breakdown of macroinvertebrates from the stream showed the dominance of Odonata, Hemiptera, Ephemeroptera and Coleoptera. This groups except Ephemeroptera belong to pollution tolerant class in water body. Few presences of Decapoda, Oligochates, Mollusc and Diptera was an indication of pollution due to presence of organic waste in the stream. There was a positive correlation between macroinvertebrates species and measured physico-chemical parameters in the streams. The scarcity of Ephemeroptera, absence of Trichoptera and Plecoptera in the stream signified the deterioration of biotic and overall ecological status of the stream. The survey of macroinvertebrate organisms gives an important insight into the status of the stream and appends to the knowledge and understanding of the management strategies involved in biomonitoring as a significant tool in River restoration studies.

5.2 Recommendations

The Emikpata stream is found to be gradually affected by human activities, thus their is need for close monitoring of the stream and its macroinvertebrates. There is also a need from the government to enlighten the catchment villages on their activities which tend to have side effects on the stream and its macroinvertebrate.

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