ALGAE-BASED INDICES IN RELATION TO ANTHROPOGENIC IMPACT ON WATER QUALITY OF TUDUN WADA-MAKERA DRAINAGES AND A SEGMENT OF RIVER KADUNA

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DECLARATION

I declare that the work in this dissertation entitled 'Algae-based indices in relation to anthropogenic impact on water quality of the Tudun wada-Makera drainages and River Kaduna ' has been carried out by me in the Department of Biological Sciences under the supervision of Prof. S.P. Bako, Prof. M.L. Balarabe and Dr. A.M. Chia. The information derived from the literature has been duly acknowledged in the text and a list of references provided. No part of this thesis was previously presented for another degree or diploma at this or any other Institution.

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Signature Date

CERTIFICATION

This dissertation 'ALGAE-BASED INDICES IN RELATION TO ANTHROPOGENIC IMPACT ON WATER QUALITY OF THE TUDUN WADA-MAKERA DRAINAGES AND RIVER KADUNA ' by Yahuza TANIMU, meets the regulations governing the award of the degree of Doctor of Philosophy (Ph.D.) in Botany of Ahmadu Bello University, Zaria, and is approved for its contribution to knowledge and literary presentation.

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DEDICATION

I dedicate this dissertation to my late parents Hon. Mazuba Daniel Tanimu and Deaconess Lois Daniel Tanimu who taught that "I can be whatever I want to be".

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ABSTRACT

Surface water physico-chemical properties, periphytic and planktonic algae were sampled and analysed once a month for 24 months (January, 2013 to December 2014) in Tudun wada (TW), Makera (MK) drainages and a segment of River Kaduna in Kaduna metropolis, northern Nigeria using standard methods. The drainages which are modified by the deposition of solid and liquid wastes from urban residential areas, markets and industries transport such wastes downstream to River Kaduna, a major source of drinking water for the Kaduna town. Three sampling stations were selected along each drain (TW_1, TW_2, TW_3, MK_1, MK_2 and MK_3) to reflect the nature of pollution activities on the drain, while six stations were selected on River Kaduna (RK_1, RK_2, RK_3, RK_4, RK_5, RK_6), three associated with each drain- one point before the point each drain impacts the river, the second at the point each drain impacts the river and the third after each drain impacts the river. The values for surface water temperature (23.3 to 38.3°C), pH (6.12 to 10.79), electrical conductivity (EC) and total dissolved solids (TDS) (29 to 2253 µS/cm and 17 to 1125 ppm for EC and TDS respectively), total alkalinity (TA) (21 to 900 mg/L), sulphate (SO_4) (1.30 to 225 mg/L) in surface water were observed to be significantly higher ($P<0.05$) on stations on the Makera drain (MK_1, MK_2 and MK_3). While values for dissolved oxygen (DO) (0.10 to 4.16 mg/L), biochemical oxygen demand (BOD) (0.30 to 37.80 mg/L); total hardness (TH) (10 to 660 mg/L); nitrate-nitrogen (NO_3-N) (0.17 to 14 mg/L); phosphate-phosphate, (0.1 to 2.30 mg/L); total nitrogen (TN), (17.80 to 70.72 mg/L); and total phosphorus (0.18 to 7.14 mg/L), were observed not to vary significantly among all the sampling stations ($P\geq0.05$). Indicator species analysis and Species richness for periphyton followed this order epilithic>epipelic>episamic>epiphytic>epidendric, while Diversity and Evenness indices followed this order epipelic>epilithic> episamic>epiphytic>epidendric. Indicator species analysis showed species indicative of the varying levels of pollution in the sampling stations while cluster analysis and non-metric multidimensional scaling using algae grouped sampling stations according to the level of pollution. Principal Component analysis and Canonical Correspondence Analysis showed the relationships that exist among algae, surface water physico-chemical characteristics and sampling stations. Indicator species of the Makera drain include *Achnanthes hungarica, Aulacoseira ambigua, Epithemia* sp., *Gyrosigma* sp., *Melosira calognosa, Melosira sulcata, Melosira* sp., *Sirurella augusta, Oscillatoria limosa* and *Botryococcus* sp. Those of the Tudun Wada drain are *Nitzchia* sp., *Nostoc* sp., *Oscillatoria brevis, Oscillatoria tenuis* and *Euglena* sp., while those of the stations on River Kaduna include *Anomoneis* sp., *Aulacoseira granulata, Coconeis placentula, Frustulia rhomboides, Gyrosigma accumunata, Melosira distans, Pinnularia viridis, Synedra ulna, Coelastrum,* all species of *Closterium,* all species of *Scenedesmus, Staurastrum* sp., *Merismopedia glaucau, M. elegans amd Oscillatoria lacustris*. Drains conveying wastewaters from industrial and residential areas, and markets altered water quality considerably to the extent that such alterations led to significant variations in physico-chemistry and algal composition and community structure of such waters when compared to waters that are less impacted by human activities. The selection of substrate is a very vital component of water quality assessment using periphytic algae because of the specificity shown among species and the variations in community structure of algae on different substrates. A combination of epilithic and epipelic community is recommended for water quality analysis.

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CHAPTER ONE

1.0 INTRODUCTION

1.1 Background

Algae are primary producers in the aquatic ecosystem that possess chlorophyll a as the primary photosynthetic pigment (Verlencar and Desai, 2004; Herring, 2008; Opute and Kadiri, 2013). They are dependant on sunlight for photosynthesis and require carbon in the form of carbon dioxide, oxygen, phosphates, nitrates and silicates in the case of diatoms for growth and development (Rabalais, 2002; Chia *et al.*, 2013).

Algae are considered to be a loose group of organisms that have all or most of the following characteristics: aquatic, photosynthetic, simple vegetative structures without a vascular system, and reproductive bodies that lack a sterile layer of protecting cells (Sheath and Wehr, 2003). They have a wide range of vegetative morphologies, which includes unicellular, colonial, pseudofilamentous, filamentous, pseudoparenchymatous, parenchymatous and siphonous or coenocytic forms (Sheath and Hambrook, 1990). In addition, planktonic (free-floating) forms are typically small and microscopic, and mostly consist of simpler forms, benthic algae (attached to macrophytes, sand, clay/silt and stone/rock surfaces) include the entire range of morphologies, and flagellated taxa are less common (Ambrose *et al*., 2006; Reynolds, 2006; Opute and Kadiri, 2013).

The algae are no longer regarded as a phylogenetic concept, but still represent an ecologically meaningful and important collection of organisms (Salmaso *et al*., 2014). They are important primary producers in the aquatic ecosystem, age long water quality indicators, sources of many plant products useful in pharmaceutical, chemical and food industries (Reynolds, 2006; Maschek and Baker, 2008) and represent a vital feed stock for future biofuel development (Chisti, 2007; Kelman *et al.,* 2012).

Algae are found in both polluted and unpolluted waters, and they are very sensitive to variations in physical and chemical characteristics of the water body in which they are found. They are easy to collect and not expensive to analyse. These attributes makes them suitable indicators of water quality. Anthropogenic activities such as agriculture, industries and domestic discharges have been implicated in the deterioration of the environment Pollutants from these activities are released either directly into the aquatic ecosystem in the form wastewater discharges, oil spillages, agricultural run-offs or indirectly through deposition from soil or air within the catchment of such water bodies.

The most important factors affecting the distribution, abundance and diversity of algae include pH, ionic strength, nutrients, velocity of water, availability of light, and grazing (Pla *et al*., 2005; Potapova and Charles, 2005; Bere and Tundisi, 2011a; Stenger-Kovacs *et al*., 2013). These factors in turn are defined by climatic conditions, geology and bedrock topography, and land-use (Triest *et al*., 2012). Many species of algae have been found to be ubiquitous; while others appear to be restricted in distribution by climate or geography or may be endemic to some specific water bodies (Potapova and Charles, 2005, Bere *et al.*, 2013). Local factors such as water chemistry that is largely affected by anthropogenic activities determines the abundance and diversity of algae (Stenger-Kovacs *et al*., 2013).

Algae are found in both polluted and unpolluted waters, and they are very sensitive to variations in physical and chemical characteristics of the water body in which they are found (Jafari and Gunale, 2006; Bere *et al*., 2013). Algae are easy and inexpensive to collect and analyse (Verlencar and Desai, 2004; Li *et al*., 2010). These attributes make them suitable indicators of water quality.

Biotic indices have found much acceptance in water quality assessment because of their cost effectiveness in comparison to the often used physico-chemical characteristics; and they reveal temporal and spatial impact of pollution on a water body (Jaweir *et al*., 2014; Hassan *et al*., 2014a; Gara and Stapanian, 2015). The use of algae as bioindicators of water quality was recognised as far back as the 19th century (Cohn, 1853). The first attempt to classify aquatic organisms as indicators of water quality was made by Cohn (1870), and was later modified by Mez (1898). The relationship of organisms to the quality of water was more clearly defined by Kolkwitz and Marsson (1902; 1909), who also created the name '*saprobic organisms*'.

1.2 Statement of Research Problem

Anthropogenic activities such as agriculture, industrial and domestic discharges have contributed to the deterioration of the environment (Ansari *et al*., 2014, and Van Dover, 2014). Pollutants from these activities are released either directly into the aquatic ecosystem in the form of wastewater discharges, oil spillages, agricultural run-offs (Adeyemo *et al*., 2002, and Hassan *et al*., 2014b), or indirectly through deposition from soil or air within the catchment of such water bodies (Bako *et al*., 2014).

Developed algae-based water quality indices are mostly from works done in the temperate regions (Bere, 2011), while the few studies from the tropical region may lead to erroneous interpretations of water quality because of overlaps in species composition between regions or variation in ecological characteristics of some key taxa (Pan *et al*., 1996). An example is the classification of *Gomphonema parvulum* as an indicator species for oligotrophic/mesotrophic environments in Gravatai River, Brazil, by Salomoni *et al*. (2011), which disagrees with the classification of the same species as a tolerant species to organic pollution in Japanese Rivers (Kobayasi and Mayama, 1989; Lobo *et al*., 2006). The same species was assigned indicative and saprobic values corresponding to highly eutrophic environments when evaluating water quality in English waters (Kelly and Whitton, 1995). These conflicting classifications leave us with a problem on where to place this alga if it found in Nigeria.

Some species are endemic, complicating the situation, thereby making it necessary for the development of an algal index unique to a region to reflect the species present in that locality. New species may be incorporated into biotic indices, which combine ecological information with environmental information through specific indicative rates or values assigned to species from multivariate analysis (Salomoni *et al*., 2011).

1.3 Justification

Different land use patterns have been shown to impact differently on physical, chemical and biological components of water quality. The need to develop locally applicable biological indices is imperative for environmental monitoring agencies, researchers and conservationists.

The Tudun Wada, Makera drain and River Kaduna presents a representative environment that reflect the major sources of pollution in Kaduna metropolis, receiving industrial, domestic, urban run-off and agriculture based pollutants from its catchment. This characteristic makes it a suitable 'laboratory' for the initiation of the development of a local algal based water pollution index, reflecting pollution from various land use patterns.

This study attempted to utilize principles in multivariate analysis, diversity indices, species abundance and indicator organisms to develop algae based water quality indices using the Tudun Wada Makera drain and River Kaduna, which may be applicable in Nigeria and possibly the West African sub-region. The study will therefore elucidate interactions between periphyton algal diversity and substrate types; ionic strength; nutrient composition; and other physico-chemical characteristics.

1.4 Aim

The aim of this study was to evaluate the applicability of algae-based indices in relation to the impact of anthropogenic activities on water quality status of the Tudun Wada-Makera drainages and River Kaduna.

1.5 Objectives

The specific objectives are to determine the:

i) effects of anthropogenic activities on the water quality of the Tudun Wada-Makera drains and River Kaduna.

ii) Algae species indicative of changing water quality status associated with varying land use patterns along the Tudun Wada-Makera drains and River Kaduna.

iii) effects of substrate-type on periphytic algal community structure in the Tudun Wada-Makera drains and River Kaduna.

iv) Relationship among surface water physico-chemical characteristics in the Tudun Wada-Makera drains and River Kaduna.

v) Relationship between surface water physico-chemical characteristics and algal species in the Tudun Wada-Makera drains and River Kaduna.

1.6 Hypotheses

i) Anthropogenic activities do not have any significant effect on water quality along the Tudun Wada-Makera drains and River Kaduna.

ii) There are no species that indicate the significant change water quality status associated with varying anthropogenic activities along the Tudun Wada-Makera drains and River Kaduna.

iii) Periphytic algal community structure is not significantly affected by substrate-type in the Tudun Wada-Makera drains and River Kaduna.

iv) There is no significant relationship among surface water physico-chemical characteristics in the Tudun Wada-Makera drains and River Kaduna.

v) There is no significant relationship between algae species and water quality parameters in the Tudun Wada-Makera drains and River Kaduna.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Lotic Water Systems

Lotic waters are flowing water systems like springs and seeps, rivers, streams, creeks, brooks and side channels (Bere *et al.*, 2013). Walsh *et al*. (2007) reported a four dimensional framework of lotic systems. The first is the longitudinal framework, which captures the entire flow length of the water body from the head waters upstream through the transfer zone and down to the depositional zone downstream. Changes have been associated with flowing water as it flows from upstream to downstream. The second is the lateral dimensional framework, which cuts across the channel. This covers the thalweg, which is the deepest part of the channel; followed by the flood plains which are divided into the low flood plains (that are frequently inundated), the higher flood plains (that are rarely inundated), and the terraces (which are former flood plains that are no longer flooded by the down cutting stream and the hillslopes or upland areas which extend up-gradient to the boundary of the water shed). The third is the vertical framework which divides the lotic system into surface water and ground water with the waters continually interacting in terms of exchanges in chemical and biological components. A variation may occur in terms of water along the length of a lotic system due to leakages into the aquifer or addition of water from the aquifer. The fourth is the temporal framework which emphasizes the importance of time as a factor in the determination of water quality and the physical structure of a lotic system. The fact that everything changes with time is important for the management of water bodies.

Lotic systems are important components of the biogeochemical cycles, at local, regional or global levels (Li *et al.*, 2010; Bere, 2011). They are used for transportation; act as source of drinking water; used for fisheries and irrigation; waste removal systems; and of enormous aesthetic value. A great deal of interaction occurs among physical, chemical and biological processes in lotic systems (Wehr and Descy, 1998; Pace *et al*., 2012).

In lotic systems, activities that alter water quality at one location (upstream) affect processes and organisms downstream, making the management of these systems very difficult (Nagorski *et al.*, 2014). A longitudinal difference in the time scales of chemical and biological processes is characteristic of these systems, rendering it difficult to design polices and assess the results of management actions (Fan and Shibata, 2015). Therefore great innovative approaches are needed to strike a balance between human needs and ecological integrity in these characteristic and dynamic environmentally heterogeneous systems (Pace *et al*., 2012).Ecological principles have now been found to be very important in the management of lotic systems (Salmaso *et al.*, 2014).

Rapid increase in population densities and increase in industrial and agricultural activities expose most hydrographic basins to negative environmental impacts especially to pollution by domestic and industrial waste residues (Geurts *et al.,* 2009; Salomoni *et al*., 2011). The ever increasing influence of anthropogenic activities on lotic environments as a consequence of increase in civilisation has captured public interest due to the deterioration of water quality and its associated problems (Salvia *et al.*, 1999; Bere, 2007; Chukwu *et al.*, 2012).

2.2 Water Quality Assessment in Lotic Systems

There are two basic approaches to the assessment of water quality in lotic systems that run through literature. The first, involves the use of physical and chemical variables of lotic systems to provide some insight into the water quality (Thangaradjou *et al.*, 2012). The use of this method allows only instantaneous measurements, providing information on water conditions at the period when the measurements were taken ignoring temporal variation of water quality variables that are usually high in lotic environments (Rocha, 1992). Sophisticated chemical analytical methods have been developed but still they cannot provide the impact of pertinent compounds, especially synthetic organic compounds that are highly toxic (Aidar and Sigand, 1993; Bere and Tundisi, 2011b).

The major natural source of heat to water bodies is solar radiation, and most of heat energy from the atmosphere absorbed by the water while a significant quantity of it may absorbed by the sediment and later tranfered to the water (Wetzel, 2001; Keder, *et. al.*, 2005). Temperature is an important water quality parameter that affects aquatic organisms, by placing an important role in the determination of the rates of chemical and biological processes (Khare and Jadhav, 2006). It affects the survival, reproduction, growth and behaviours of phytoplankton and other biota (Paulose and Maheshwahr, 2008). Physical parameters that affect water temperature include riparian vegetation, ground water – hyporheic water interactions, tributary inflow, water depth and air temperature (Welch, *et al*., 1998). Several workers in Nigeria have reported that surface water temperature varies with season (Adakole, *et al.*, 2008; Chia and Bako, 2008; Tanimu and Bako, 2013).

pH is the negative logarithm to base 10 of the hydrogen ion concentration of a water body. Several workers have shown that the pH of unpolluted water bodies in Nigeria is circum-neutral pH (Adakole *et al.*, 2003; Chia and Bako, 2008; Tiseer *et al.*, 2008; Ibrahim and Abdullahi, 2009). pH affects solubility of trace metals and influences uptake to metal by phytoplankton (Odhiambo and Gichuk, 2000 and Zhang and Xu, 2001).

Alkalinity refers to the acid neutralizing capacity (ANC) of water or is a measure of its buffer capacity or resistance to a change in pH. Most of the ANC of natural waters is caused by bicarbonates, carbonates, and hydroxides, the relative amounts of which are dependent on pH. For a pH less than 8.3 the ANC of natural waters is composed almost conclusively of HCO^{-}_{3}, at higher pH (>8.3) CO_3^{2-} increases and composes a greater portion of ANC (Welch *et. al.*, 1998; Khare and Jadva, 2008). Alkalinity may also increase significantly in streams and lakes that drain urbanized watersheds because more surface area of relative erodible sources of (Ca^{2+}) such as concretes is exposed to naturally acidic precipitation, and sometimes, to more acidic precipitation from anthropogenic sources of strong acids (nitrate and sulphates) (EPA/QPWS, 1999).

Ecologically, the acceptable pH for life is in the range of 6 and 9 (WHO, 2006). Acidification from humic soil, and effluents from industries and other agricultural chemicals may result in very low pH. High pH (above 9) may be caused by photosynthesis at night when CO_2 is no longer depleted (Welch *et al.*, 1998).

This is the measure of the ability of a solution to conduct electrical current. Conductivity varies with both number and types of ions that the solution contains. Conductivity provides baseline information against which changes in water quality can be detected and also is used to trace the movement of the substances discharged into the water body (Welch *et al.*, 1998). Conductivity may be an indictor of soluble substances, including nutrients and soluble metal that enrich ground water in urbanized areas and may also serve as an indicator of soluble reactive phosphorus (SRP) and nitrate-nitrogen ($NO_{3-}N$) for algal growth (Rabalais, 2002).

Electrical conductivity is affected by temperature because temperature affects the solubility of chemical substances in water. Water temperature affects the electrical conductivity, such that its value increases by 2 to 3% per 1^0C rise in temperature (Lenntech, 2008).

Several workers in Nigeria have shown that electrical conductivity in Nigerian waters is variable from one water point to another even in the same water body and from one water body to another (Ibrahim and Abdullahi, 2009; Tiseer *et al.*, 2008_1). Some of the EC values for Nigerian waters include lake Chad, 380.63$\pm$51.75 μS/cm (Umeham, 1989), Challawa River Kano, from 44 to 48.65 μS/cm (Ibrahim and Abdullahi, 2009), Bindare stream, Zaria EC of 430.83$\pm$196.33 μS/cm (Adakole *et al.*, 2002), Samaru stream 328.1$\pm$63.92 μS/cm (Tiseer, *et al.*, 2008), and Alaro River, Ibadan 13900$\pm$280.7 μS/cm (Fakayode, 2005).

Water hardness is caused by divalent metallic cations, majorly Ca^{2+} and Mg^{2+} which are often associated with the acid neutraling capacity anions HCO_3^- and CO_3^{2-} (UNESCO/WHO/UNEP, 1996; Khare and Jadva 2008). Hydrocarbons are transformed during the boiling of water into carbonates, which usually precipitate. Therefore, carbonate hardness is also known as temporary hardness, whereas the hardness remaining in the water after boiling is called constant/ permanent hardness (Mahesha and Balasubramanian 2005). Seasonal variation of water hardness often occur reaching the highest values during low flow conditions and the lowest values during floods (Adakole *et al.*, 2003; Gupta e*t al*., 2008).

Nutrients such as carbon, nitrogen, phosphorus, sulphur, calcium, magnesium, potassium, iron, manganese and sodium that are essential to the growth of living organisms (Botkin and Keller, 1998). Nitrogen or phosphorus and sometimes both usually limit autothrophic production of freshwater (Rabalais, 2002). The amount of phosphorus and nitrogen in urban streams is greater because of introduction of fertilizers, detergents, and the products of sewage treatment plants. However, the highest concentration of phosphorus and nitrogen are often found in agricultural areas, where the sources are fertilized farm fields and feedlots. Over 90% of the total nitrogen added to the environment by human activity is from agricultural activity (Nagare and Tsuno, 2005; Saad and Hemedu 2005). Nitrogen and phosphorus limit the growth of terrestrial plants, phytoplankton, macroalgae and vascular plants in fresh water and marine ecosystems and silicon additionally limits the growth of diatoms (Kadiri and Opute, 2013).

Condition of increased level of nutrients, chiefly nitrogen and phosphorus is called eutrophication (Purushothaman and Chakrapui, 2008). Increased nutrient levels or shifts in nutrient ratios or both often leads to excessive phytoplankton growth and may result to a bloom of a single or more species that has some negative impact (Rabalais, 2002; Nagare *et al*., 2005; Murthy *et. al*., 2008; Chia and Bako 2008). Harmful algal blooms (HAB) include red tides, brown tides and toxic and noxious blooms (Rabalais, 2002; Cook *et. al*., 2004).

Nitrogen is essential for living organisms as important constituent of proteins, including genetic material. Plants and micro-organisms convert inorganic nitrogen to organic forms. When influenced by human activities, surface waters can have nitrate concentrations up to 5mgL^{-1} No_3^- N, but often less than 1 mgL^{-1} No_3^- N (UNESCO/WHO/UNEP, 1996).Phosphorus is an essential nutrient for living organisms and exists in water bodies as both dissolved and particulate species. Natural sources of phosphorus are mainly weathering of phosphorus bearing rocks and decomposition of organic matter. Domestic waste waters (particularly those containing detergents), industrial effluents and fertilizer run offs contribute to elevated level in surface waters. Phosphorus associated with organic and mineral constituents of sediments in water bodies can also be mobilized by bacteria. In most natural surface waters phosphorus ranges from 0.005 to 0.020 $mg1^{-1}$ of $P0_4$-P (UNESCO/WHO/UWEP, 1996).

Dissolved oxygen refers to the amount of gaseous oxygen (O_2) dissolved in an aqueous solution is influenced by the rates of diffusion from the surrounding air; aeration (rapid movement); and photosynthesis (UNESCO/WHO/UNEP, 1996). Oxygen is essential for life processes of most aquatic organism. Low concentration of dissolved oxygen indicates the presence of excessive organic load, while high values can indicate excessive plant production (i.e. eutrophication). Many aquatic organisms will suffocate if there is insufficient volume of dissolved oxygen in the water (EPA/QPWS, 1999; and Hamzah and Hattasrul, 2008). Dissolved oxygen may be higher in wet season than dry season due to interaction of rain water with oxygen in the air as it falls (Chia and Bako, 2008). Oxygen has been shown to dissolve more easily at low altitude than at high altitudes because of higher atmospheric pressure and shows significant negative correlation with surface water temperature because the solubility oxygen is greater in cooler water (Senese, 2005; Bere, *et al.*, 2013). As dissolved oxygen levels in water drops below 5.0mg/L, aquatic life is put under stress. The lower the concentration, the greater the stress, Oxygen levels that remain below 1 – 2 mg/L for a few hours can result in large fish kills (UNESCO/WHO/UNEP, 1996).

The biochemical oxygen demand (BOD) is defined by the amount of oxygen required for the aerobic micro-organisms present in the sample to oxidize the organic matter to a stable form (Botkin and Keller, 1998). Unpolluted waters normally have BOD values of 2mgL^{-1} O_2 or less, whereas those receiving waste waters may have values up to 10mgL^{-1} O_2 or more particularly near to the point of waste water discharge (WHO, 2006). Raw sewage has a BOD of about 400mg1^{-1} O_2 whereas treated sewage effluents have BOD values ranging from 20 to 100mgL^{-1} O_2 depending on the level of treatment applied. Industrial waters may have BOD values up to 25,000mgL^{-1} O_2 (UNESCO/WHO/UNEP, 1996).

Biological monitoring is the second approach, and it is governed by the theory which provides a direct measure of ecological integrity by the use of response of biota to changes in environmental conditions (Karr, 1991; Joshi *et al.,* 2013). The advantage of this is that it allows for the detection of effect of long-term impact of changes in water quality that are not present at the time of sample collection and analysis (Li *et al.,* 2010; Bere *et al.,* 2013). Key to the use of the aquatic biota as reliable indicators of the changes in lotic environmental conditions is unveiling the integrated environmental information in species rich assemblages (Pan *et al*., 1996, Sutela *et al.,* 2013).

The preceeding advantages of biological monitoring have made it gain more momentum in aquatic health management programmes as a result of several shortcomings in use of standard physical and chemical methods described above (Li *et al*., 2010; Bere *et al.,* 2013). Biological monitoring now has the reputation of an ideal means of integrated water resources management as it provides a summary of conditions of a lotic system (Walmsley, 2000; Joshi *et al.,* 2013). Biological monitoring has now become an important branch of applied ecology where the scientific and economic interests of the society meet in the management of lotic systems (Passy, 2007; Salmaso *et al*., 2014).

Physical and chemical methods are, however, important compliments of biological methods, contributing to the correct assessment of the quality of running waters (Lobo *et al.*, 2004; Hassan *et al.*, 2014a). Since the biological response is to the integrated physical and chemical environment to which the organism has been exposed for some time, it is not surprising that the physical and chemical indicators often do not correlate with biological indices (Schoemann, 1979; Round, 1991; Guo *et al.*, 2010).

2.3 Development of Biotic Indices

The biota inhabiting lotic systems are a function of the nature of the physical and chemical characteristics of these systems, thus providing a direct, holistic and integrated measure of the integrity of the systems (Karr, 1991; Linstead *et al.*, 2012). Therefore, the ultimate monitor of the aquatic system is the aquatic life itself (John, 2000; Brabets and Ourso, 2013). It is on this premise that biotic indices enjoy widespread usage in the assessment of the ecological status of lotic ecosystems.

A number of indices of biotic integrity have been developed at local, regional and global levels to assess the health status of lotic systems. These indices are based on the use of niche requirements and habitat preferences of the individual species (autecology), a population (synecology) or higher taxonomic groupings to infer environmental conditions in ecosystems (Stoermer and Smol, 1999). Long-term data can be gathered on the tolerances of a species to be used, to compile an index to deduce environmental conditions from the species composition. This index can take into account the specific tolerances of the species in the community surveyed (De La Rey *et al*., 2008). These indices can be designed to measure specific pollutants or general environmental conditions.

Many indices of water quality have been developed using fish, macroinvertebrates, zooplanktons and phytoplanktons and benthic diatoms.

Already developed algae-based indices of water quality are mostly from works done in the temperate regions (Bere, 2011; Salomoni *et al*., 2011). Only a few have been carried out in the tropical region and include the works Lobo *et al*. (2004, 2006) and Salmoni *et al*. (2011).

Contradictions abound in the interpretations of water quality because of overlaps in species composition between regions or variation in ecological characteristics of some key taxa (Pan *et al.*, 1996). An example is the classification of *Gomphonema parvulum* as an indicator species for oligotrophic/mesotrophic environments in Gravatai River, Brazil, by Salomoni *et al.* (2011), which disagrees with the classification of the same species as a tolerant species to organic pollution in Japanese Rivers (Kobayasi and Mayama, 1989; Lobo *et al*., 2006). The same species was assigned indicative and saprobic values corresponding to highly eutrophic environments when evaluating water quality in English waters (Kelly and Whitton, 1995).

The need to incorpoarate endemic species from different regions of the world into algae-based water quality indices has being stressed in many works to necessitate the development of an algal index unique to a region. Thereby reflecting the species present in that locality. The incorporation of new species into biotic indices, will combine ecological information with environmental information through specific indicative rates or values assigned to species from multivariate analysis (Salomoni *et al*., 2011).

2.4 History of the Development of Algae-Based Indices

To date over a hundred water quality indices have been developed based on algal responses to water quality. They include the Trophic Classification of Rivers and Lakes, Organic pollution, Saprobic, Biotic and Diversity indices of Preston (1948), Knopp (1954), Rawson (1956), Palmer (1969), Dresscher and Van der Mark (1976), Descy (1979), Lange-Bertalot (1979), Heinonen (1980), Sládecék (1986), Watanabe *et al*. (1986), Hellawell (1986), Rumeau and Coste (1988), Felfoldy (1987), Plafkin *et al*. (1989), Kummerlin (1990), Schiefele and Kohmann (1993), Kelly and Whitton (1995); Kelly (1996), Schonfelder (1997), Schmitt(1998), Rott *et al.* (1999) and Coring *et al*. (1999).

2.5 Algae and Biomonitoring in Lotic Systems

The algae of lotic ecosystems are important components of the ecosystems and their diversity increases as anthropogenic influences on the system increase (Round, 1991; Kshirsaga, 2013). This agrees with the intermediate disturbance hypothesis of Sutela *et al*. (2013), which states that the highest diversity is maintained at intermediate levels of pollution. These assemblages are an integral part of the energy cycle, providing much of the food needed in maintaining the ecological balance in nearly all lotic ecosystems (Rocha, 1992; Li *et al.,* 2010).

On the other hand, algae purify waters by absorbing many impurities such as nutrients and heavy metals and are sites of the breakdown of bacterial and other organic matter contamination (Salmaso *et al.*, 2014). They have the ability to respond rapidly to degradation of water quality, often changing in both taxonomic composition and biomass even with slight variations (Rocha, 1992; Biggs and Kilroy, 2000; Doung *et al*., 2006; Barinova *et al.*, 2010). They also play an important role in global cycling of nitrogen, phosphorus, silica and carbon (Chia *et al.*, 2013). The maintenance of proper community structure and functioning of algae in lotic systems in the face of increasing human development and climate change, is therefore, important in river health management.

A multiple of factors acting at different temporal and spatial levels play an important role in structuring algae communities in lotic systems (Potapova and Charles, 2002; Li *et al.*, 2010), with the local environmental conditions identified as playing a more important role compared to broad-scale climatic, vegetation and geographical factors (Pan *et al.*, 1996; Kshirsagar, 2013). The understanding of the role of temporary factors in shaping global communities is, however, still in its infancy (Passy, 2007).

Some of the important factors that determine the distribution patterns of algae in lotic systems are water chemistry (particularly pH, ionic strength and nutrient concentrations), substrate type for periphyton, current velocity, light (degree of shading), grazing and temperature (Round, 1991; Pan *et al.*, 1996; Potapova and Charles, 2005; Bere *et al.*, 2013). Most of these factors are dependent on climate, geology, topography, land-use patterns and other landscape characteristics, and therefore algal communities are similar within ecological regions defined by these characteristics (Pan *et al*., 1996). Short-term differences in community composition are also affected by immigration of cells, differences in growth rate, and death, emigration and sloughing (Bere and Tundisi, 2011a).

Changes in any of the above factors may not necessarily bring about the death of some algal species, if the changes remain within the limits of tolerance of the species, but may affect reproductive potentials (Pan *et al*., 1996).

2.6 Effects of Anthropogenic activities on Water Quality

The impact of anthropogenic activities such as agriculture, industrial and domestic discharges to the deterioration of water quality is well documented in literature. Agricultural activities and domestic wastes have linked to increased conentration of nutrients (nitrogen and phosphorus), electricity conducting ions, total dissolved solids, heavy metals, herbicides and pesticides (Bere and Tundisi, 2011a,b; Tanimu *et al*., 2011a).

Elevated temperatures, concentrations of oils and greeze, heavy metals, sulphates, chlorides have associated to industrial areas (Adeyemo *et al*., 2002; Olorode and Fagade, 2012).

The pollutants from these activities are released either directly into the aquatic ecosystem in the form of wastewater discharges, oil spillages, agricultural run-offs (Adeyemo *et al*., 2002, and Hassan *et al*., 2014b), or indirectly through deposition from soil or air within the catchment of such water bodies (Bako *et al*., 2014).

2.7 Algae and Water Quality Monitoring in Nigeria

The earliest published works of algae as it relates to water quality include the works of Imevbore (1960) on the planktonic algae of Eleiyele reservoir; Adegbenro (1970), who studied the seasonal changes in phytoplankton in the Nigerian Tobacco Company lake in Zaria; Smith (1975), who studied the algal flora of an urban polluted stream in Zaria, Northern Nigeria; Ndama (1970), who evaluated the pollution status of some streams in Zaria using algae; Anyam (1980); Ebuehi (1988) who studied the ecology of suspended algae in Makwaye Lake, Zaria.

More recent studies include the study on desmids in Ikpoba reservoir in Benin City, Southern Nigeria (Kadiri, 1996); desmids from freshwater swamps south Niger Delta, Nigeria (Nwankwo, 1996); phytoplankton of Gubi reservoir, Bauchi (Ezra and Nwankwo, 2001); Phytoplankton as indicators of pollution in an urban stream (Adakole and Joshua, 2002); phytoplankton of the lower Bonny river, Niger Delta, Nigeria (Chinda and Braide, 2004); Diatoms of Gubi reservoir, Bauchi (Ezra, 2007); Chia *et al*., (2011a,b) reported the records diatoms; and interactions of green algae with some surface water physico-chemical characteristics of some man- made ponds in Zaria, Northern Nigeria.

Other recently published works include: Phytoplankton algae of Samaru stream (Tiseer *et al*., 2008); effects of domestic wastewater on water of some reservoirs supplying drinking water in Kaduna State, Nigeria (Tanimu *et al*., 2011a); Phytoplankton as bioindicators of water quality in Saminaka reservoir, Northern Nigeria (Tanimu *et al*., 2011b); Seasonal Survey of phytoplankton as biondicators of water quality in the streams of Kagoro Forest, Kaduna, State-Northern Nigeria (Abagai *et al*., 2011); Survey of phytoplankton in the Bauchi and Yobe States segment of the Hadejia-Nguru wetlands (Tanimu *et al*., 2012); Diversity and abundance of planktonic diatoms as they relates to physico-chemical characteristics of Gimbawa and Zaria reservoirs, Kaduna State, Northern-Nigeria (Tanimu and Bako, 2013); A comparative study on phytoplankton abundance and physico-chemical characteristics between a Concrete and an Earthened fish pond in the Department of Biological Sciences, Ahmadu Bello University, Zaria, Kaduna State, Nigeria was undertaken by Tanimu *et al*. (2013); and Physico-chemical Characteristics and Phytoplankton Diversity of the Lower Niger River in Kogi State, Nigeria (Zakariya *et al*., 2013).

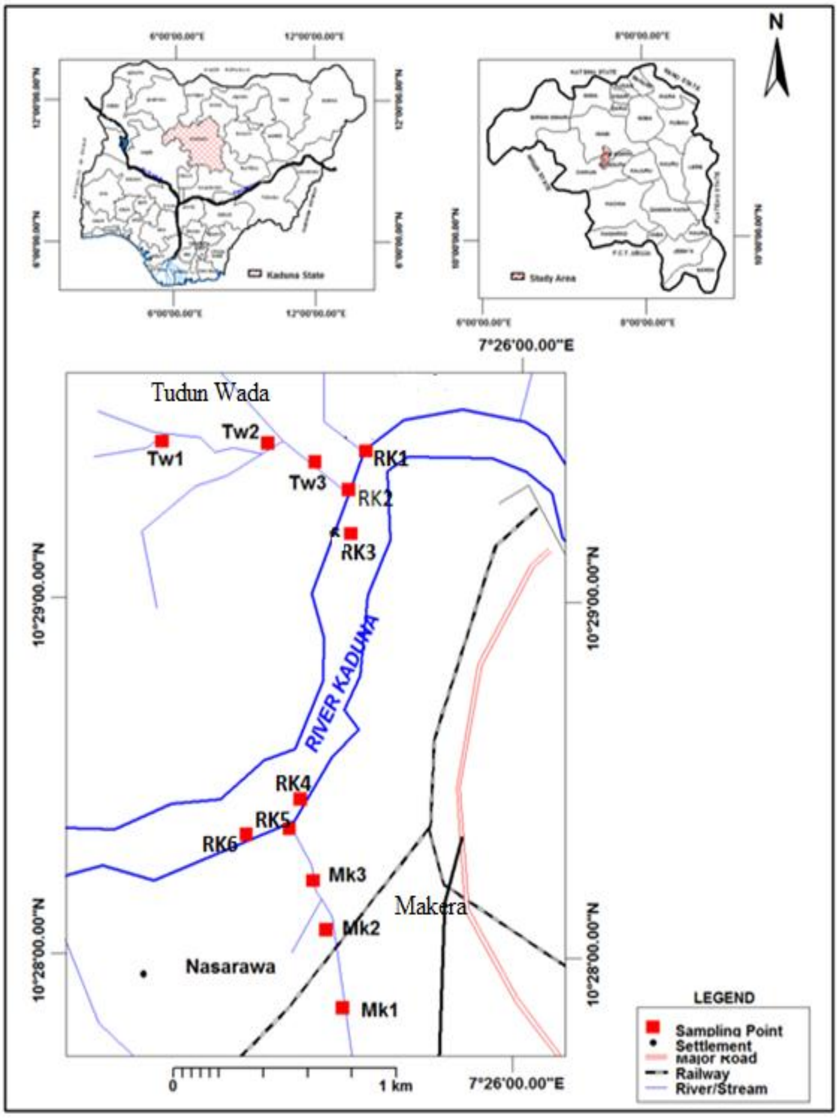
CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Study Area

The Tudun Wada-Makera drains and River Kaduna are located in Kaduna metropolis (Lat. 10.20^{o}N, long. 7.23^{o}E) (Dadi-Mamud *et al*., 2012). Kaduna has a tropical continental climate with distinct wet and dry seasons. The wet season lasts between May and October and is characterized by torrential rainfall, while the dry season starts from November and ends in April. The natural vegetation cover is tropical grassland of the Northern Guinea Savannah type with short scattered trees interspersed with tall grasses (Oniye *et al.,* 2002). Urbanization has taken over the original vegetation of Kaduna. The soil is mainly sandy clay, which reduces infiltration and accelerates overland flow and erosion particularly where the soil surface has little or no vegetation cover.

The Tudun Wada and Makera drains are located in the southern part of Kaduna metropolis; the former collects effluents from the Sheik Mamud Gumi Central Market and residential areas of Tudun Wada Kaduna, while the latter receives effluent largely from United Nigerian Textile Plc, Kaduna Textile Limited (KTL), Zamfara Textile Limited, Nigerian Brewery Limited and Chanchangi oil depots. These drains are among the 53 drains that empty to the River Kaduna (Dadi-Mamud *et al*., 2012). The River Kaduna has its origin from the Jos plateau (at Kaduna –Vom).It is an important source of potable water for Kaduna metropolis and a tributary of the River Niger (Fig. 3.1).



Source: Modified From Kaduna Metropolis Map

Fig 3.1: Map of the study area showing the sampling stations along Makera (MK) drain, Tudun Wada (Tw) drain and a segment of River Kaduna (Rk)

3.2 Sampling

3.2.1 Sampling Stations

Twelve sampling stations were selected for the study. Three (3) stations were located on the Tudun Wada drain across the gradient towards River Kaduna, the first, TW_1 at the confluence of the drain from the Central Market and the Tudun Wada Kaduna residential area, the second, TW_2 by the bridge on the road leading to Kachia road from Tudun Wada, the third station TW_3, is some meters before the drain discharges into River Kaduna. The first station, RK_1 located a few meters upstream River Kaduna before the drain discharges into the River Kaduna while the second, RK_2 is located at the point the water from the drain impacts the River Kaduna, and the third RK_3 located a few meters downstream after the point of impact.

Three (3) other stations are located on the Makera drain across the gradient towards River Kaduna, Station 1 MK_1, after the discharge point of effluent from Nigerian Breweries, Station 2, MK_2 receives effluents from the Kaduna Textile Limited, Station 3, MK_3 receives domestic effluents from residential areas. Three other stations were located on River Kaduna, RK_4, a few meters upstream before the drain discharges (point of impact) into the River Kaduna, RK_5 located at the point the Makera drain impacts the River Kaduna, while RK_6 was located downstream after the point of impact (Table 3.1).

3.2.2 Sampling Duration and Sample Collection

Samples for surface water physico-chemical and algal analyses were collected for 24 months (January 2013 to December 2014). Samples for Total hardness, Total alkalinity, Nitrate-Nitrogen, Phosphate-Phosphorus, Total Nitrogen, Total Phosphorus and Sulphate were collected in a two litre plastic container that was acid washed and rinsed

Table 3.1: Global positioning system coordinates and altitude of sampling stations on Makera (MK) drain, Tudun Wada (TW) drain and River Kaduna (RK)

Stations	Longitude	Latitude	Altitude
TW_1	7^0 08' 08.00"E	10^0 30' 25 40"N	601m
TW_2	7^0 25 07.59"E	10^0 30' 32. 50"N	609m
TW_3	7^0 25' 06.35"E	10^0 30' 17.58"N	601m
MK_1	$7^0$24' 41.06"E	10^0 28' 45. 10"N	606m
MK_2	7 ^{0}24' 40. 36"E	10 28' 53.01"N	635m
MK_3	7 ^{0}24' 39.73"E	10^0 28' 53.01"N	620m
RK_1	7^0 25' 06.35"E	10^0 30' 13. 40"N	603m
RK_2	7^0 25' 07.82"E	10^0 30' 09. 62"N	599m
RK_3	7^0 25' 05.07"E	10^0 30' 10. 56"N	595m
RK_4	7^0 24' 15.92"E	10^0 29' 01.00"N	605m
RK_5	7^0 24' 14.24"E	10^0 29' 07.50"N	605m
RK_6	7^0 24' 07.97"E	10^0 29' 05.58"N	600m

Key: MK= Makera, RK= River Kaduna, TW= Tudun Wada

with distilled water. The plastic container was deeped below the water and placed against the water current for sample collection. Samples were transported in ice packs to the Hydrobiology Laboratory of the Department of Biological Sciences for further analyses.

3.2.3 Sampling Time and Frequency

Sampling was carried out once a month from 9 a.m. to 3.00 pm on the last wedenesday of every month.

3.3 Determination of Physico-chemical Parametres

3.3.1 Surface Water Temperature

The surface water temperature was measured *in situ* using a portable HANNA Combo pH/EC/Temp metre model/HI 98129. The metre was turned on and then the probe inserted into the water. It was allowed to equilibrate and the value of the surface water temperature was recorded as displayed on the meter in degrees centigrade (^oC).

3.3.2 Surface Water pH

The surface water pH was measured *in situ* using a portable HANNA Combo pH/EC/Temp metre model/HI 98129. The metre was turned on and then the probe inserted into the water. It was allowed to equilibrate and the value of surface water pH was recorded as displayed on the meter.

3.3.3 Electrical Conductivity (EC)

The surface water EC was measured *in situ* using a portable HANNA Combo pH/EC/Temp metre model /HI 98129. The metre was turned on and then the probe inserted into the water. It was allowed to equilibrate and the value of the surface water EC was recorded as displayed on the meter in Microsiemen per cm (μ/cm).

3.3.4 Total Dissolved Solids (TDS)

The surface water TDS was measured *in situ* using a portable HANNA Combo pH/EC/Temp metre model /HI 98129. The metre was turned on and then the probe inserted into the water. It was allowed to equilibrate and the value of the surface water TDS was recorded as displayed on the meter (ppm).

3.3.5 Dissolved Oxygen (DO)

DO was determined by the azide modification of the Winkler method (APHA, 2005). To the 300 ml of sample of surface water collected in 300ml BOD bottle, 2ml of Manganous sulphate solution was added followed by addition of 2ml of alkali-iodide-azide reagent. The resulting solution was stoppered carefully to exclude air bubbles and mixed by inverting bottle a few times. Two (2) ml of concentrated tetraoxosulphate(vi) acid was then added, re-stoppered and mixed by inverting several times until dissolution was complete. 200mL of the treated sample was then titrated with sodium thiosulphate (0.002N) until a light yellow colour remains. At this point 1ml of Starch (indicator) was added turning the sample dark blue. Titration continued until the disappearance of the blue colour by the complete reduction of iodine molecules by the thiosulphate. The volume of the thiosulphate used is equivalent to the volume of the dissolved oxygen per litre.

3.3.6 Biochemical Oxygen Demand (BOD)

DO was determined by the azide modification of the Winkler method (APHA, 2005). To 300 ml of sample of surface water collected by dipping a 300ml BOD in the running water against the water current. The sample was incubated in the dark for five days at room temperature, 2ml of Manganous sulphate solution was added followed by addition of 2ml of alkali-iodide-azide reagent. The resulting solution was stoppered carefully to exclude air bubbles and mixed by inverting bottle a few times. Two (2) ml of concentrated tetraoxosulphate(vi) acid was then added, re-stoppered and mixed by inverting several times until dissolution is complete. 200mL of the treated sample was then titrated with sodium thiosulphate (0.002N) until a light yellow colour remained. At this point 1ml of Starch (indicator) was added turning the sample dark blue. Titration continued until the disappearance of the blue colour by the complete reduction of iodine molecules by the thiosulphate. The volume of the thiosulphate used is equivalent to the volume of the dissolved oxygen (DO_5) per litre.

$$BOD = \frac{DO1 - DO5}{P}$$

Where DO1 = dissolved oxygen of sample in day one (day of sampling)

DO_5= dissolved oxygen after 5 days of incubation

P= volumetric fraction of dilution (APHA, 2005)

3.3.7 Total Hardness

Total hardness was determined by adding 25ml of distilled water to 25ml of water sample in a conical flask. Then 1ml of ammonium molybdate buffer (pH 10.4) was added followed by 0.8g of Eriochrome black T (an indicator dye) to the sample. The purplish solution formed was titrated with Ethylenediaminetetraacetic acid (EDTA) until the solution turned blue when there were no longer any free calcium and magnesium ions.

Hardnes (EDTA) as mg $CaCO_3$/L = A×B×1000/mL of sample

A= mL titration of sample

B= mg $CaCO_3$ equivalent to 1.00 mL EDTA titrant (APHA, 2005)

3.3.8 Total Alkalinity

To 100ml of water sample, 2 drops of methyl red indicator were added followed by the addition of 2 drops of bromocresol green indicator. The soution was then titrated against standard sulfuric acid (0.02N) to a homogenous pink color. The volume of standard sulfuric acid used is equivalent to the alkalinity of the water in mg/L (APHA, 2005).

3.3.9 Nitrate-Nitrogen

One hundred (100) ml of water sample was poured into a crucible and evaporated to dryness in an oven at 100^{o}C and cooled. Two millilitres of Phenoldisulphonic acid were then added and smeared around the crucible. After ten minutes, 10 mL of distilled water was added, followed by the addition of 5 mL of strong ammonia solution. The absorbance of the treated sample was read using in a colorimeter (Sherwood colorimeter 257) at 430 nm, using distilled water as blank. The concentration of Nitrate-Nitrogen was obtained from a calibration curve (Appendix XXXIV) (APHA, 2005).

3.3.10 Phosphate-Phosphorus

To 100 mL of water sample, 1 mL of Denigs reagent was added, followed by 2 drops of stannous chloride. The treated sample was allowed to stand for 10 minutes after which it turned blue. The absorbance of the solution was taken at 690 nm (Sherwood colorimeter 257) using distilled water as blank. The concentration of phosphate-phosphorus was obtained from a calibration curve (Appendix XXXV) (APHA, 2005).

3.3.11 Total Nitrogen

A hundred millimetres of sample for Total Nitrogen determination was digested by the addition of 50 mL of low nitrogen Potassium Persulphate solution (20.1g of potassium persulphate added with 3.0g of sodium hydroxide and dissolved in 1000 mL of distilled water) and heated for 20 minutes on a hot plate, after which the solution was allowed to cool and transferred into a volumetric flask and made up to 100 ml with distilled water. All the forms of nitrogen in the sample are converted into nitrates and therefore total nitrogen was determined as nitrate using the phenoldisulphonic acid method (APHA, 2005).

3.3.12 Total Phosphorus

A hundred millimetre of sample for Total Phosphorus determination was digested by the addition of 50 mL of low nitrogen Potassium Persulphate solution (20.1g of potassium persulphate added with 3.0g of sodium hydroxide and dissolved in 1000 ml of distilled water) and heated for 20 minutes on a hot plate, after which the solution was allowed to cool and transferred into a volumetric flask and made up to 100 ml with distilled water. All the forms of phosphorus in the sample were converted into phosphates and therefore total phosphorus was determined as phosphate using the stannous chloride (APHA, 2005).

3.3.13 Sulphate

To 100ml of water sample, 1g of Barium chloride was added and vortexed for one minute. The solution was left for two minutes for turbidity development and read calorimetrically (Sherwood colorimeter 257) at the wavelength of 430nm using distilled water as blank (APHA, 2005).

3.4.0 Sampling of algae

3.4.1 Phytoplankton

Phytoplankton samples were collected by filtering 2 litres of surface water sample through a plankton net of 25µm mesh size. The net has attached at its base a collection vial of 60ml where concentrated phytoplankton samples were collected. The collected sample is transferred into another 60 ml sampling container and two to three drops of Lugol's iodine solution (20g of potassium Iodide + 200ml of distilled water + 10g of pure Iodine crystals + 20ml of glacial acetic acid) was added to the sample as a preservative (Perry, 2003).

3.4.2 Periphytic Algae

At each sampling site, epilithic, epiphytic, epipelic, epidendric, and episamic algae were collected separately according to methods described by Moulton *et al.,* (2002).

Epilithic algae were collected on at least five pebble-cobble sized stones at each site, each of which were shaken in stream water to remove any loosely attached sediments and non-epilithic algae, and then a brush was used to remove the epilithic flora. The resulting algal suspension was pooled to form a single sample, which was put in a labeled plastic container and preserved by the addition of 2 to 3 drops of Lugol's iodine solution.

Epiphytic algae were sampled from different species of submerged macrophytes at each sampling site. The whole stalk and leaves were carefully removed from the stream. Periphyton was then removed from the macrophytes by brushing with a toothbrush adding distilled water. The resulting algal suspension from the selected macrophytes was then pooled into a single sample, which was put in a labeled plastic container and preserved by the addition of 2 to 3 drops of Lugol's iodine solution.

Epipelic and episamic algae were sampled by pressing a Petri dish lid into the top layer of sand or silt/clay to a depth of 5-7mm followed by sliding a spatula blade under the Petri dish to isolate the contents in the dish, which was then gently brought to the surface. The content was then emptied into a labeled container. Five samples were collected at each site and pooled into a single sample and preserved by the addition of 2 to 3 drops of Lugol's iodine solution.

Epidendric algae was removed from submerged woody dead plant material by brushing with a toothbrush into a 5ml plastic sampling container followed by the addition of distilled water enough to cover the algal material. The resulting algal suspension preserved by the addition of 2 to 3 drops of Lugol's iodine solution.

3.5.0 Identification and analyses of Algae

3.5.1 Diatomic Algae (Periphytic and Phytoplankton)

Diatom frustules were cleaned using the Hydrogen Peroxide/Potassium Dichromate Oxidation method. To 5-10 ml subsample of preserved alga placed in a beaker, 50% Hydrogen Peroxide was added and the sample allowed to oxidise overnight, then a microspatula of potassium dichromate was added.

When the sample color changed from purple to yellow and boiling stopped, the beaker was then filled with distilled water and allowed to stand for four (4) hours; the supernatant was then siphoned off (Biggs and Kilroy, 2000).

3.5.2 Mounting

A drop of Naphrax (in toluene) fixative was placed onto the centre of a clean glass slide, the slide was then placed onto a hotplate at ~ 120°C and heated until the Naphrax–toluene solution began to bubble gently. A coverslip (with cleaned diatoms transferred using a dropper, facing down) was placed in the Naphrax–toluene solution and eased down very gently. Heating continued until bubbling subsided then the slide was removed from the hotplate. The coverslip was then gently pressed down with forceps until all air bubbles had been squeezed out. The slide was allowed to cool and then labelled. The slide was examined under oil immersion at x1000 magnification (Biggs and Kilroy, 2000).

Three (3) replicate mounts of each specimen were prepared and viewed consecutively under the microscope under oil immersion at x1000 magnification. At least 250-400 cells were counted (depending on the abundance in the sample). Algal species encountered were identified using guides by Prescott (1961, 1977). Digital images were also captured from each slide reference and identification purpose.

3.5.3 Non-diatomic algae

3.5.3.1 Periphytic Algae

Three (3) wet mounts of the specimen were prepared and viewed consecutively under the microscope at x100 and x400 magnification. At least 400 cells were counted (depending on the abundance in the sample). Efforts were made to scan as many divergent forms as possible. Algal species encountered were identified using guides such as Prescott (1961, 1977) and APHA (2005). Digital images and drawings were also captured from each slide for reference purpose (Potapova and Charles, 2005).

3.5.3.2 Phytoplankton

Phytoplankton samples were concentrated by by the addition of three drops of Lugol's Iodine solution and allowed to sediment for 24 hours. After which the supernatant was decanted. A sub-sample of concentrated phytoplankton was observed under a microscope using the Improved Neubauer counting chamber and systematically identifying and counting algal units in microscopic fields. The phytoplanktons were counted from the top four large corner squares of the chamber. Cells lying on the two sides of each large square are included. The number of cells of each species per litre was reported by dividing the number of cells counted in the four large corner squares by 20 and the number obtained multiplied by 10^9 (Cheesbrough, 2000).

3.6 Data analyses

Palaeontological Statistics (PAST) software version 1.95 was used for:

a) Analysis of variance to compare surface water physico-chemical characteristics among the sampling stations (as they were found to be normally distributed, based on Shapiro-Wilk test for normality ($p<0.05$)).
b) Community structure analyses including Shannon-Wiener diversity index,Simpsons index, Dominance, Abundance, in sampling stations and subtrates.
c) Correlation by Principal Component Analysis to determine important environmental gradients along various sampling sites.
d) Canonical Corresponding Analysis to determine the relationship between algal community structure and environmental variables.

e) Cluster Analysis based on Bray-Curtis similarity index was used to group sampling stations with similar surface water characteristics or algal species and also periphyton algal composition among substrates.

f) Non-metric Multidimensional Scaling (NMDS) was used to determine the dissimilarity between sampling stations in terms of algal abundance and diversity.

Indicator species were determined by the Individual Value index (IndVal index) as described by Dufrêne and Legendre (1997).

$\text{INDVAL}_{ij} = A_{ij} \times B_{ij} \times 100$

Where INDVAL = Indicator Value of species i in site cluster j

$$A_{ij}\text{ (measure of specificity)} = \frac{\text{mean number of individuals of species } i \text{ across sites of group } j}{\text{mean number of individuals of species } i \text{ across all sites}}$$

$$B_{ij}\text{ (measure of fidelity)} = \frac{\text{number of sites in cluster } j \text{ where species } i \text{ is present}}{\text{the total number of sites in that cluster } j}$$

The indicator value of a species (i) for a typology of sites is the largest value of INDVAL_{ij} over all groups (j) of that typology.

CHAPTER FOUR

4.0 RESULTS

4.1.0 Surface Water Physico-chemical Characteristics

4.1.1 Surface water temperature

The mean surface water temperature was observed to be between 26.91 to 30.07°C, with stations conveying industrial wastes (MK_1, 29.91 °C, MK_2, 30. 06 °C and MK_3, 30.07 °C observed to have significantly ($p<0.05$) higher temperatures than the other stations which do not vary among themselves (TW_1, 26.91°C, TW_2, 27.46 °C, TW_3, 27.91°C, RK_1, 27.85 °C, RK_2, 28.08°C, RK_3, 27.67°C, RK_4, 28.36°C, RK_5, 28.08°C, and RK_6, 28.54°C) (Fig. 4.1) (Table 4.1).

Surface water temperatures were observed to be generally higher in 2013 than in 2014 in all stations except TW_1 and TW_2 (Fig. 4.1). These observed variations were significantly higher ($p<0.05$) in 2013 but not between seasons ($p>0.05$) (Table 4.1).

4.1.2 pH

The mean surface water pH was observed to be slightly alkaline (between 7.56- 8.35), with only the first two stations of the Makera drain having mean pH values above 8 (MK_1, 8.35 and MK_2, 8.29) (Fig. 4.1). The pH values for these stations (MK_1 and MK_2) were observed to be significantly higher than the values observed in all the other stations. The pH values observed in the other sampling stations did not differ among one another (MK 3, 7.99, TW_1, 7.61, TW_2, 7.61, TW_3, 7.56, RK_1, 7.54, RK_2, 7.65, RK_3, 7.56, RK_4, 7.73, RK_5, 7.46, and RK_6, 7.88)(Fig. 4.1) (Table 4.1).

Comment [MaC1]: Rephrase...

The pH was also observed to be significantly higher in the wet season (8.06) than in the dry season (7.49) ($p<0.05$) and significantly higher ($p<0.05$) in 2014 (7.82) than 2013 (7.59) (Table 4.1).

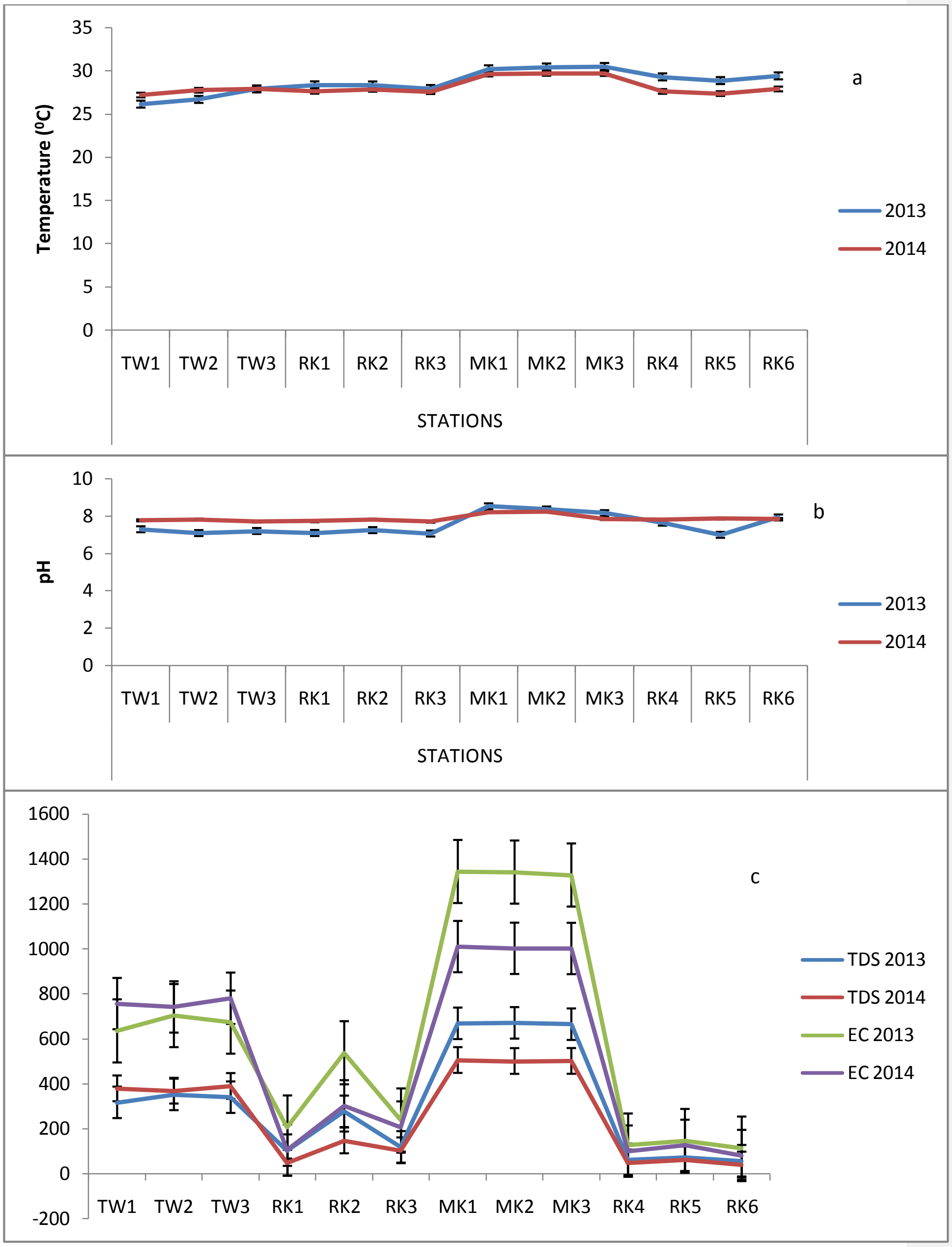


Fig. 4.1: Variation of (a) surface water temperature, (b) pH and (c) electrical conductivity (µS/cm) and total dissolved solids in Tudun Wada (TW)- Makera (MK) drains and River Kaduna (RK)

Comment [MaC2]: Revise the name of the water bodies studied throughout your work. It should be Tudun Wada-Makera drains and River Kaduna.

Table 4.1: Mean for surface water physico-chemical characteristics in Tudun Wada (TW)- Makera (MK) drains and River Kaduna (RK)

Stations	Temperature (°C)	pH	Total Dissolved Solids (ppm)	Electrical Conductivity (µS/cm)	Dissolved Oxygen (mg/L)	Biochemical Oxygen Demand(mg/L)	Total Hardness (mg/L)	Total Alkalinity (mg/L)	Sulphate (mg/L)	Phosphate-Phosphorus (mg/L)	Nitrate-Nitrogen (mg/L)	Total Nitrogen (mg/L)	Total Phosphorus (mg/L)
TW$_1$	26.91^{c}	7.64^{bc}	361.68^{b}	722.04^{b}	1.23^{ab}	3.31^{a}	94.44^{a}	320.92^{ab}	24.32^{c}	0.17^{ab}	2.38^{a}	17.54^{a}	0.75^{a}
TW$_2$	27.46^{c}	7.61^{bc}	364.12^{b}	730.36^{b}	1.05^{b}	3.78^{a}	92.56^{a}	331.28^{ab}	24.91^{c}	0.13^{ab}	2.36^{a}	17.17^{a}	0.72^{a}
TW$_3$	27.91^{c}	7.56^{c}	375.76^{b}	750.08^{b}	1.10^{ab}	2.95^{a}	100.52^{a}	282.88^{ab}	25.13^{c}	0.13^{ab}	2.64^{a}	18.43^{a}	0.70^{a}
RK$_1$	27.85^{abc}	7.54^{c}	63.92^{cd}	133.08^{cd}	1.61^{ab}	3.27^{a}	83.68^{a}	154.80^{bc}	18.47^{c}	0.16^{ab}	2.24^{a}	17.21^{a}	0.63^{a}
RK$_2$	28.01^{abc}	7.65^{abc}	183.72^{c}	367.40^{c}	1.29^{ab}	2.26^{a}	94.48^{a}	187.88^{bc}	17.39^{c}	0.11^{b}	2.31^{a}	17.49^{a}	0.63^{a}
RK$_3$	27.67^{c}	7.56^{c}	106.87^{cd}	213.83^{cd}	1.51^{ab}	2.70^{a}	72.61^{a}	170.30^{bc}	17.14^{c}	0.15^{ab}	2.29^{a}	16.88^{a}	0.52^{a}
MK$_1$	29.91^{ab}	8.35^{a}	579.27^{a}	1161.50^{a}	1.35^{ab}	4.46^{a}	67.15^{a}	442.67^{a}	52.24^{ab}	0.37^{a}	3.07^{a}	16.35^{a}	0.93^{a}
MK$_2$	30.06^{a}	8.29^{ab}	580.62^{a}	1161.50^{a}	1.47^{ab}	6.33^{a}	78.59^{a}	449.82^{a}	54.23^{ab}	0.36^{ab}	2.84^{a}	16.68^{a}	0.84^{a}
MK$_3$	30.07^{a}	7.99^{bc}	578.03^{a}	1155.00^{a}	1.32^{ab}	4.34^{a}	106.71^{a}	446.53^{a}	62.14^{a}	0.35^{ab}	3.31^{a}	14.99^{a}	0.74^{a}
RK$_4$	28.36^{abc}	7.73^{abc}	55.78^{d}	111.78^{d}	1.66^{ab}	3.47^{a}	56.69^{a}	134.69^{bc}	32.8b^{c}	0.22^{ab}	2.80^{a}	13.06^{a}	0.52^{a}
RK$_5$	28.08^{abc}	7.46^{c}	67.67^{d}	135.70^{d}	1.78^{ab}	4.26^{a}	69.90^{a}	160.77^{bc}	37.94^{abc}	0.18^{ab}	2.78^{a}	14.08^{a}	0.56^{a}
RK$_6$	28.54^{abc}	7.88^{abc}	47.35^{d}	94.16^{d}	1.67^{ab}	3.54^{a}	59.52^{a}	116.10^{c}	35.86^{abc}	0.24^{ab}	2.65^{a}	12.08^{a}	0.56^{a}
Seasons													
Wet	28.53^{a}	8.06^{a}	261.00^{b}	521.00^{b}	1.53^{a}	7.92^{a}	107.00^{a}	204^{b}	29.68^{b}	0.17^{b}	2.78^{a}	19.16^{a}	0.84^{a}
Dry	28.53^{a}	7.49^{b}	330.00^{a}	662.00^{a}	1.31^{a}	2.20^{b}	49.79^{b}	358^{a}	42.38^{a}	0.29^{a}	2.59^{a}	13.85^{b}	0.56^{b}
Years													
2013	28.91^{a}	7.59^{b}	327.13^{a}	654.92^{a}	2.16^{a}	6.56^{a}	170.06^{a}	172.98^{b}	48.95^{a}	0.37^{a}	3.71^{a}	11.98^{b}	0.57^{b}
2014	28.29^{b}	7.82^{a}	270.94^{b}	543.01^{b}	1.11^{b}	2.35^{b}	46.04^{b}	335.06^{a}	24.45^{b}	0.14^{b}	2.19^{b}	20.65^{a}	0.80^{a}

Means with the same super script along the columns are not significantly different ($P \geq 0.05$), ($a > b > c > d$). Temp= temperature, TDS= Total Dissolved Solids, EC= Electrical Conductivity, DO= Dissolved Oxygen, BOD= Biochemical Oxygen Demand

4.1.3 Electrical conductivity and total dissolved solids

Electrical conductivity (EC) and total dissolved solids (TDS) values were observed to range between 29 to 2253 µS/cm and 17 to 1125 ppm. On the drains, higher values were recorded in the upstream stations (TW_1, 722.04 µS/cm and 361.68 ppm; TW_2, 730.36 µS/cm and 364.12 ppm; TW_3, 750.08 µS/cm and 375 ppm; MK_1, 1161.50 µS/cm and 579.27 ppm; MK_2, 1165.50 µS/cm and 580.62 ppm; MK_3, 1155.00 µS/cm and 578.03 ppm for EC and TDS respectively) than the stations on River Kaduna (RK_1, 133.08 µS/cm and 63.92 ppm; RK_2, 367.40 µS/cm and 183.72 ppm; RK_3, 213.83 µS/cm and 106.87 ppm; RK_4, 111.78 µS/cm and 55.78 ppm; RK_5, 135.70 µS/cm and 67.67 ppm; RK_6, 94.16 µS/cm and 47.35 ppm respectively) (Fig. 4.1).

These observed variations in EC and TDS were significant between sampling stations ($p<0.05$), although results from the stations on the Makera drain (MK_1, MK_2, MK_3) were not significantly different from one another ($p \geq 0.05$). However, the values were higher than in the other stations. Furthermore, stations on the TudunWada drain stations did not statistically vary from one another ($p \geq 0.05$), but had significantly lower EC and TDS values than those of the Makera drain ($P<0.05$). Also, Tudun Wada drain stations still presented higher values of both parameters than all the stations located on the River Kaduna ($P<0.05$). Electrical conductivity and TDS values observed in stations on the River Kaduna, around the Tudun Wada drain (RK_1, RK_2 and RK_3) were significantly ($p<0.05$) higher than those obtained from stations on the River Kaduna around the Makera drain (RK_4, RK_5 and RK_6) (Table 4.1). The mean EC and TDS values from all the sampling stations were observed to be higher in the dry season (662.00 µS/cm and 330.00 ppm, respectively) than in the wet season (521.00 µS/cm and 261.00 ppm) ($p<0.05$) (Table 4.1).

Comment [MaC3]: Modify statement to show you are talking about EC.

Comment [MaC4]: Re-phrase the whole sentence to make for easy comprehension. Be careful with the use and positions of verbs and adjectives in this sentence.

Comment [MaC5]: Where was this observed? Or is this a mean for all sampling station.

Similarly, the mean EC and TDS values recorded for all the sampling stations were also observed to be higher in 2013 (654.92 µS/cm and 327.1300 ppm, respectively) than in 2014 (543.01 µS/cm and 270.94 ppm) ($p<0.05$) (Table 4.1).

Comment [MaC6]: Ditto as in comment MaC7.

4.1.4 Dissolved Oxygen (DO)

The variation of DO was between 0.10 to 4.16 mg/L. Sampling stations located on each of the two drains were observed to have lower mean DO values (TW_1, 1.23 mg/L; TW_2, 1.05 mg/L; TW_3, 1.10 mg/L;MK_1, 1.35 mg/L; MK_2, 1.47 mg/L and MK_3, 1.32 mg/L) when compared with stations on River Kaduna (RK_1, 1.61 mg/L; RK_2, 1.29 mg/L; RK_3, 1.51 mg/L;RK_4, 1.66 mg/L; RK_5, 1.78 mg/L; and RK_6, 1.67 mg/L) on River Kaduna (Fig. 4.2).

Station TW_2 was found to be significantly ($p<0.05$) lower DO than all the other stations, whereas no statistical significance ($p\geq0.05$) between the other stations was noted (Table 4.1). DO was also observed to be significantly higher in the wet season (1.53 mg/L) than in the dry season (1.31 mg/L) ($p<0.05$) and also significantly higher in 2013 (2.16 mg/L) than 2014 (1.11 mg/L) ($p<0.05$) (Table 4.1).

4.1.5 Biochemical Oxygen Demand (BOD)

The Biochemical Oxygen Demand was observed to range between 0.30 to 37.80 mg/L, with means generally higher in 2013 than 2014 (Fig 4.2) and higher in upstream stations (TW_1, 3.45 mg/L; TW_2, 4.08 mg/L; TW_3, 3.44 mg/L, MK_1, 4.46 mg/L; MK_2, 6.33 mg/L and 4.34 mg/L) in comparison to their corresponding downstream stations located on the River Kaduna. (RK_1, 2.46 mg/L; RK_2, 1.82 mg/L; RK_3, 1.81 mg/L; RK_4, 3.47 mg/L;RK_5, 4.26 mg/L; and RK_6, 3.53 mg/L) in 2013.

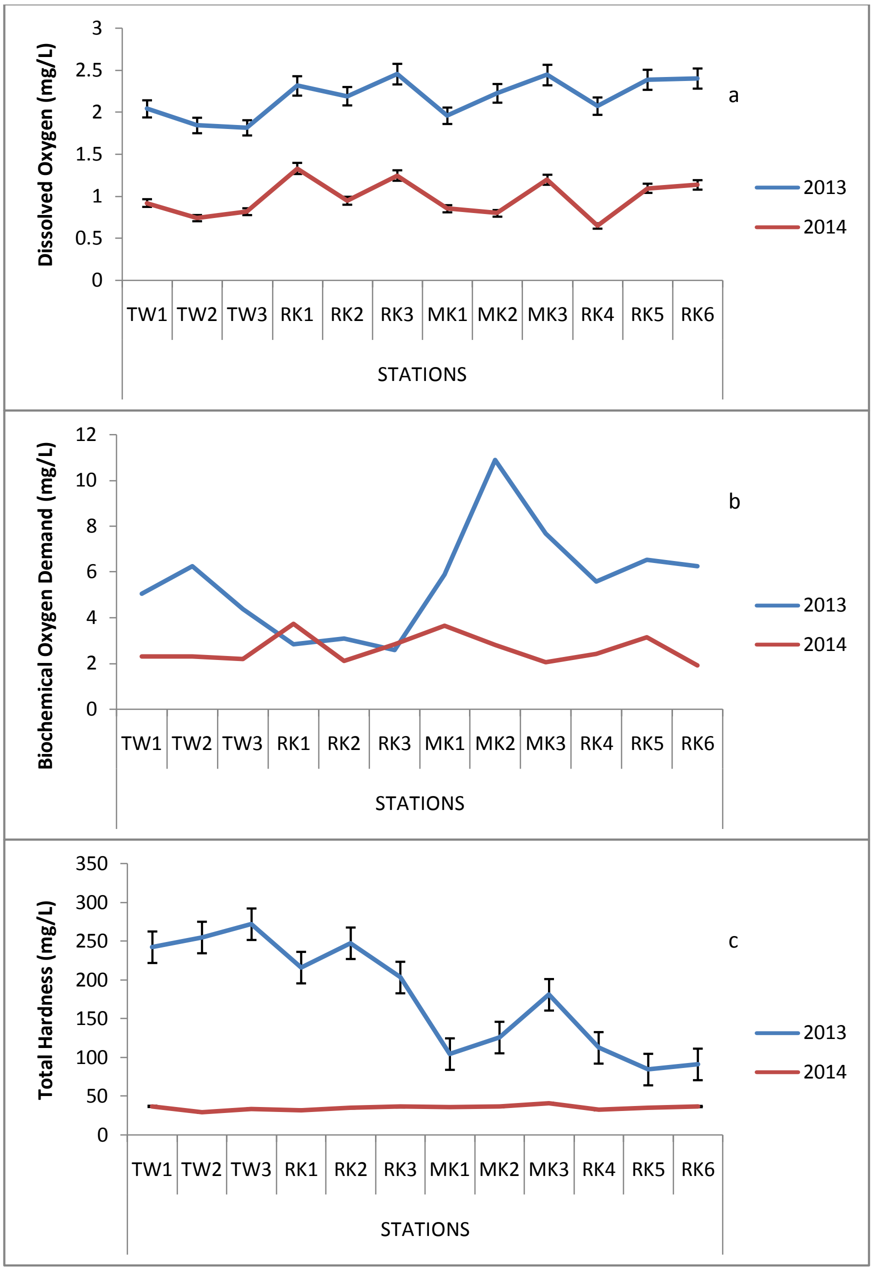


Fig. 4.2: Variation of Surface water Dissolved Oxygen, Biochemical Oxygen Demand and Total Hardness in Tudun Wada (TW)- Makera (MK) drains and River Kaduna (RK)

The variation was however, not discernible between stations in 2014 (Fig. 4.2). The observed variation was statistically significant between years and seasons ($p<0.05$) but not among the sampling stations ($p\geq0.05$) (Table 4.1).

4.1.6 Total Hardness

The Total Hardness ranged from 10 to 660 mg/L and the mean was observed to be lower in 2014 than 2013. Stations on the drains were observed to have higher mean values (TW_1, 94.44 mg/L; TW_2, 92.56 mg/L; TW_3, 100.52 mg/L, MK_1, 67.15 mg/L; MK_2, 78.59 mg/L and MK_3, 106.71 mg/L) as compared to on River Kaduna (RK_1, 83.68 mg/L; RK_2, 94.48 mg/L; RK_3, 72.61 mg/L;RK_4, 56.69 mg/L; RK_5, 69.90 mg/L; and RK_6, 59.52 mg/L). In 2014, the mean Total Hardness was observed to be lower than 50 mg/L in all the sampling stations (Fig. 4.2).

The mean Total Hardness did not vary significantly among the sampling stations ($p\geq0.05$) but was significantly different between seasons (wet, 107.00 mg/L and dry, 49.79 mg/L) and between years (2013, 170.06 mg/L and 2014, 46.04 mg/L) ($p<0.05$) (Table 4.1).

4.1.7 Total Alkalinity

Total Alkalinity values were observed to fall in the range of 21 to 900 mg/L. The mean Total Alkalinity was observed to be higher in 2014 than 2013 in all the sampling stations (Fig. 4.3). The stations on the Makera drain (MK_1, 442. 67 mg/L MK_2, 449.82 mg/L and MK_3, 446.53 mg/L) were observed to have significantly higher Total Alkalinity than all the other stations ($p<0.05$) but they did not vary among themselves (Table 4.1).

Comment [MaC7]: Confirm and ensure that all write-ups in the results section are in past tense.

Comment [MaC8]: Try to properly format the whole work. For example, why is this sentence standing on its own...

Comment [MaC9]: Revise sentence. Break dow if necessary to make easier to understand.

Comment [MaC10]: Revise sentence.

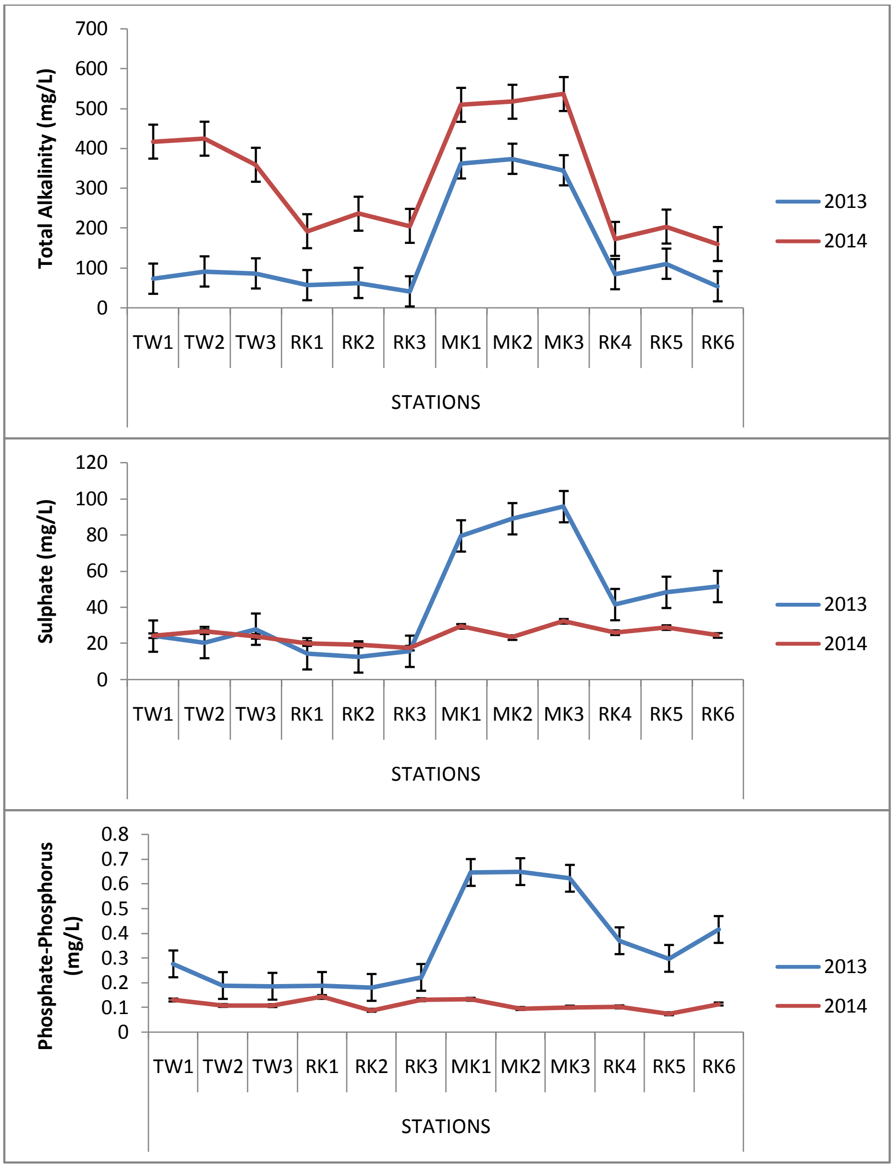


Fig. 4.3: Variation of surface water total alkalinity, sulphate, and phosphate-Phosphorus in Tudun Wada (TW)- Makera (MK) drains and River Kaduna (RK)

The stations on the Tudun Wada drain (TW_1, 320.92 mg/L, TW_2, 331.28 mg/L, and TW_3, 282.88 mg/L) lower than stations in the Makera drain (MK_1, MK_2 and MK_3) in terms of statistical significance, being higher than all stations on River Kaduna downstream of both drains. Except for one of the stations, RK_6 (116.10 mg/L) which ranked lower than the other stations located on the River Kaduna ($p<0.05$), all the other stations did not vary significantly among themselves (RK_2, 187.88 mg/L; RK_1, 154.80 mg/L; RK_3, 170.30 mg/L, RK_5, 160.77 mg/L; RK_4, 134.69 mg/L) ($p\geq0.05$) (Table 4.1).

Comment [MaC11]: You don't have to always use the word statistical significance. With the provision of the *p* value, it is already clear that statistical significance is being implied.

The mean Total Alkalinity was observed to be significantly higher in the dry season (358 mg/L) than in the wet season (204 mg/L) ($p<0.05$); and it was also higher in 2014 (335.06mg/L) than 2013 (172.98 mg/L) ($p<0.05$) (Table 4.1).

4.1.8 Nitrate-Nitrogen

The concentration of Nitrate-Nitrogen was observed to fall in the range of 0.17 to 14 mg/L, with mean higher ($p<0.05$) in 2013 (3.71 mg/L) than in 2014 (2.19 mg/L) in all the sampling stations (Fig. 4.4, Table 4.1). Stations on the Makera drain (MK_1, 3.07 mg/L, MK_2, 2.81 mg/L, MK_3, 3.31 mg/L) were observed to have higher mean concentrations of nitrate-nitrogen than stations on the Tudun Wada drain (TW_1, 2.38 mg/L TW_2, 2.36 mg/L TW_3, 2.64 mg/L).

The lowest concentrations were observed on stations located on the River Kaduna with stations closer to the Makera drain (RK_4, 2.80 mg/L RK_5, 2.78 mg/L, RK_6, 2.65 mg/L) recording concentrations greater than those stations closer to the Tudun Wada drain (RK_1, 2.24 mg/L, RK_2, 2.31 mg/L, RK_3, 2.2 9mg/L). These variations however, are not significant among the sampling stations and between seasons (≥0.05) (Table 4.1).

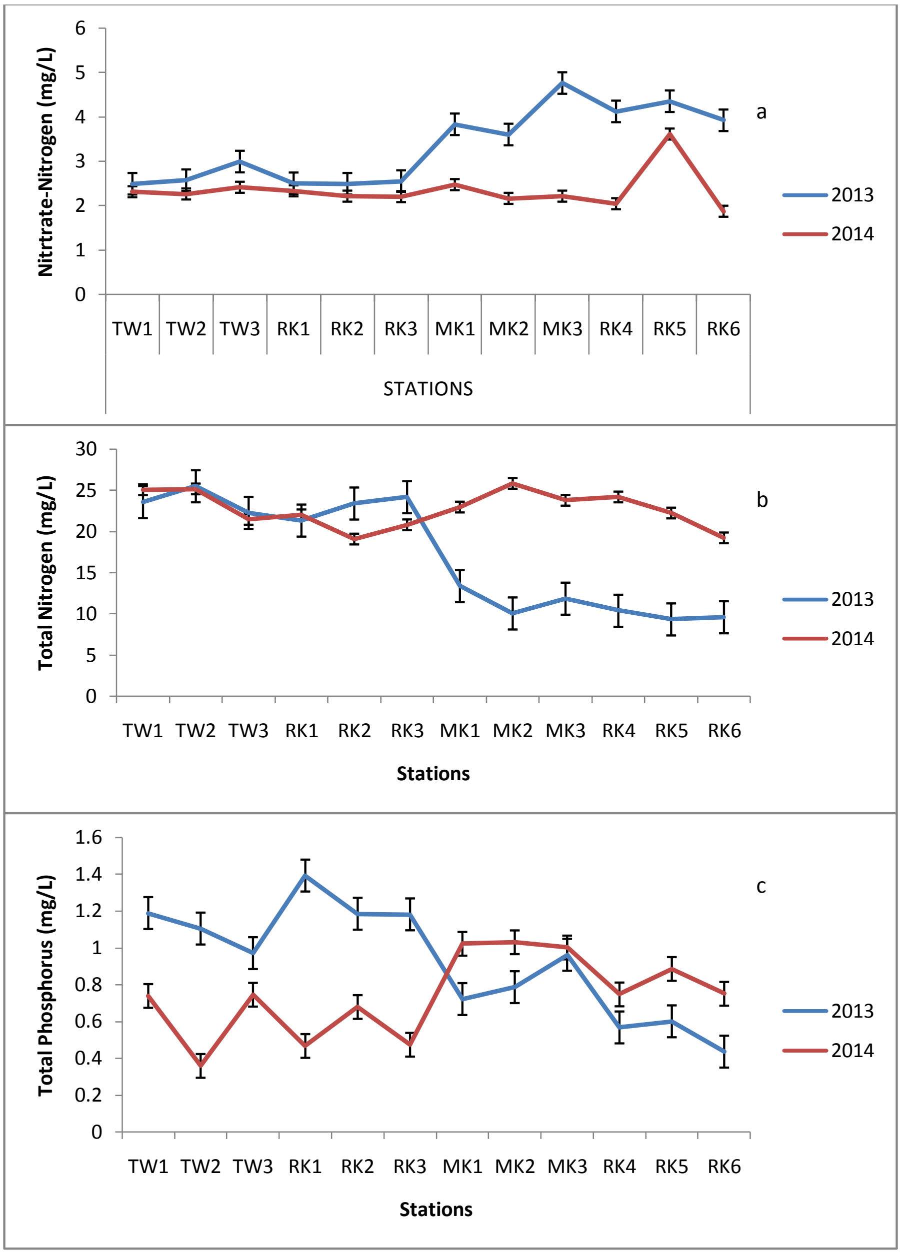


Fig. 4.4: Variation of Surface water Nitrate-Nitrogen, Total Nitrogen and Total Phosphorus in Tudun Wada (TW)- Makera (MK) drains and River Kaduna (RK)

4.1.9 Phosphate-Phosphorus

Phosphate-phosphorus concentration ranged from 0.1 to 2.30 mg/L. The mean Phosphate-phosphorus was concentration was observed to be higher in 2013 than in 2014 in all the sampling stations (Fig 4.3). This variation was statistically significant between s ($p>0.05$) (Table 4.1).

MK_1 (0.37 mg/L) was observed to have the highest mean phosphate-phosphorus concentration among the stations,although, it only differed statistically significantly with RK_2 (0.11) ($p<0.05$) but not with all other stations (TW_1, 0.17 mg/L; TW_2, 0.13 mg/L; TW_3, 0.13 mg/L; RK_1, 0.16 mg/L, RK_3, 0.15 mg/L, MK_2, 0.36 mg/L, MK_3, 0.18 mg/L; RK_5, 0.18 mg/L, RK_4, 0.22mg/L; and RK_6, 0.24mg/L) ($p>0.05$) (Table 4.1).

The mean phosphate-phosphorus concentration was observed to be statistically significantly in the dry season (0.29mg/L) than that observed in the wet season (0.17mg/L) ($p>0.05$) (Table 4.1).

4.1.10 Total Nitrogen

The concentration of total nitrogen was observed to be from 17.80 to 70.72 mg/L. Stations on the Makera drain (MK_1, MK_2, MK_3) and those impacted by it on River Kaduna (RK_4, RK_5 and RK_6) showed higher concentrations in 2014 than 2013. Some other stations (TW_1,TW_2, TW_3 and RK_1, 17.21 mg/L) did not show marked variations between s, while a few other stations (RK_2 and RK_3) had higher concentration in 2013(Fig. 4.4).

Total Nitrogen concentrations were not significantly different among the stations (TW_1,17.54 mg/L, TW_2, 17.17 mg/L, TW_3, 18.43 mg/L, RK_1, 17.21 mg/L, RK_2, 17.49 mg/L, RK_3, 16.88 mg/L, MK_1, 16.88 mg/L, MK_2, 16.35 mg/L, MK_3, 16.68 mg/L, RK_4, 17.21 mg/L RK_5, 17.49 mg/L, RK_6, 16.88 mg/L) ($p \geq 0.05$ but were between seasons (wet, 19.16 mg/L and dry 13.85 mg/L) and between years (2013, 11.98 mg/L and 2014, 20.65) ($p<0.05$) (Table 4.1).

4.1.11 Total Phosphorus

The concentration of total phosphorus was observed to be from 0.18 to 7.14 mg/L. Stations on the Tudun Wada Drain (TW_1, TW_2 and TW_3) and stations on River Kaduna impacted by the drain (RK_1, RK_2 and RK_3) were observed to show higher concentrations in 2013, whereas stations on the Makera drain and those impacted by it on River Kaduna (MK_1, MK_2, MK_3, RK_4, RK_5 and RK_6) were observed to have higher concentrations in 2014 (Fig. 4.4).

Total Phosphorus concentrations were not significantly different among the stations (TW_1,0.75 mg/L, TW_2, 0.72 mg/L, TW_3, 0.70 mg/L, RK_1, 0.63 mg/L, RK_2, 0.63 mg/L, RK_3, 0.52 mg/L, MK_1, 0.93 mg/L, MK_2, 0.84 mg/L, MK_3, 0.74 mg/L, RK_4, 0.52 mg/L RK_5, 0.56 mg/L, RK_6, 0.56 mg/L) ($p \geq 0.05$) but werebetween seasons (wet, 0.84 mg/L and dry 0.56 mg/L) and between years (2013, 0.57 mg/L and 2014, 0.80) ($p<0.05$) (Table 4.1).

Comment [MaC12]: Use between not among....

4.1.12 Sulphate

Concentrations of sulphate were observed to be from 1.30 to 225 mg/L, with the mean concentration higher in sampling stations on the Makera drain and the downstream stations influenced by the drain on the River Kaduna (Fig. 4.3). MK_1, MK_2, and MK_3 (52.24 mg/L, 54.23 mg/L and 62.14 mg/L, respectively) were ranked highest in terms of statistical significance ($p<0.05$), followed by RK_5 and RK_6 (37.94 mg/L and 35.86 mg/L, respectively) and then the other stations (TW_1, TW_2, TW_3, RK_2, RK_1, RK_3 and RK_4). The latter stations were observed not to be significantly different from one another ($p<0.05$) (Table 4.1). Mean sulphate concentration was significantly higher in the dry season (42.38 mg/L) than in the wet season (26.68 mg/L); and also higher in 2013 (48.95 mg/L) than in 2014 (24.45 mg/L) (Table 4.1).

Comment [MaC13]: Break sentence into two...

4.2 Algae

4.2.1 Distribution of periphytic algae on Substrates

A total of 63 species of algae were identified in this study with 21 species belonging to the bacillariophyta (Table 4.2), 34 to cholorophyta (Table 4.3), 7 to cyanobacteria and 1 to euglenophyta (Table 4.4). Indicator species analysis showed that the algal species are not only restricted to a particular type of substrate.

A number of species showed preferences to certain substrates as reflected by their high indicator values, shown in perenthesis the respective substrates. Indicators values of species were from 0 to 70. Three of the diatoms, *Melosira distans* (33), *Nitzchia* sp. (20) and *Sirurella augusta* (54) showed preference to the epilithic substrate while nine species *Achnanthes* sp. (27), *Coconeis placentula* (20), *Cymbella cistula* (51), *Epithemia* sp. (25), *Frustulia rhomboides* (70), *Gyrosigma accumunatum* (20), *Melosira calognosa* (20), *Melosira* sp. (61) and *Synedra ulna* (48). *Anomoneis* sp. (24), *Aulacoseira ambigua* (20), *Aulacoseira varians* (60), *Epithemia zebra* (20), *Gyrosigma* sp. (43), *Melosira sulcata* (35) showed a highest preference of being episamic. Only *Aulacoseira granulata* (67) and *Pinnularia* sp. (15) were the diatoms that showed preference of being epiphytic and epidendric, respectively (Table 4.2).

Among the chlorophyta *Closterium* sp.2 (31), *Closterium* sp.3 (20), *Closterium* sp.4 (27), *Cosmarium botrytis*(20), *Cosmarium margarifeferum*(20), *Cosmarium marigatum*(20), *Cosmarium quassilus* (20)*Cosmarium* sp2. (20), *Pediastrum duplex* (35), *Pediastrum* sp1 (20), *Pediastrum* sp2 (20), *Scenedesmus opolinensis*(20),

Table 4.2: Periphytic diatom (Bacillariophyta) indicator species characterizing the five substrates sampled in the Tudun Wada-Makera Drains and River Kaduna.

	Bacillariophyta	Epilithic	Epipelic	Episamic	Epiphytic	Epidendric
1	*Achnanthes hungarica* Grun.	13	**27**	0	0	0
2	*Anomoneis* sp.	16	0	**24**	0	0
3	*Aulacoseira ambigua* (Grunow) Simonsen	**20**	**20**	**20**	0	0
4	*Aulacoseira granulata* (Grunow) Simonsen	4	17	12	67	0
5	*Aulacoseira* sp.	0	0	20	0	0
6	*Aulacoseira varians* (Grunow) Simonsen	10	9	**60**	0	0
7	*Coconeis placetula* RV (Ehr.) Hust	0	**20**	0	0	**20**
8	*Cymbella cistula* Ehr. (Ehr.)Kirchener	5	**51**	4	0	0
9	*Epithemia* sp.	0	**25**	18	16	0
10	*Epithemia zebra* Kutz.	0	0	**20**	0	0
11	*Frustulia rhomboids* Ehr.	2	**70**	1	0	7
12	*Gyrosigma* sp.	2	14	**43**	0	0
13	*Gyrosigma acumunatum* (Ehr.)Smith	0	**20**	0	0	0
14	*Melosira calognosa* Ehr.	0	**20**	0	0	0
15	*Melosira distans* Ehr.	**33**	15	12	0	0
16	*Melosira* sp.	13	**61**	5	1	0
17	*Melosira sulcata* Ehr	26	14	**35**	5	0
18	*Nitzchia* sp.	**20**	0	0	0	0
19	*Pinularia* sp.	0	5	0	0	**15**
20	*Sirurella augusta* kg.	**54**	7	19	0	0
21	*Synedra ulna* (Nitzch) Chr	7	**48**	2	27	15
	Total Number	**4**	**9**	**6**	**0**	**2**

Table 4.3: Periphytic Chlorophyta indicator species characterizing the five substrates sampled in the Tudun Wada-Makera Drains and River Kaduna

	Chlorophyta	**Epilithic**	**Epipelic**	**Episamic**	**Epiphytic**	**Epidendric**
1	*Botryococcus sp.*	0	0	**20**	0	0
2	*Closterium aerosum* Ralfs.	0	0	**20**	0	0
3	*Closterium moniliferum* Turn.	0	0	**20**	0	0
4	*Closterium lonula* (Mull.) Nitz	13	**44**	2	21	0
5	*Closterium* sp.1	37	**38**	3	0	2
6	*Closterium* sp.2	**31**	20	0	0	9
7	*Closterium* sp3	**20**	0	0	0	0
8	*Closterium* sp4	**27**	13	0	0	0
9	*Coelastrum intermedium* (Bohl) Kros	12	**28**	0	0	0
10	*Cosmarium botrytis* Menegh.	**20**	0	0	0	0
11	*Cosmarium margarifeferum* Menegh.	**31**	20	20	0	9
12	*Cosmarium marigatum* Menegh.	**20**	0	0	0	0
13	*Cosmarium quasillus* Menegh.	**20**	0	0	0	0
14	*Cosmarium* sp.1	16	**24**	0	0	0
15	*Cosmarium* sp.2	**20**	0	0	0	0
16	*Pediastrum duplex* Smith	**34**	26	9	0	11
17	*Pediastrum simplex* (Meyen) Lemmerman	0	**20**	0	0	0
18	*Pediastrum duplex var.regulosum* Raciborski	**20**	0	0	0	0
19	*Pediastrum duplex* var. *reticulatum* Largerhein	**20**	0	0	0	0
20	*Penium* sp.	0	**20**	0	0	0
21	*Scenedesmus acumunatus* (Lag) Chodat	2	0	6	19	**53**
22	*Scenedesmus acutus* Meyen	0	**40**	0	0	0
23	*Scenedesmus bijuga* Turp Legerhem	27	**33**	2	0	19
24	*Scenedesmus bijuga* var.(Reinsch) Hansgird	0	0	**20**	0	0
25	*Scenedesmus obliquus*	8	9	9	7	**67**
26	*Scenedesmus opolinensis* P. Richt 1896	**20**	0	0	0	0
27	*Scenedesmus quadricauda* Smith	**48**	9	24	0	0
28	*Scenedesmus incrasatulus* Bohlin	**36**	34	8	0	2
29	*Scenedesmus* sp.	16	0	**24**	0	0
30	*Scenedesmus dimorphus* (Turp) Kg.	0	0	20	0	0
31	*Spirogyra* sp.	17	**23**	1	0	0
32	*Staurastrum* sp.	0	16	0	**24**	0
33	*Stigeoclonium pachydermum Prescott*	0	0	0	**20**	0
34	Ui	0	0	19	**21**	0

Table 4.4: Periphytic Cyanobacteria and euglenophyta indicator species characterizing the five substrates sampled in the Tudun Wada-Makera Drains and River Kaduna.

S/No	Divisions/species	Epilithic	Epipelic	Episamic	Epiphytic	Epidendric
	Cyanobacteria					
1	*Gleotrichia echinulata*	0	0	20	0	0
2	*Merismopedia glaucau* Ehr.	8	8	0	**45**	0
3	*M. elegans* Braun	16	**24**	0	0	0
4	*Oscillatoria brevis* Ag.	19	12	**45**	3	0
5	*Oscillatoria lacustris* (Kleb) Goitler	21	**29**	18	12	0
6	*Oscillatoria limosa* (Roth) Ag.	**39**	14	20	8	0
7	*Oscillatoria tenuis* Ag.	**39**	25	8	9	0
	Euglenophyta					
1	*Euglena* sp.	30	18	12	0	0

Scenedesmus quadricauda (48), and *Scenedesmus* sp2 (36) showed a preferences of being epilithic, while *Closterium lonula* (44), *Closterium* sp.1 (38), *Ceolastrum* sp. (28), *Cosmarium*sp1 (24), *Pediastrum simplex* (20), *Penium* sp. (20), *Scenedesmus acutus* (40), *Scenedesmus bijuga* (33) and *Spirogyra* sp. (23) were observed to show the highest preference of being epipelic. *Botryococcus* sp. (20), *closterium aerosum* (20), *Closterium moniliferum* (20), *Scenedesmus bijuga var.* (20), and *Scenedesmus* sp.3 (24) were observed to show a preference of being episamic. *Staurastrum* sp. (20) and *Stigeoclonium pachydermum* (20) had the highest preference of being epiphytic, while *Scendesmus acumunatus* (53) and *Scenedesmus obliquus* (67) preferred being epidendric (Table 4.3).

Among the seven cyanobacteria species observed, two showed more preference to being epilithic (*Oscillatoria limosa*, *Oscillatoria tenius* with indicator value of 39 each), another two to epipelic (*Merismopedia elegans,* 24 and *Oscillatoria lacustris,* 29). One species showed preference of being episamic (*Merismopedia glaucau,* 45) and epiphytic (*Oscillatoria brevis,* 45) in each case (Table 4.4).

Euglena sp. had the highest preference for being epilithic with an indicator value of 30 (Table 4.4).

The Species richness (Number of species, Menhinnick, Margalef and Fisher_alpha indices) of algae species on the substrates was observed to show the following order epilithic>epipelic<episamic>epiphytic>epidendric (Fig.4.5).

Dominance (Dominance_D and Berger-Parker) and Evenness (Simpson_1-D, Evenness_eH/S and Equitablity_J) indices showed similar trends among substrates but contrast between themselves. The highest Dominance was observed in the episamic

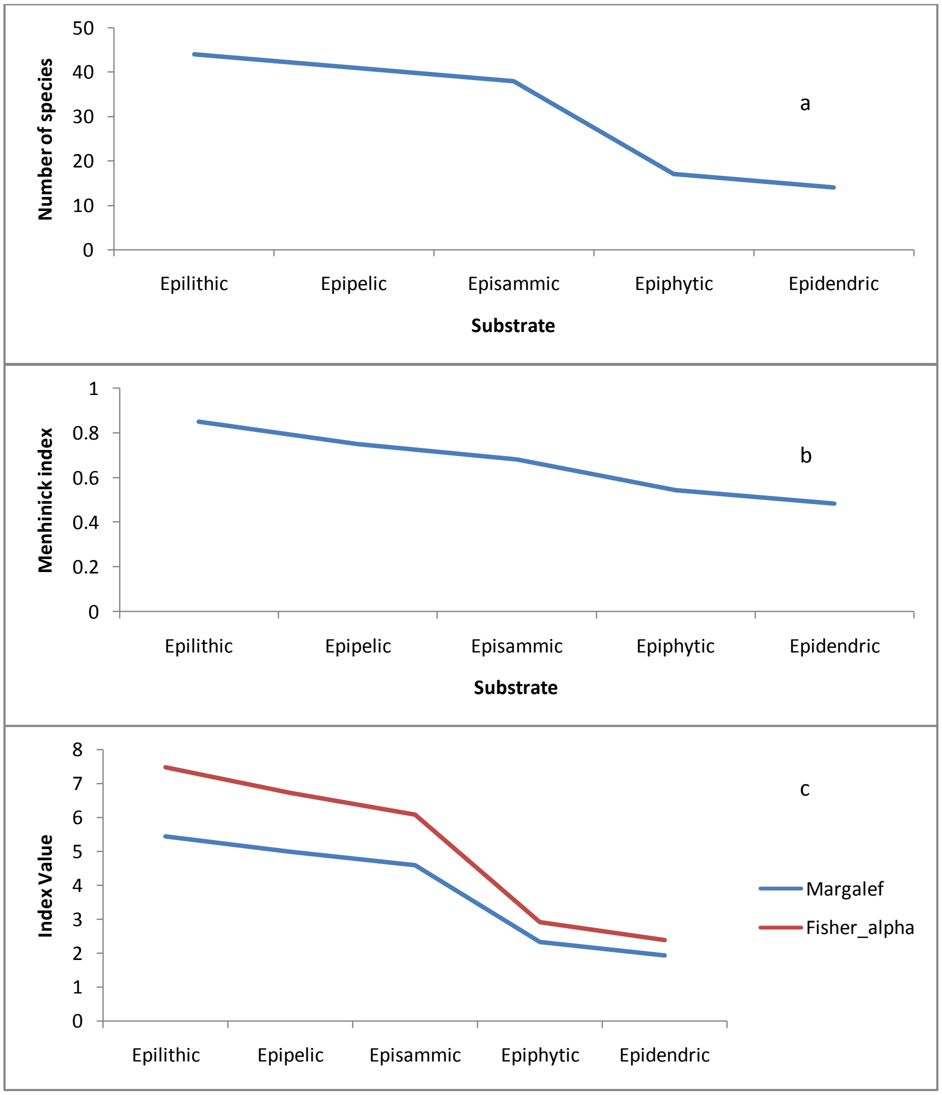


Fig. 4.5 Algal Indices of species richness, (a) Number of species (b) Menhinnick index (c) Margalef and Fisher_alpha indices in the Tudun Wada-Makera Drains and River Kaduna

community and the lowest on the epipelic community, and by contrast the Evenness of species distribution was highest in the epipelic community while the lowest in the episamic community. Species diversity (Shannon_H) was highest on the epipelic community than lowest on the epidendric community (Fig 4.6).

Cluster analysis based on Bray-Curtis similarity index grouped the periphytic algal communities into two major clusters, with the episammon, epilithon and epipelon in one group while the epidendron and epilithon in another group (Fig 4.7).

4.2.2 Distribution of Algae in Sampling Stations

Based on the means of data of surface water physico-chemical characteristics (temperatute, pH, electrical conductivity, total dissolved solids, dissolved oxygen, biochemical oxygen demand, total alkalinity, total hardness, sulphate, phosphate-phosphorus, nitrate-nitrogen, total nitrogen and total phosphprus) collected over two years, a cluster analysis based on Bray-Curtis similarity index was carried out. Three major clusters were observed. The sampling stations on the Tudun Wada drain (TW_1, TW_2 and TW_3) were in one cluster, stations on the Makera drain (MK_1, MK_2 and MK_3) in another cluster while all staions on River Kaduna (RK_1, RK_2, RK_3, RK_4, RK_5 and RK_6) on the other cluster (Fig. 4.8). Since the stations on the Tudun Wada drain and those on the Makera drain were grouped with a similarity of over 95% confidence limit, they are therefore, not significantly different, so, they are treated as a unit for algal indicator species analysis while the similarity of stations on the River Kaduna was less than 95%, therefore they are not significantly similar.

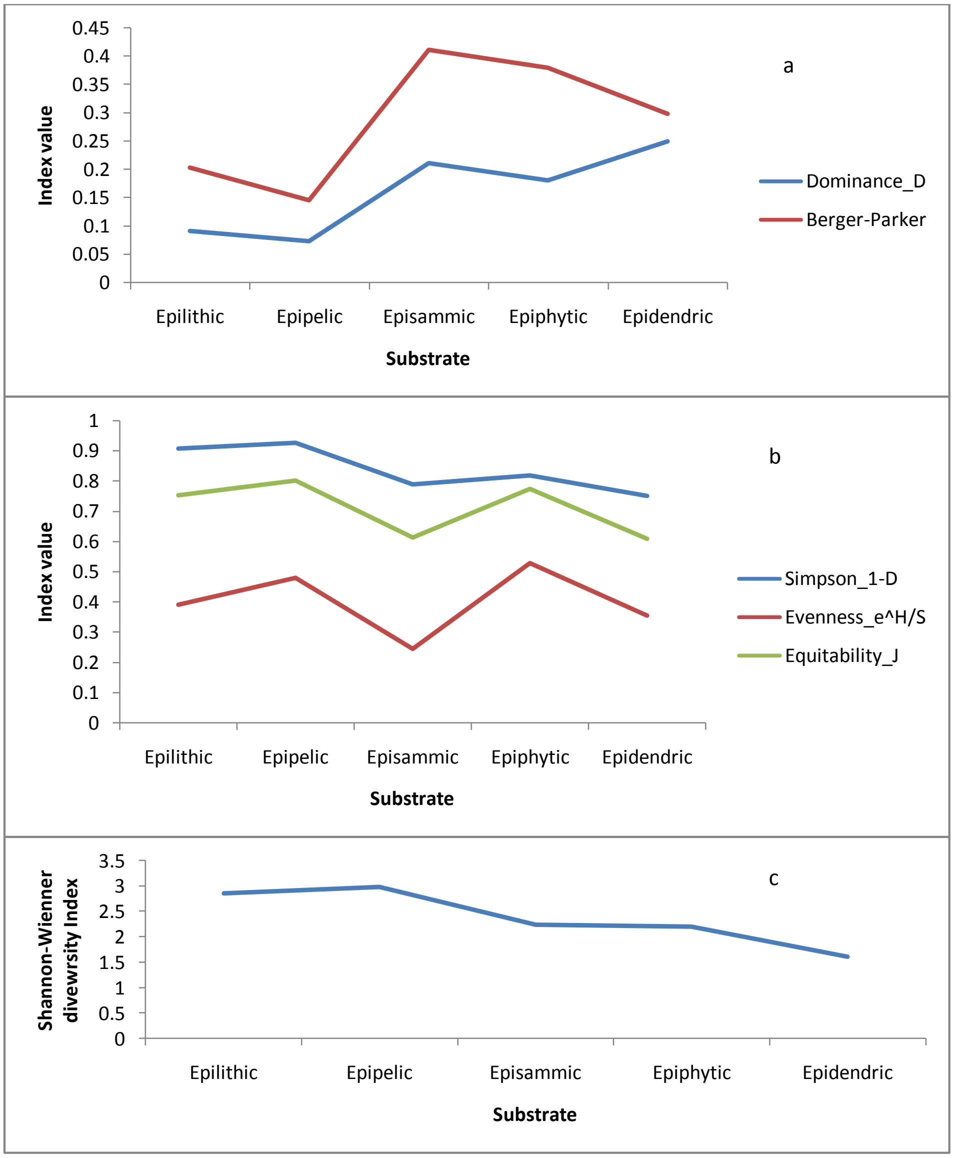


Fig. 4.6 Algal Indices such as Species Dominannce (a) Dominance_D and Berger-Perker; Eveness (b) Simpson_1-D, Eveness_eH/S and Equitability_J; and Diversity (c) Shannon_H indices of the Tudun Wada-Makera Drains and River Kaduna

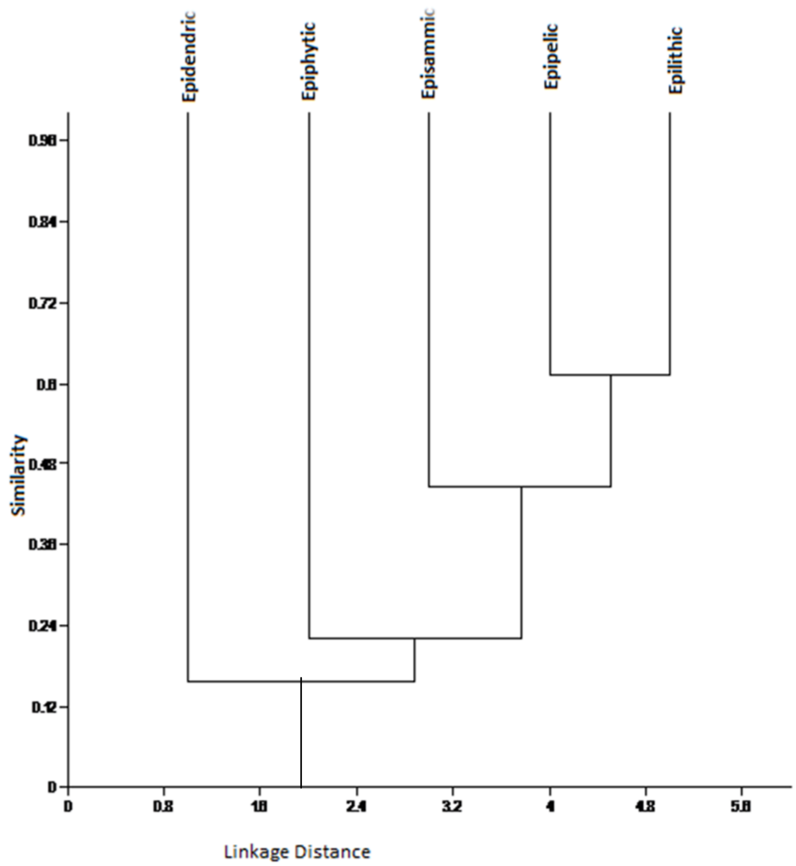


Fig. 4.7: Cluster Analysis of periphytic algae on substrate based on Bray-Curtis similarity index in the Tudun Wada-Makera Drains and River Kaduna

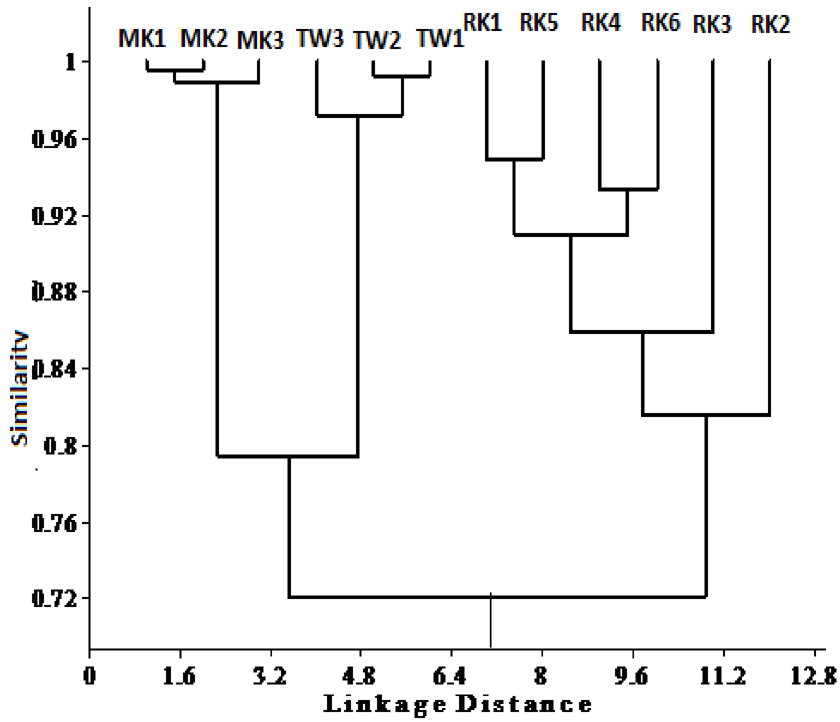


Fig. 4.8: Cluster analysis of sampling stations based on means of surface water physico-chemical Characteristics in Tudun Wada-Makera drains and River Kaduna

Periphytic algal species with significant (≥5) indicator values in the Tudun wada drain (TW_1, TW_2 and TW_3) include *Nitzchia* sp. (17), *Pediastrum* sp3. (8), *Nostoc* sp. (17), *Oscillatoria brevis* (40) and *Oscillatoria tenius* (26) and *Euglena* sp. (25) (Tables 4.5, 4.6 and 4.7).

Species with the highest indicator value in the Makera drain (MK_1, MK_2 and MK_3) include *Achnanthes* sp. (17), *Aulacoseira ambigua* (15), *Aulacoseira varians, Aulacoseira granulata, Epithemia* sp. (17), *Gyrosigma* sp. (16), *Melosira calognosa* (17), *Melosira* sp. (34), *Melosira sulcata* (33), *Sirurella augusta* (33), *Botryococcus* sp. (17), *Oscillatoria brevis, Oscillatoria limosa* (26) and *Euglena* sp.

Species with significant (≥ 5) indicator values in sampling stations on the River Kaduna (RK_1, RK_2, RK_3, RK_4, RK_5 and RK_6) include *Frustulia rhomboides, Aulacoseira varians, Anomoneis* sp., *Aulacoseira granulate, Coconeis placentula,Gyrosigma* sp., *Gyrosigma acumunatum, Melosira distans, Pinnularia* sp., *Synedra ulna, closterium moniliferum, closterium lonula, closterium* species1, 2, 3 and 4,*Coelastrum* sp., *Cosmarium marigatum, Cosmarium nudum, Cosmarium margarifeferum, Cosmarium quasillus, Cosmarium* sp.2, *Cosmarium* sp., *Pediastrum simplex, pediastrum duplex, Pediastrum* sp.2 and 3, *Penium* sp., *Scenedesmus acumunatus, Scenesmus acutus, Scenedesmus bijuga, Scenedesmus obliquus, Scnedesmus opoliensis, Scenedesmus quadricauda, Scenedesmus* sp. 1, 2, and 3, *Spirogyra* sp., *Staurasmus* sp., *Stigeoclonium pachydermum,Merismopedia glaucau, Merismopedia elegans*and *Oscillatria lacustris* (Tables 4.5, 4.6 and 4.7).

Table 4.5: Indicator values for periphytic diatoms among sampling stations in Tudun Wada-Makera and River Kaduna

	Bacillariophyta	**TW $_{1,2,3}$**	**MK $_{1,2,3}$**	**RK$_1$**	**RK$_2$**	**RK$_3$**	**RK$_4$**	**RK$_5$**	**RK$_6$**
1	*Achnanthes hungarica* Grun.	0	**17**	0	0	0	0	0	0
2	*Anomoneis* sp.	0	0	0	0	0	**17**	0	**17**
3	*Aulacoseira ambigua* (Grunow) Simonsen	0	**15**	0	0	0	1	0	1
4	*Aulacoseira granulata* (Grunow) Simonsen	0	12	0	0	0	3	**32**	3
5	*Aulacoseira* sp.	0	0	0	0	0	0	0	17
6	*Aulacoseira varians* (Grunow) Simonsen	0	**13**	0	0	0	8	0	**13**
7	*Coconeis placetula*	0	0	0	0	0	**8**	0	**8**
8	*Cymbella cistula* Ehr. (Ehr.)Kirchener	0	3	0	0	0	9	0	**22**
9	*Epithemia* sp.	0	**17**	0	0	0	0	0	0
10	*Epithemia zebra* Kutz.	0	0	0	0	0	8	0	8
11	*Frustulia rhomboids* Ehr.	0	1	**21**	0	**21**	0	0	7
12	*Gyrosigma* sp.	0	**16**	0	0	0	8	0	**10**
13	*Gyrosigma acumunatum* (Ehr.)Smith	0	0	0	0	0	0	**17**	0
14	*Melosira calognosa* Ehr.	0	**17**	0	0	0	0	0	0
15	*Melosira distans* Ehr.	0	2	0	0	0	5	0	**27**
16	*Melosira* sp.	0	**34**	0	0	0	7	1	8
17	*Melosira sulcata* Ehr	0	**33**	0	0	0	0	0	0
18	*Nitzchia* sp.	**17**	0	0	0	0	0	0	0
19	*Pinularia* sp.	0	0	0	0	0	0	0	**17**
20	*Pleurosigma* sp.	0	0	8	0	8	0	0	0
21	*Sirurella augusta* kg.	0	**41**	0	0	0	4	0	5
22	*Synedra ulna* (Nitzch) Chr	0	0	0	0	0	2	9	**22**

Table 4.6: Indicator values for periphytic chlorophyta among sampling stations in Tudun Wada-Makera and River Kaduna

S/No.	Species	TW 1,2,3	MK 1,2,3	RK_1	RK_2	RK_3	RK_4	RK_5	RK_6
1	*Botryococcus sp.*	0	**17**	0	0	0	0	0	0
2	*Closterium aerosum* Ralfs.								
3	*Closterium moniliferum* Turn.	0	0	0	0	0	0	0	**17**
4	*Closterium lonula* (Mull.) Nitz.	0	2	**24**	0	**24**	0	0	0
5	*Closterium* sp.1	0	0	**16**	0	**16**	0	0	2
6	*Closterium* sp.2	0	0	**14**	0	**14**	0	0	5
7	*Closterium* sp3	0	0	0	0	0	0	0	**17**
8	*Closterium* sp4	0	0	0	0	0	0	0	**17**
9	*Coelastrum intermedium* (Bohl) Kros	0	0	0	0	0	0	0	**17**
10	*Cosmarium botrytis* Menegh.	0	0	0	0	0	**8**	0	**8**
11	*Cosmarium margarifeferum* Menegh.	0	0	0	0	0	0	0	**17**
12	*Cosmarium marigatum* Menegh.	0	0	0	0	0	0	0	**33**
13	*Cosmarium quasillus* Menegh.	0	0	**8**	0	**8**	0	0	0
14	*Cosmarium* sp.1	0	0	0	0	0	0	0	**17**
15	*Cosmarium* sp.2	0	0	0	0	0	0	0	**17**
16	*Pediastrum duplex* Smith	0	0	8	0	8	0	0	**17**
17	*Pediastrum simplex* (Meyen) Lemmerman	0	0	0	0	0	**8**	0	**8**
18	*Pediastrumduplex var.regulosum* Raciborski	0	0	0	0	0	0	0	**17**
19	*Pediastrumduplex* var. *reticulatum* Largerhein	8	0	0	0	0	0	0	**8**
20	*Penium* sp.	0	0	0	0	0	0	0	**17**
21	*Scenedesmus acumunatus* (Lag) Chodat	0	0	0	0	0	**8**	0	**8**
22	*Scenedesmus acutus* Meyen	0	0	0	0	0	0	0	**17**
23	*Scenedesmus bijuga* Turp Legerhem	0	0	0	0	0	3	3	**28**
24	*Scenedesmus bijuga* var.(Reinsch) Hansgird	0	0	0	0	0	0	0	**17**
25	*Scenedesmus obliquus*	0	0	0	0	0	6	0	**11**
26	*Scenedesmus opolinensis* P. Richt 1896	0	0	0	0	0	0	0	**17**
27	*Scenedesmus quadricauda* Smith	0	0	0	0	0	0	0	**17**
28	*Scenedesmus incrasatulus* Bohlin	0	0	0	0	0	**8**	0	**8**
29	*Scenedesmus* sp.	0	0	0	0	0	**8**	0	**8**
30	*Scenedesmus dimorphus* (Turp) Kg.	0	0	0	0	0	0	0	**16**
31	*Spirogyra* sp.	4	0	4	0	4	0	**17**	4
32	*Staurastrum* sp.	0	0	0	0	0	**8**	0	**8**
33	*Stigeoclonium pachydermum Prescott*	0	0	0	0	0	**8**	0	**8**
34	Ui	0	0	0	0	0	**8**	0	**8**

Table 4.7: Indicator values for periphytic cyanobacteria and euglenophyta among sampling stations in Tudun Wada-Makera and River Kaduna

	$TW_{1,2,3}$	**$MK_{1,2,3}$**	**RK_1**	**RK_2**	**RK_3**	**RK_4**	**RK_5**	**RK_6**
Cyanobacteria								
Merismopedia glaucau (Ehr.) Kutz.	0	0	0	0	0	4	0	**12**
M. elegans A. Braun	0	0	0	0	0	0	**17**	0
Nostoc sp.	**17**	0	0	0	0	0	0	0
Oscillatoria brevis Kutz.	**40**	**26**	0	0	0	0	1	0
Oscillatoria lacustris (Kleb) Ag.	0	0	0	0	0	7	12	**14**
Oscillatoria limosa	0	**27**	0	0	0	1	20	1
Oscillatoria tenuis Ag.	**26**	22	16	0	16	0	3	0
Euglenophyta								
Euglena sp.	**25**	**8**	0	0	0	0	0	0

For the planktonic algal species with significant indicator values (≥ 5) on the sampling stations on the Tudun Wada drain include the diatoms *Aulacoseira granulata, Cymbella cistula, Melosira sulcata, Synedra ulna, Nitzchia* sp., *Sirurella augusta, Sirurella ovalis, Navicula* sp.4; the chlorophyta *Closterium* sp.; the cyanobacteria *Oscillatoria lacustris, Oscillatoria limosa, Oscillatoria brevis, Spirulina* sp., and *Nostoc* sp.; and *Euglena* sp. and *Phacus* sp. of the eulglenophyta (Table 4.8).

Comment [MaC14]: Algae is used here as an adjective for species, so it should be written as 'algal'…

Planktonic algae significant indicator values (≥ 5) of the Makera drain include *Aulacoseira varians, Melosira sulcata, Melosira numuloides, Cosmarium marigatius, Oscillatoria tenius, O. brevis, Nostoc* sp. and *Euglena* sp (Table 4.8). Species indicative of stations on the River Kaduna include *Aulacoseira varians, Aulacoseira granulata, Melosira sulcata, Melosira numuloides, Pleurosigma* sp., *Frustulia rhomboides, Navicula* sp. 1,2 and 3, *Synedra ulna, Nitzchia* sp., *Sirurella augustaCosmarium marigatius, Oscillatoria tenius, O. brevis, O. lacustris, Nostoc* sp. and *Euglena* sp. and *Phacus* sp. (Table 4.8).

4.2.3 Algal Non Metric Multidimensional Scaling (NMDS)

A Non Metric Multidimensional Scaling (NMDS) of sampling stations based on periphytic algae species composition and abundance groups TW_1, TW_3 and RK_2 in the same axis, RK_1 and RK_2 in another axis and MK_1, MK_2 and MK_3 while TW_2, RK_4, RK_5 and RK_6 where observed to be dispersed away from the other sampling stations (Fig. 4.9).

For the planktonic algae, stations RK_1 and RK_2 were much similar, thus grouped together. Most of the stations on the Makera drain (MK_1 and MK_3) were grouped together with stations on the River Kaduna (RK_4, RK_5 and RK_6) that are close to the drain (Fig.4.9).

Comment [MaC15]: Rephrase…..

Table 4.8: Indicator values for planktonic algae among sampling stations in Tudun Wada-Makera and River Kaduna

	$TW_{1,2,3}$	**RK_1**	**RK_2**	**RK_3**	**$MK_{1,2,3}$**	**RK_4**	**RK_5**	**RK_6**
Bacillariophyta								
Aulacoseira granulata (Grunow) Simonsen	26	6	13	0	4	6	29	32
Aulacoseira varians (Grunow) Simonsen	0	29	10	0	19	0	10	0
Pleurosigma sp.	0	0	0	0	0	0	17	0
Frustulia rhomboids Ehr.	0	17	0	17	0	0	0	0
Navicula sp3	0	0	0	0	0	0	17	17
Navicula sp2	0	0	0	0	0	17	0	0
Navicula sp1	0	0	0	0	0	0	17	0
Cymbella cistula Ehr.	17	0	0	0	0	0	0	0
Melosira sulcata Ehr.	5	31	15	0	15	0	0	0
Synedra sp.	31	0	9	0	0	9	0	0
Nitzchia sp.	7	0	21	0	0	0	21	0
Sirurella augusta Kg.	35	0	10	0	0	0	5	0
Sirurella ovalis Kg.	17	0	0	0	0	0	0	0
Navicula sp4	0	0	17	0	0	0	0	0
Melosira numuloides Kg.	0	0	0	0	13	20	0	0
Chlorophyta								
Cosmarium marigatius Menegh	0	0	0	0	8	25	0	0
Closterium sp.	17	0	0	0	0	0	0	0
Staurastrum sp.	0	0	0	0	0	17	0	0
Cyanobacteria								
Oscillatoria lacustris (Kleb) Goitler	87	17	13	2	2	6	2	4
O. tenuis Ag.	26	19	28	16	10	9	14	12
O. Limosa (Roth) Ag.	7	20	20	20	0	0	0	0
O. brevis Ag.	19	7	7	0	42	0	0	7
Spirulina sp.	17	0	0	0	0	0	0	0
Nostoc sp.	27	0	0	0	15	8	0	0
Euglenophyta								
Euglena sp.	9	4	52	0	14	0	4	0
Phacus sp.	0	17	0	0	0	0	0	0

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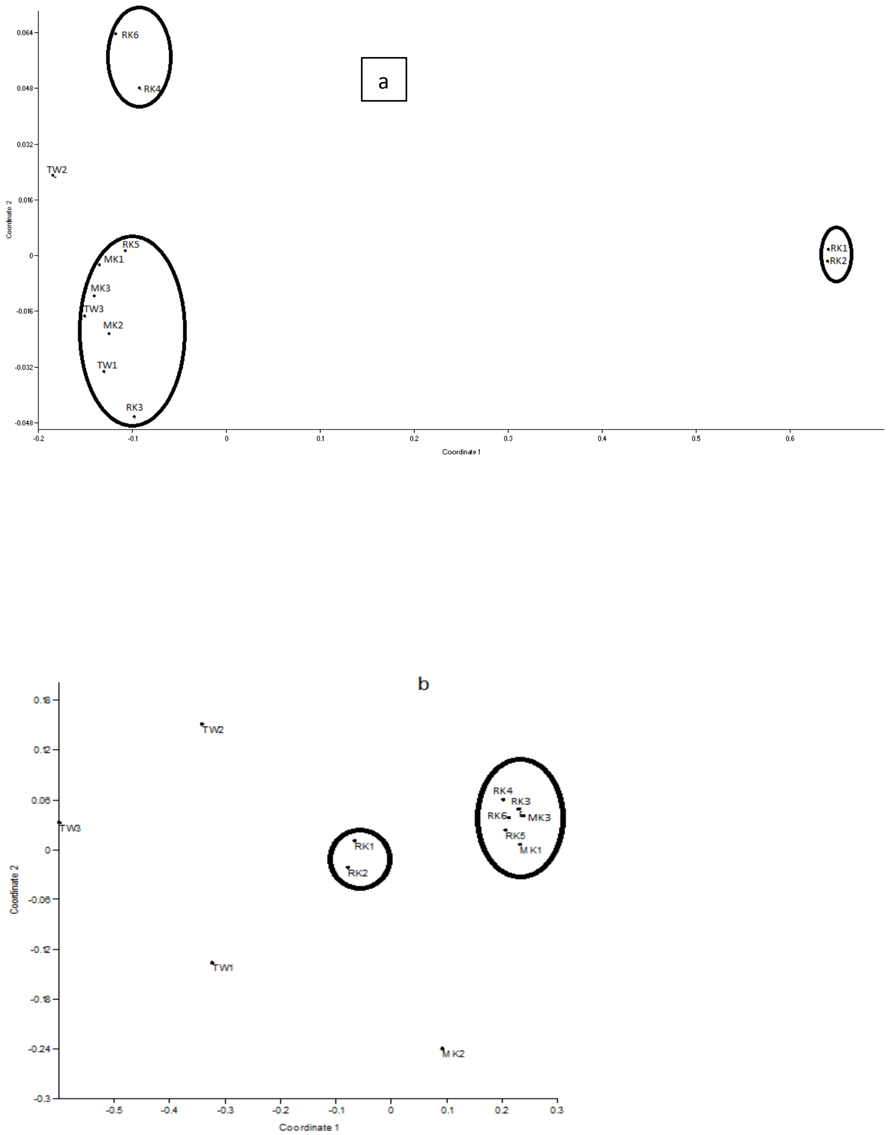

Fig. 4.9: Non-metric multidimensional scaling (NMDS) (based on Bray-Curtis similarity) of sampling stations using algae species in Tudun Wada-Makera drains and River Kaduna a) periphyton algae, b) planktonic algae

4.2.4 Cluster Analysis of Algae

Cluster analysis of sampling stations based on Bray-Curtis similarity index using the phytoplankton algae groups the sampling stations into three major groups; sampling stations on the Tudun Wada drain (TW_1, TW_2 and TW_3) were clustered in the one group, most of the stations on the Makera drain and most of the stations located on the River Kaduna impacted by the Makera drain (MK_1, MK_3, RK_4, RK_5 and RK_6) were also grouped together in a separate group; and the third group consists of upstream stations of the River Kaduna (RK_1 and RK_2) and MK_2 (Fig. 4.10).

The sampling stations were also grouped into three major groups based on clustering using the periphytic algae. Stations RK_5 and RK_6 were clustered in the first group whereas all the stations on the two drains were clustered together (TW_1, TW_3, MK_1, MK_2 and MK_3 with the exception of TW_2). While the third major cluster has RK_1, RK_2, RK_3. Station RK_4 and TW_2 tend to be deviants (Fig. 4.11).

4.2.5 Periphytic Algal Community Structure based on Sampling Stations

In the periphytic algal community, indices showing how evenly species are distributed; Simpson, Evenness and equitability among stations were observed to show similar patterns. A sharp decrease in these indices was observed from TW_1 (0.78, 0.86 and 0.92, respectively) to TW_2 (0.15, 0.36, and 0.26 respectively) and then rapidly increased in TW_3 (0.73, 0.79 and 0.85 respectively). The following index values were observed for Stations on River Kaduna close to the Tudun Wada drain, RK_1, 0.67, 0.99, 1.0, 1.0; RK_2, 0.94,1.0,1; RK_3, 0.54,0.29,0.44 for Simpson, Evenness and equitability respectively.

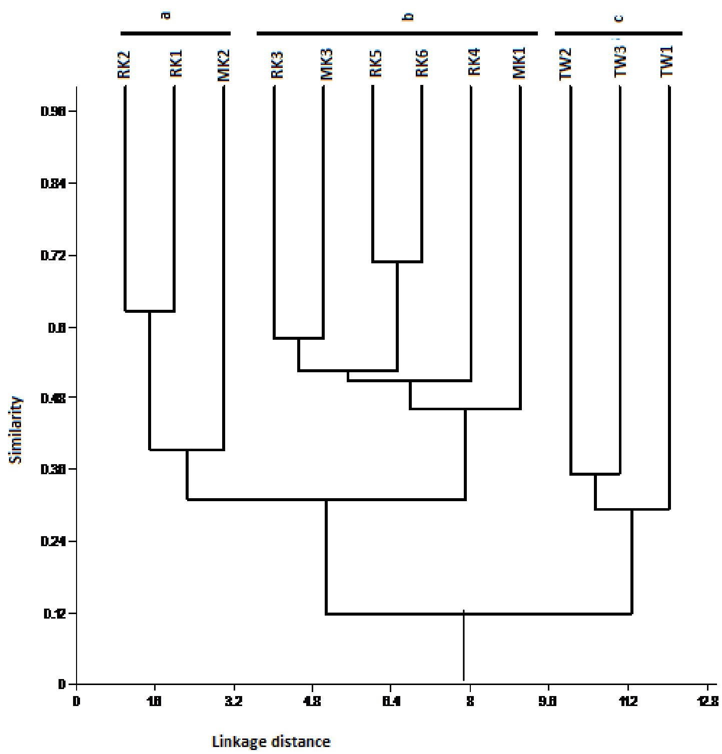

Fig 4.10: Cluster analysis of sampling stations based on Phytoplankton in Tudun Wada-Makera drains and River Kaduna

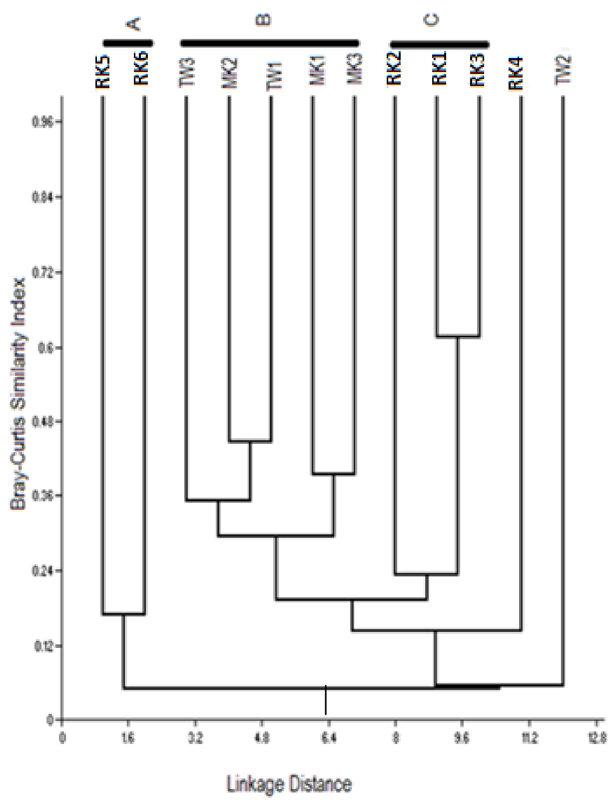

Fig. 4.11: Cluster analysis of sampling stations based on Periphytic algae in Tudun Wada-Makera drains and River Kaduna

The variations of these indices on the Makera drain and stations impacted by it on the River Kaduna did not show a discernable trend, MK_1, 0.85,0.67,0.8; MK_2, 0.77,0.49,0.72; MK_3, 0.79, 0.63, 0.80; RK_4, 0.91, 0.60, 0.85; RK_5, 0.80, 0.58, 0.78; and RK_6, 0.83, 0.28, 0.65 for Simpson, Evenness and equitability (Fig. 4.12).

Indices showing the level of dominance of species (Dominance_D and Berger-Parker) were also observed to show a similar pattern of distribution in all the sampling stations. The indices in the sampling stations showed the following values TW_1, 0.22, 0.31; TW_2, 0.85, 0.92; TW_3, 0.27, 0.31; RK_1, 0.34, 0.37; RK_2, 0.06, 0.06, RK_3, 0.46, 0.58; MK_1, 0.15, 0.24, MK_2, 0.22, 0.34, MK_3, 0.20, 0.37; RK_4, 0.09, 0.19; RK_5, 0.20, 0.36; and RK_6, 0.17, 0.30 for Dominance and Berger-Parker, respectively (Fig. 4.12).

The highest values of Shannon-Weiner diversity index were observed on stations on the River Kaduna (RK_1, 1.10; RK_2, 2.89; RK_3, 0.97; RK_4, 2.93; RK_5, 1.93; and RK_6, 2.35) and the lowest among values on the drains (TW_1, 1.65; TW_2, 0.35; TW_3, 1.40; MK_1, 2.08; MK_2, 1.84; and MK_3, 1.85) (Fig. 4.12).

Indices of species richness (Fisher_alpha, Margalef and number of species and Menhinick) generally showed a similar trend among the sampling stations. Species richness was observed to be generally lower on stations located on the drains (TW_1, 0.71, 0.62, 6, 0.11; TW_2, 0.60, 0.49, 4, 0.19; TW_3, 0.66, 0.56, 5, 0.14; MK_1, 1.93, 1.60, 12, 0.39; MK_2, 1.93, 1.63, 13, 0.32; MK_3, 1.74, 1.43, 10, 0.43 for Fisher_alpha, Margalef, number of species and Menhinick, respectively) than in the stations on River Kaduna (RK_1, 0.37, 0.281, 3, 0.09; RK_2, 2.23, 1.94, 18, 0.21; RK_3, 1.23, 1.09, 9, 0.23; RK_4, 6.04, 4.20, 28, 1.12; RK_5, 2.04, 1.67, 12, 0.45; RK_6, 6.54, 4.78, 37, 0.86 Fisher_alpha, Margalef, number of species and Menhinick respectively) (Fig 4.13).

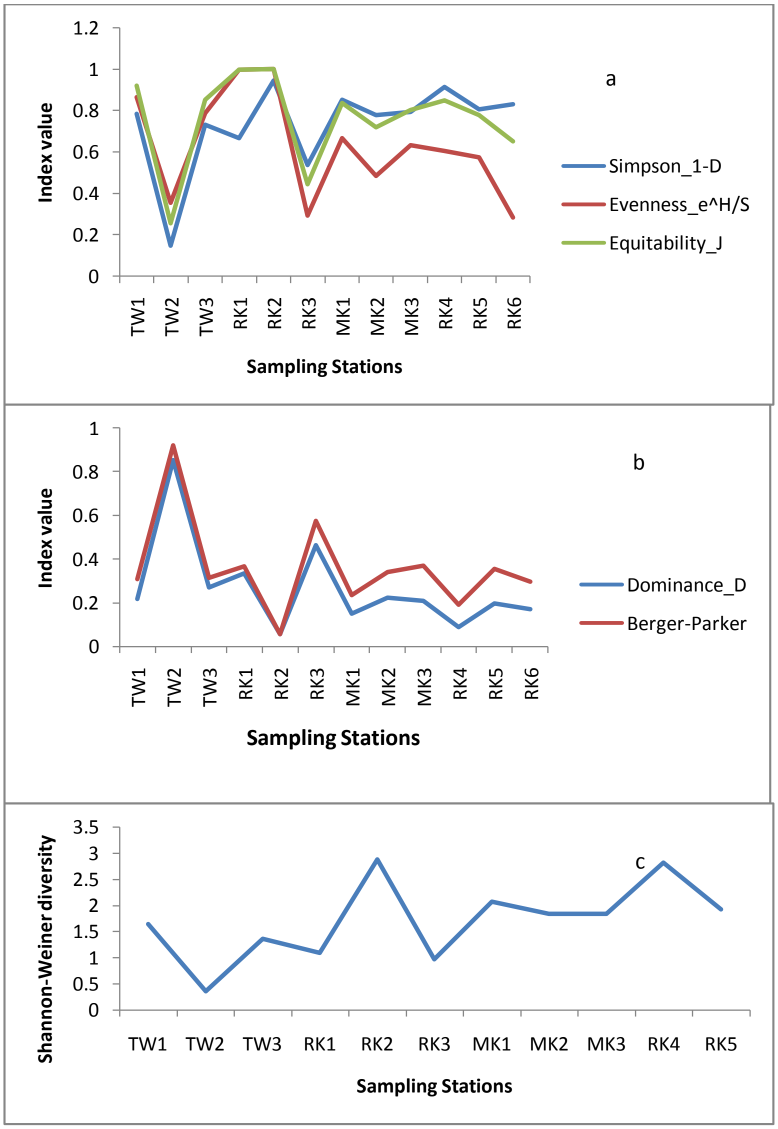

Fig. 4.12: Periphytic algal(a) evenness (Simpson, Evenness and Equitability), (b) dominance (Dominance and Berger Parker), and (c) diversity (Shannon-Weiner) indices in Tudun Wada-Makera drains and River Kaduna

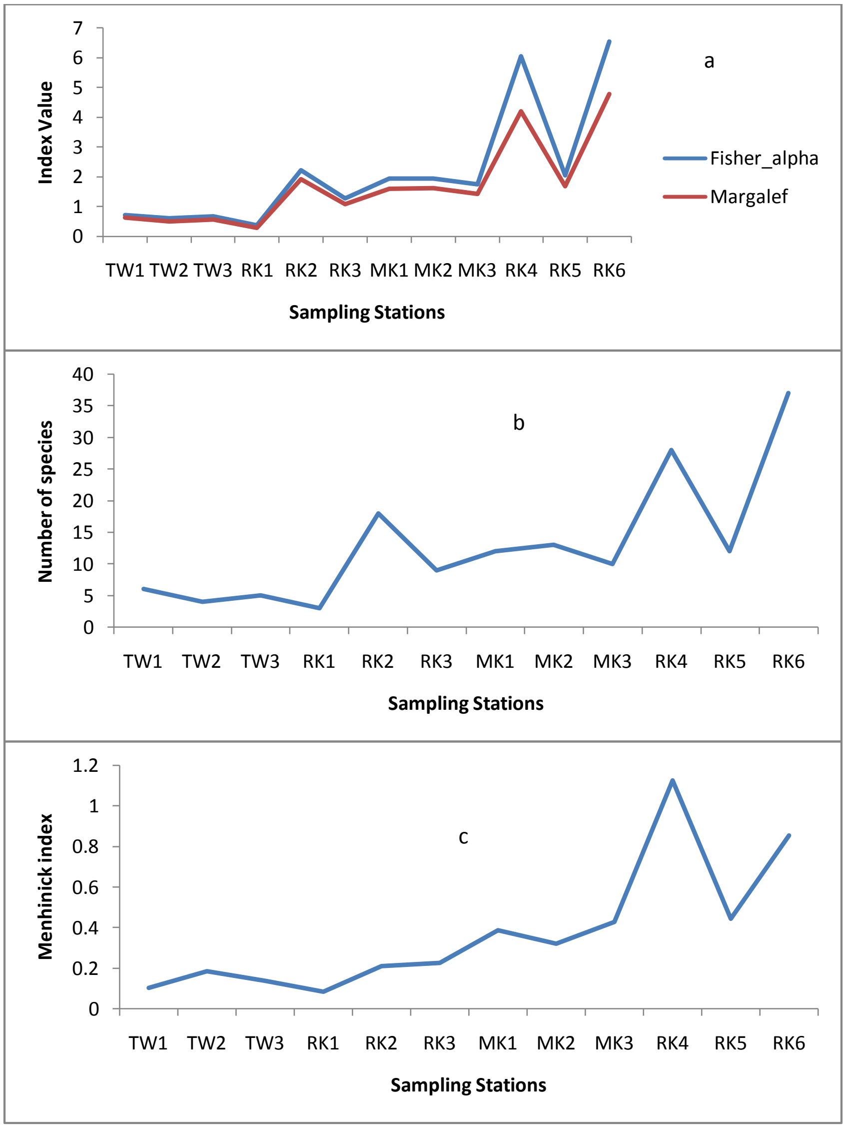

Fig. 4.13: Periphytic algae indices of species richness (a) Fisher_alpha and Margalef (b) number of species and (c) Menhinick in Tudun Wada-Makera drains and River Kaduna

4.2.6 Phytoplankton Community Structure based on Sampling Stations

Indices of evenness in the distribution of planktonic algae species (Simpson's, Evenness, and Equitability) were observed to show a similar pattern of variation among the sampling stations showing a decline on stations on the Tudun Wada from upstream-downstream; TW_1 (0.85, 0.65 and 0.83 for Simpson's, Evenness, and Equitability, respectively), TW_2 (0.55, 0.25 and 0.47 for Simpson's, Evenness, and Equitability, respectively), TW_3 (0.36, 0.23 and 0.34 for Simpson's, Evenness, and Equitability, respectively). On the Makera drain, the evenness indices generally decreased from MK_1 (0.85, 0.91 and 0.95 for Simpson's, Evenness, and Equitability, respectively) to MK_2 (0.76, 0.61 and 0.78 for Simpson's, Evenness, and Equitability, respectively) and then increased with the exception of Simpson's index in MK_3 (0.75, 0.86 and 0.90 for Simpson's, Evenness, and Equitability, respectively). On the River Kaduna, stations near the Tudun Wada drain RK_1 (0.65, 0.44 and 0.66 for Simpson's, Evenness, and Equitability, respectively), RK_2 (0.75, 0.41 and 0.66 for Simpson's, Evenness, and Equitability, respectively) and RK_3 (0.65, 0.71 and 0.79 for Simpson's, Evenness, and Equitability, respectively) were observed to show lower evenness in planktonic algae distribution in comparison to stations near the Makera drain, RK_4 (0.74, 0.60 and 0.77 for Simpson's, Evenness, and Equitability, respectively), RK_5 (0.84, 0.76 and 0.88 for Simpson's, Evenness, and Equitability, respectively) and RK_6 (0.72, 0.80 and 0.86 for Simpson's, Evenness, and Equitability, respectively) (Fig 4.14).

The indices showing the dominance of phytoplankton (Dominance and Berger-Parker) were observed to show an opposing realationship with the indices of evenness in all the sampling stations. On the Tudun Wada drain, Dominance and Berger-Parker were observed to increase from TW_1 (0.15 and 0.24) to TW_2 (0.45 and 0.64) and the highest

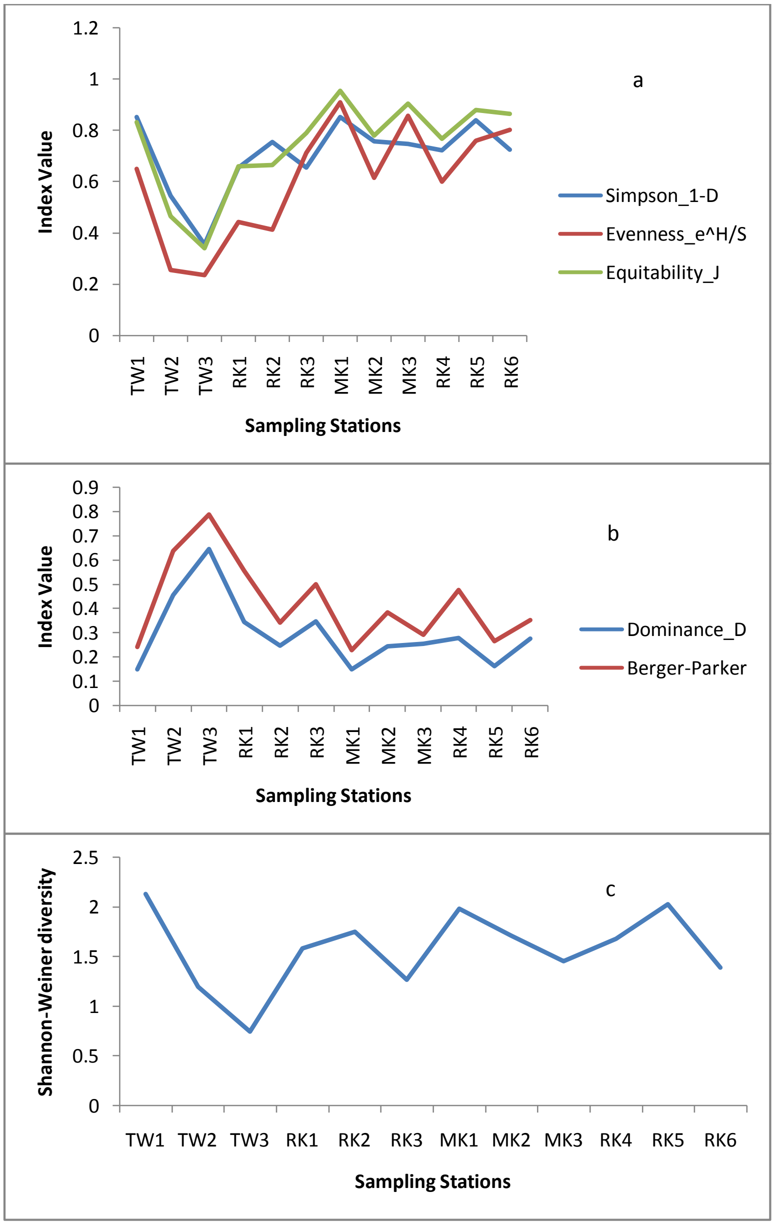

Fig. 4.14: Phtoplankton algae indices of (a) evenness (Simpson, Evenness and Equitability), (b) dominance (Dominance and Berger Parker), and (c) diversity (Shannon-Weiner) in Tudun Wada-Makera drains and River Kaduna

values in TW_3 (0.64 and 0.79). On the Makera drain, Dominance was observed to increase from MK_1 (0.15) to MK_2 (0.24) and peaking at MK_3 (0.25) while Berger-Parker index increased from MK_1 (0.23) to MK_2 (0.38) and then decreased in MK_3 (0.29). On the stations on the River Kaduna, Dominance and Berger Parker indices were observed to show decreased valued at the points the two drains impact the River (RK_2, 0.25 and 0.34; and RK_5, 0.16 and 0.27, respectively) in comparison to the stations before the point of impact (RK_1, 0.35 and 0.34; and those after the point of impact (RK_3, 0.35 and 0.50; and RK_5, 0.28 and 0.35 respectively) (Fig. 4.14).

Comment [MaC17]: Check and rephrase.

Shannon-Weiner diversity index was observed to decrease from TW_1 (2.13) to TW_2 (1.20) and then lowest at TW_3 (0.75) on the Tudun Wada drain. On the Makera drain it was also observed that it decreased from up stations MK_1 (1.98) to MK_2 (1.71) to the lowest value at MK_3 (1.46). Stations on River Kaduna were observed to show increased Shannon-Weiner diversity at the point the water from the drains impact the River (RK_2, 1.75 and RK_5, 2.03) in comparison to the points before (RK_1, 1.58 and RK_3, 1.27) or after impact (RK_4, 1.68 and RK_6, 1.39) (Fig 4.14).

Comment [MaC18]: Replace word….

Indices of species richness (Margalef, Fisher_alpha, Number of species and Menhinick) were observed to show a similar pattern in all the sampling stations. On the Tudun Wada drain, Margalef, Fisher_alpha and Menhinick indices, there was an increase from TW_1 (1.38, 1.57 and 0.17 respectively) to TW_2 (1.47, 1.71 and 0.22 respectively) and then a decrease in TW_3 (0.87, 0.98 and 0.09 respectively), while the number of species observed in TW_1 and TW_2 was the same (13), the number decreased at TW_3 (9). On the Makera drain, Margalef and Fisher_alpha decreased progressively from MK_1 (1.18, and 1.43 respectively) to MK_2 (1.12 and 1.30 respectively) to MK_3 (0.69 and 0.83 respectively). The

Number of species was observed to increase from MK_1 (8) to MK_2 (9) and then decreased in MK_3 (5), while the Menhinick index in a contrast manner was observed to show a decrease from MK_1 (0.41) to MK_2 (0.25) and then increasing slightly in MK_3 (0.27) (Fig. 4.15).

4.2.7 Relationships among Sampling Stations, Surface Water Physico-Chemical Characteristics and Algal Species

The first (58.67%) and second (28.64%) axes of the Principal Component Analysis (PCA) were significant and accounted for 87.31% of the variation in the environmental data. Positive associations were observed among surface water pH, BOD, Temperature, sulphate, nitrate-nitrogen and phosphate-phosphorus. These parameters were also observed to show a positive association with sampling stations on the Makera drain (MK_1, MK_2 and MK_3). Positive associations were also observed among surface water total nitrogen, total phosphorus, electrical conductivity, total dissolved solids, total alkalinity and total hardness. These parameters were also found to be negatively associated with dissolved oxygen. PCA also grouped sampling stations on each drain together (MK_1, MK_2 and MK_3 grouped together; and TW_1, TW_2 and TW_3, grouped together) and also sampling stations on the River Kaduna based on the drain impacting it (RK_1, RK_2, RK_3) impacted by the Tudun Wada drain were grouped together, while RK_4, RK_5 and RK_6 impacted by the Makera drain were also grouped together (Fig.4.16).

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Canonical correspondence analysis (CCA) was observed to group periphtyic algae species, sampling stations and surface water physico-chemical characteristics into two major groups.

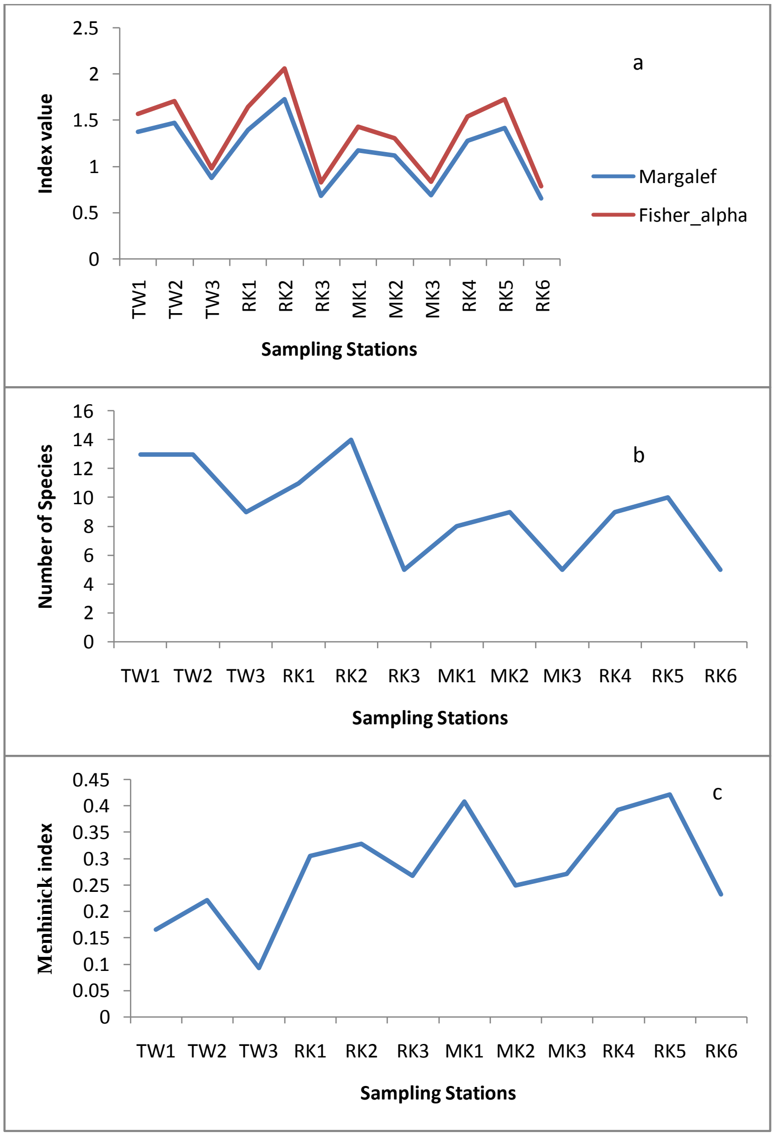

Fig. 4.15: Planktonc algae indices of species richness (a) Fisher_alpha and Margalef (b) number of species and (c) Menhinick in Tudun Wada-Makera drains and River Kaduna

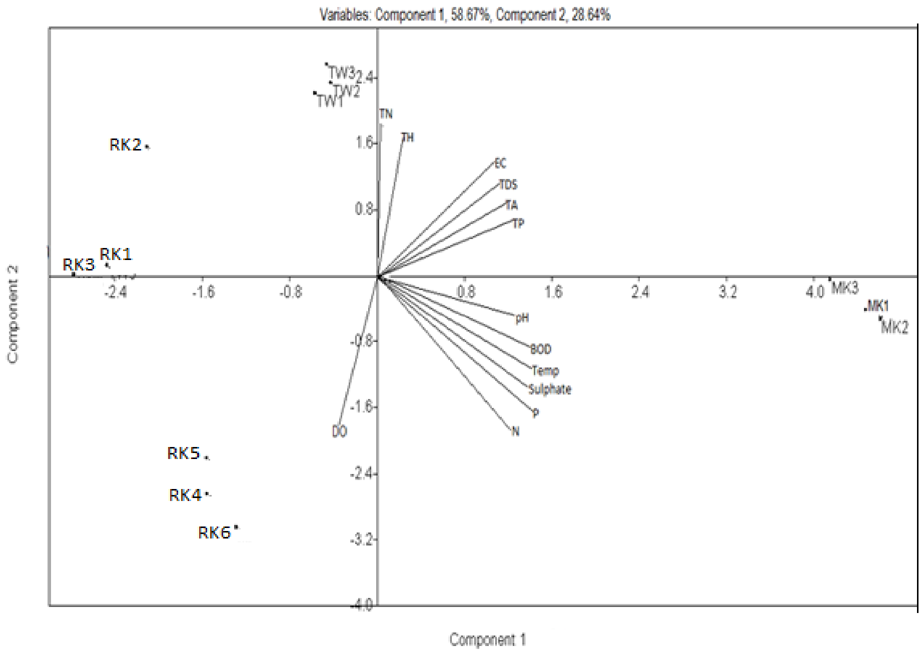

Fig 4.16: Principal Component Analysis (PCA) biplot for 13 surface water physico-chemical characteristics in Tudun Wada (TW)-Makera drains (MK) and River Kaduna (RK) (Temp= temperature, TDS= Total Dissolved Solids, EC= Electrical Conductivity, DO= Dissolved Oxygen, BOD= Biochemical Oxygen Demand, TH= Total Hardess, TA= Total Alkalinity, TP = Total Phosphorus, TN = Total Nitrogen, P = Phosphate-phosphorus, N = Nitratre- Nitrogen)

Species indicative of high pollution such as *Euglena* sp., *Aulacoseira ambigua, A. varians*, *Oscillatoria brevis* and *Sirurella augusta* were grouped with heavily polluted sites (TW_1, TW_3, MK_1, MK_2, RK_1 and RK_3) with high EC, TDS, TA and BOD. The second group comprised pollution less tolerant species such as *Aulacoseira granulate, Navicula cuspidata, Nitzchia* sp., *Oscillatoria lomosa, Cymbella cistula, Synedra ulna, Cosmarium marigatum* and *C. nodum gouped* with less polluted sites RK_5, TW_2 and RK_2 (Fig 4.17).

The CCA of sites, surface water physico-chemical characteristics and phytoplankton species was however observed to group almost all the species both indicators of high pollution (*Euglena* sp., *Aulacoseira varians, Oscillatoria tenius)* and low pollution (*Synedra ulna, Aulacoseira granulata, Oscillatoria lacustris* with all the sampling sites (TW_1, TW_2, TW_3, MK_1, MK_2, MK_3, RK_1, RK_2, RK_3, RK_4, RK_5 and RK_6(Fig. 4.18).

Photomicrographs of *Aulacoseira granulata, Synedra ulna, Oscillatoria brevis, Nostoc* sp., *Staurastrum* sp., *Closterium lonula, Phacus* sp. and *Spirogyra* sp. are presented on Plates I to VIII.

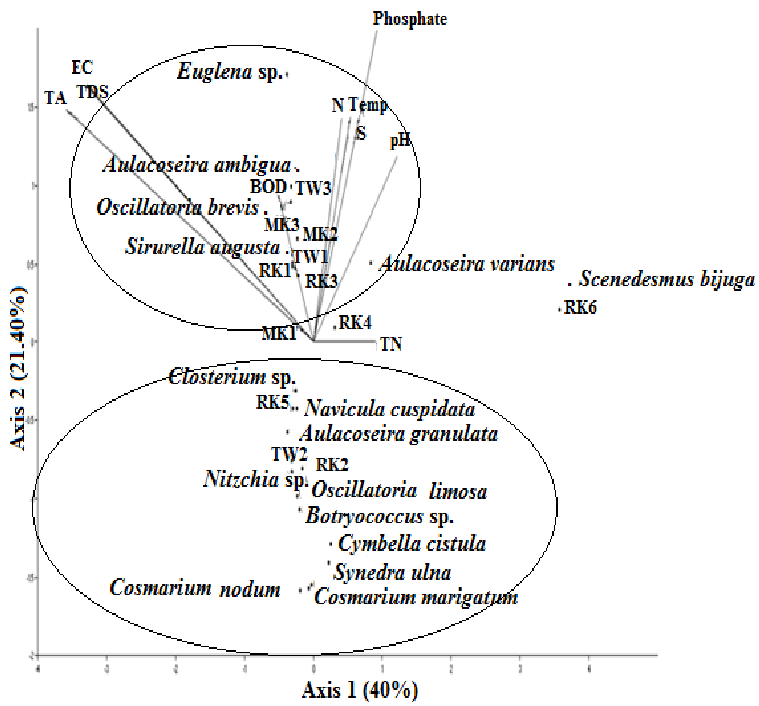

Fig. 4.17: Canonical Correspondence Analysis (CCA) triplot for 11 surface water physico-chemical characteristics and most abundant (relative abundance > 5%) periphyton algae species in Tudun Wada-Makera drains and River Kaduna (Temp= temperature, TDS= Total Dissolved Solids, EC= Electrical Conductivity, DO= Dissolved Oxygen, BOD= Biochemical Oxygen Demand)

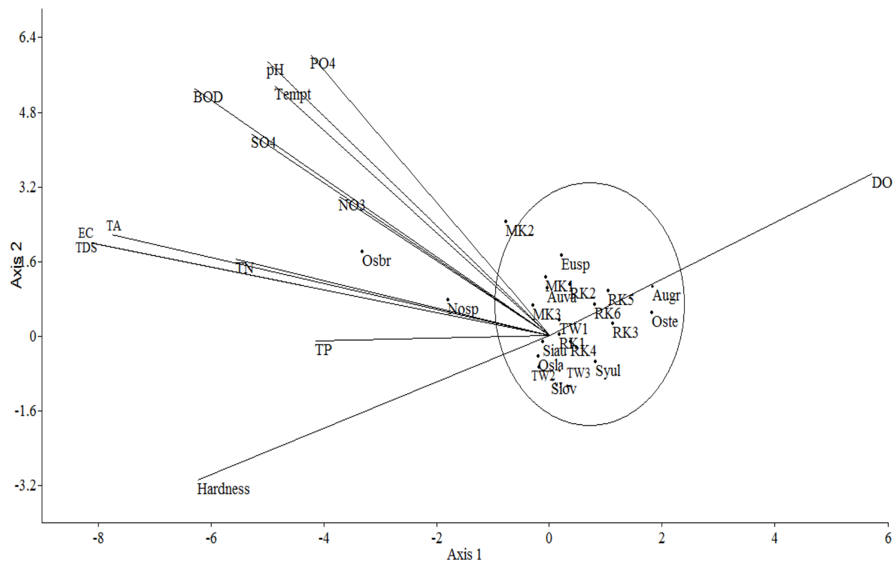

Fig. 4.18:Canonical Correspondence Analysis (CCA) triplot for surface water physico-chemical characteristics and most abundant (relative abundance > 1%) phytoplankton species in Tudun Wada-Makera drains and River Kaduna (Eusp = *Euglena* sp., Auva = *Aulacoseira varians,* Augr = *Aulacoseira granulata,* Oste = *Oscillatoria tenuis,* Siau = *Sirurella augusta,* Siova = *Sirurella ovalis,* Osbr =*Oscillatoria brevis,* Nosp= *Nostoc* sp., Temp= temperature, TDS= Total Dissolved Solids, EC= Electrical Conductivity, DO= Dissolved Oxygen, BOD= Biochemical Oxygen Demand

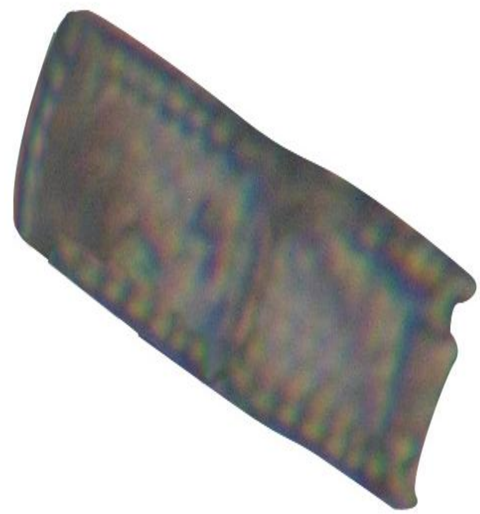

Plate I: *Aulacoseira granulata* (Bacillariophyta)

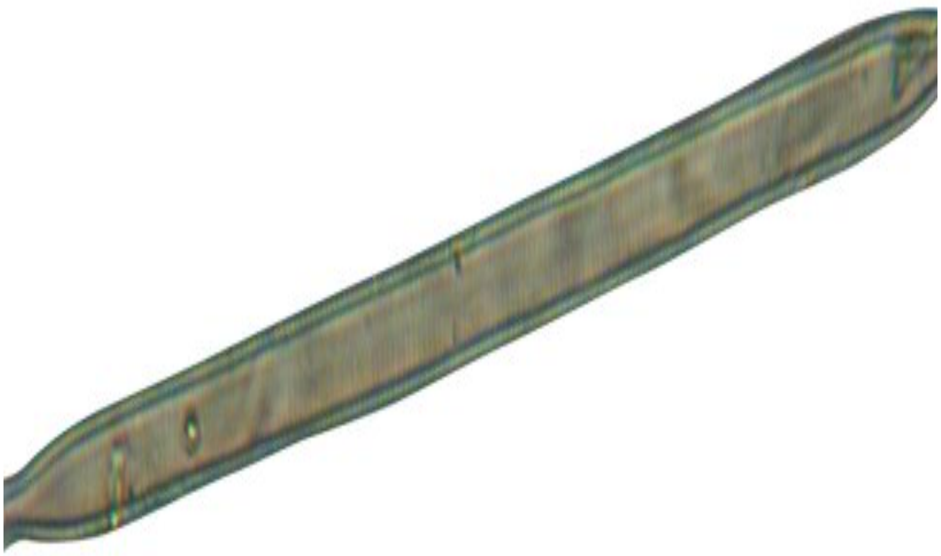

Plate II: *Synedra ulna* (Bacillariophyta)

Plate III: *Oscillatoria brevis*

Plate IV: *Nostoc* sp.

Plate V: *Staurastrum* sp. (chlorophyta)

Plate VI: *Closterium lonula* (chlorophyta)

Plate VII: *Phacus* sp. (euglenophyta)

Plate VIII: *Spirogyra* sp. (chlorophyta)

CHAPTER FIVE

5.0 DISCUSSION

5.1 Physico-Chemical Characteristics of Surface Water

The values of temperature, pH, total dissolved solids, electrical conductivity, total alkalinity, sulphate and phosphate-phosphorus in surface water were observed to be significantly higher ($p \leq 0.05$) on stations in the Makera drain (MK_1, MK_2 and MK_3) where the brewery effluent is a major component. Brewery effluent has been reported to have a higher temperature than the water of receiving streams (Olorode and Fagade, 2012; Inyang *et al.*, 2012). The brewing process involves a number of boiling and cooling processes which could result in the discharge of effluents with relatively high temperatures. The absence of any significant variation in surface water temperature among the other sampling stations (TW_1, TW_2, TW_3, RK_1, RK_2, RK_3, RK_4, RK_5 and RK_6) could be explained by the reason that solar radiation may be the major source of heat energy at the stations and there may not be differences since they are not widely separated in Longitude, Latitude or Altitude.

The absence of seasonal variation in surface water temperature is characteristic of tropical waters (Ezra and Nwankwo, 2001). This is because the intensity and duration of solar radiation in the tropics does not vary widely between seasons as compared to the temperate regions of the world (Chia *et al.*, 2011a).

Variations in mean annual temperatures could account for the variation in the annual surface water temperature between the two years (2013 and 2014) under investigation.

The observed significantly higher pH in the wet season could be due to the influx of alkaline substances from the catchment by the rains, while variations in activities (industrial, agricultural and other municipal activities) could cause a variation in surface water pH between s (Jafari and Gunale, 2006).

Brewery effluents have also been reported to have an alkaline pH and high total alkalinity values (Adebayo *et al*., 2007; Alao *et al*., 2010; Inyang 2012; Olowu *et al*., 2012). The brewing process includes the addition of some alkaline substances like caustic soda (Bokulich and Bamforth, 2013), some of which may be discharged in the effluent thereby making the pH of the receiving water alkaline and increasing its total alkalinity. The findings of Olorode and Fagade (2012) are contrary to the findings of this study. They observed an acid pH for effluents from a brewing factory. Partial treatment of the wastewater before its discharge could be the reason for the observed variation.

Total alkalinity provides information on the acid neutralizing capacity of the water body. The inflow of acidic substances during the wet season from surface runoff, or from the atmosphere could be the reason for the significantly lower total alkalinity observed in the wet season (Meays and Nordin, 2013). Simple dilutions of alkaline substances (carbonates and bicarbonates of calcium and magnesium) by rain water or concentration of such substances during the extensive dry season (lasting about 6 months) could be other reasons for such seasonal variation (Rahman *et al*., 2014). Variations in activities (industrial, agricultural and other municipal activities) that release carbonates and bicarbonates could cause a variation in surface water total alkalinity between stations.

Discharges from the industries, residential and agricultural areas may be the main reason for the significantly higher electrical conductivity and total dissolved solids on sampling stations on the Makera and Tudun Wada drains. These activities have been implicated to introduce pollutants which dissociate into ions in water (Dadi-Mamud *et al*., 2012). Electrical conductivity is the measure of electricity conducting ions (both anions and cations such as ions of hydrogen, nitrates, phosphates, sodium, chlorides) in a water body (Meays and Nordin, 2013). TDS is basically the sum of all minerals, metals, and salts dissolved in the water. These include carbonate, bicarbonate, chloride, fluoride, sulphate, phosphate, nitrate, calcium, magnesium, sodium, and potassium, but other ions dissolved in the water could also contribute to the total dissolved solids observed (Sigler and Bauder, 2015). In addition, soil organic matter compounds such as humic/fulvic acids are also vital components of TDS (Meays and Nordin, 2013).

The significantly higher concentrations of sulphate recorded on the Makera drain may be as a result of the industrial processes in Makera. Industrial areas have been reported to have sulphate concentrations compared to residential areas (Rajasulochana *et al*., 2009; Chukwu *et al*., 2012; Chowdhury *et al*., 2013).

Sulphate occurs naturally in the aquatic environment or it may have an anthropogenic origin as a salt of calcium, iron, sodium, or magnesium (Guerts, *et al*., 2012; Maeys and Nordin, 2013). When sulphate naturally occurs in aquatic environments, it could be the result of the decomposition of leaves, atmospheric deposition, or the weathering of certain geologic formations including pyrite (iron disulfide) and gypsum (calcium sulphate)(Government of Saskatchewan, 2007). Anthropogenic sources of sulphates and sulphuric acid products are used in the production of fertilizers, chemicals, dyes, glass, paper, soaps, textiles, fungicides, insecticides, astringents and emetics. They are also used in the mining, wood pulp, metal and plating industries, in sewage treatment and in leather processing. Aluminium sulphate (alum) is used as a sedimentation agent in the treatment of drinking-water. Copper sulphate has been used for the control of algae in raw and public water supplies (WHO, 2006).

The observed mean Dissolved Oxygen concentration of less than 2 mg/L is considered lower than the requirement for biological activities (WHO, 2006). Polluted waters have been known to be of low DO due to demand of aerobic bacteria (BOD) and oxidative processes of chemical species (COD) in the process of ultra-filtration (Chukwu *et al.*, 2012; Rahman *et al.*, 2014). Other important factors that control the dynamics in the concentration of surface water DO include water temperature, atmospheric pressure, photosynthetic activities of algae and aquatic macrophytes (Maeys and Nordin, 2013).

The lack of significant variation in BOD among the sampling stations could be explained by the reason that organic pollutants from stations on the drains are washed down by water current to less polluted stations on River Kaduna, thereby increasing the level of the pollutants downstream and consequently the BOD. It is well documented in literature that low polluted stations are usually contaminated by highly polluted upstream stations of the same water system (Bere and Tundisi, 2011a; Hassan *et al*., 2014b).

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The significantly higher BOD concentration observed in the wet season may be attributed to the inflow of organic pollutants along with surface run-off during the wet season and increase in water residency time during the dry season could increase the rate of water purification by algae and aerobic bacteria, thus improving water quality by the reduction of BOD.

All the sampling stations were observed to be enriched with nutrients (PO_4-P, NO_3-N, TN and TP). Potapova and Charles (2005) classified water bodies of TN concentration of greater than or equal to 3 mg/L to be of high TN while concentration of TP greater than or equal to 0.1 mg/L to be of high TP concentration. Effluents from residential areas, markets, industries, as well as surface run-off from urban areas and agricultural areas may be implicated to the high concentration of nutrients observed in sampling stations. These nutrients are vital components of many waste products of biological and chemical processes (Chia *et al*., 2013). Phosphorus can be introduced into the environment in the form of phosphoric acid, phosphate fertilizers, phospholipids in death tissues while nitrogen can be introduced in the form of urea and nitrate fertilizers, urine and other forms (Auro and Cochlan, 2013).

The grouping of sampling stations on each of the drains together and all the stations on River Kaduna gives a strong indication that the water quality of the sampling stations is greatly influenced by the activities around the station. This grouping separates highly polluted sites on the drains whose water quality is altered by discharges from industries, urban markets, and residential areas, influence the less polluted sites on River Kaduna, in addition to the contributions from agricultural activities and depositions from other drains. It is also well documented that catchment activities are the most prominent determinants of water quality in a water body (Pace *et al*., 2012; Lar, 2013).

5.2 Substrate Preferences of Periphytic Algae and its mplication on Water Quality Analysis

Autecological study of the periphyton through indicator species analysis showed the preference of most algae species (23) to the epilithic microhabitat. The reason may be that it provides the most favourable environment for their growth. The next most preferred is the epipelic microhabitat with 22 species. These findings agree with those of Potapova and Charles (2005).

The synecology of periphytic algae however puts the epipelic microhabitat as the most preferred microhabitat because of the higher values of species evenness and Shanon-Weinner diversity index as compared to the epilithic, episamic, epiphytic and epidendric subtrates.

Periphytic algal autecology and synecology showed that the periphyton in the TudunWada-Makera-River Kaduna have substrate preferences at an individual and community level. These preferences may be attributed to differences in texture and chemical composition as well as the positioning of the substrate in relation to the direction of water current of the water body (Potapova and Charles, 2003). Secondly, each algal species has a specific microhabitat requirement which may be provided by a specific kind of substrate, thus influencing the abundance, diversity and the community structure of algae growing on it. The findings of this study corroborate the findings by a number of researchers (Lowe and Gale, 1980; Round, 1991; Potapova and Charles, 2003; Cejudo-Figueiras *et al*., 2010; Bere and Tundisi, 2011a).

Since algae species show preferences, the absence of a particular substrate in a sampling station may lead to the absence of a particular species of algae thereby leading to an erroneous interpretation of water quality by the assumption that the absence may be due to anthropogenic activities.

According to Potapova and Charles (2005), the influence of substrate type on algal assemblage is more important than water quality status in small-scale studies (covering a single water body or uniform geographical area). In large-scale studies (covering several eco-regions and water bodies) the effect of substrate type is more difficult to detect because it is overridden by the influence of differences in hydrology, physical habitat, and the chemistry between streams (Soinnen and Eloranta, 2004).

The grouping of epilithic and epipelic algal community by cluster analysis is an indicator of high similarity in their species composition and this could lead to a cautious empirical inference that the substrates may be of similar chemical composition (Bere and Tundisi, 2011b). The fact that the epiphytic and epidendric microhabitats are both of plant material but only separated by the fact that the epiphytic microhabitat has life while the epidendric is dead may be the reason for the similarity.

5.3 Distribution of Algae Species in Sampling stations

Pollution tolerant species were observed to have the highest indicator species value on the drains. Most of them are observed to be members of the Bacillariophyta, cyanbacteria and euglenophyta. Indicator species of the Makera drain which is primarily modified by effluent from a brewing industry and secondarily by discharges from residential areas include *Achnanthes hungarica, Aulacoseira ambigua, Epithemia* sp., *Gyrosigma* sp., *Melosira calognosa, Melosira sulcata, Melosira* sp., *Sirurella augusta, Oscillatoria limosa* and *Botryococcus* sp. Reynolds (2006) classified *Aulacoseira ambigua*, as an indicator of eutrophic waters.

The species indicative of the water quality on the Tudun Wada drain which is modified mainly by effluents from the Kaduna Central Market and residential areas in Tudun Wada included *Nitzchia* sp., *Nostoc* sp., *Oscillatoria brevis, Oscillatoria tenuis* and *Euglena* sp. Species of *Nitzchia*, *Oscillatoria* and *Euglena* have been reported to have high tolerance for organic pollution (Bere and Tundisi, 2011a and b; Hosmani, 2013).

Species indicative of water quality in the low polluted stations on River Kaduna which is mainly influenced by the agricultural activities by its banks as well as several discharges from so many other drains include *Anomoneis* sp., *Aulacoseira granulata, Coconeis placentula, Frustulia rhomboides, Gyrosigma accumunata, Melosira distans, Pinnularia viridis, Synedra ulna, Coelastrum* all species of *Closterium* and *Scenedesmus, Staurastrum* sp., *Merismopedia glaucau, M. elegans amd Oscillatoria lacustris* . Rawson (1956), classified *Aulacoseira granulata*, to be an indicator of oligotrophic water while Bere and Tundisi (2011a) classified *Synedra ulna* as an indicator of highly polluted waters. The contradiction observed in the case of *Synedra ulna* could be due to the variation in ecological characteristics displayed by the species from one region of the world to another. Salmoni *et al*. (2011) observed similar variations for *Gomphonema parvalum* from Brazil and Japan.

Comment [MaC21]: Don't be repeating what is already in the results section. You can only write this here if you are directly comparing them with what has already been published, or has not been published. Try to show how different your finding is.

The tolerant species have been reported to be associated with waters with relatively high nutrient load, low dissolved oxygen, high ionic strength and electrical conductivity (Doung *et al*. 2006). It is also well documented that algae species are usually indicative of the upper limits of the pollution that they can tolerate and not the lower limit (Lange-Bertalot, 1979; Biggs and Kilroy, 2000; Bere and Tundisi, 2011b and Salmaso *et al*., 2014). This implies that species that develop well in polluted zones may also be found in clean waters. The grouping of sampling stations with similar water quality by cluster analysis and non-metric multidimensional scaling supports the already known fact that the distribution and abundance of algae are majorly determined by water quality, and gives credence to their use as water quality indicators. Several workers have used these tools to determine the relationship between algae and water quality in sampling stations, streams, rivers and ecoregions (Hassan, 2014b; Rahman *et al.*, 2014).

Comment [MaC22]: Did any of these authors report any of the species you listed above? If yes, then compare with the species listed above.

The community structure of algae along the sampling stations seems to be driven majorly by two anthropogenic factors: surface water physico-chemical characteristics and physical anthropogenic disturbances observed in the vicinity of the water body such as cultivation, excavation of soil and scavenging, fishing and laundry. Stations on the Tudun wada drain and those impacted by it on the River Kaduna were observed to show comparably low species evenness and diversity, and high species dominance possibly due to the high physical disturbances posed by anthropogenic activities in the sites. Conversely sampling stations on the Makera drain and the stations it impacts on the River Kaduna were observed to have generally higher species evenness and diversity and low species dominance even though the pollution level was higher. The reason for this ‘anomaly’ may be due to the reason that the foul odour produced by the wastewater in the Makera drain discourages human contact activities along the vicinity of the drain thereby reducing physical disturbances that may arise from such activities and consequently providing the needed stability for the algal community to flourish (Li *et al.*, 2010).

Comment [MaC23]: This was not measured.

5.4 Relationship among Surface Water Physico-chemical Characteristics and With Sampling Stations

The drivers of water quality in the study area are EC, TDS, pH, TA, TH, SO_4, BOD, DO and surface water temperature. This is because of their being extracted by the Principal Component Analysis to be significant in the first and second axis. These factors also clearly separate the sampling stations into four distinct groups; stations on the Makera drain in one group; stations on the Tudun Wada drain on another; stations on River Kaduna impacted by the Makera drain on another group, while stations on River Kaduna impacted by the Tudun wada drain grouped together. These groupings once again reaffirm the importance of these parameters as the drivers of water quality as observed by so many other researchers (Rahman *et al*., 2014).

The observed significant positive association between pH, BOD, surface water temperature, sulphate, PO_4-P and NO_3-N with the stations on the Makera drain could be attributed to the inflow of substances that increase the values of these parameters by the activities going on around the stations. The negative association between these parameters with sampling stations on the tudun Wada drain gives credence to this position.

The positive association between DO and sampling stations on the River Kaduna could be attributed to increased oxygen surplus between production by photosynthesis and demand from aerobic bacteria and oxidisable chemical pollutants because of low pollution in such stations. Low polluted sites and water bodies have been associated with comparable higher oxygen concentration.

5.5 Relationship among surface water physico-chemical characteristics, algae species and sampling stations

Canonical correspondence analysis triplot of periphyton, surface water physico-chemical and sampling stations clearly separates periphyton species into two major groups. The first comprise of species that are positively associated with EC, TDS, Total alkalinity and BOD such as *Aulacoseira ambigua*, *Euglena* sp., *Oscillatoria brevis and Sirurella ovalis*. Species that positively associated with these parameters have been shown to be tolerant to organic pollution and eutrophication (Kshirsagar, 2013; Hosmani, 2013; Wilson *et al*., 2014; Beyer *et al*., 2014).

The second group which comprise of *Aulacoseira granulata*, *Closterium* sp., *Navicula cuspidata, Nitzchia* sp., *Oscillatoria limosa, Botryococcus* sp., *Cymbella cistula, Synedra ulna, Cosmarium marigatum and C. nudum* could be considered indicators of low pollution because of their negative association with this factors total alkalinity, TDS, EC, BOD, NO_3-N, total nitrogen, pH and PO_4-P (Jafari and Gunale, 2006).

The significant positive association observed between Surface water temperature, TDS, EC, total alkalinity, total nitrogen, BOD, SO_4, pH, PO_4-P, NO_3-N with Oscillatoria *brevis and Nostoc* sp., in the CCA for the phytoplankton species, surface water physico-chemical characteristics and sampling stations, categorise these species as indicators of pollution.

On the other hand, the grouping of all the sampling stations in this study, together with specific phytoplankton species strongly suggests that the water quality in these sampling stations may not be chiefly responsible for the distribution of all the phytoplankton species as some of them may have a wide tolerance range for pollution.

Comment [MaC24]: Contradictory… Revise sentence.

CHAPTER SIX

6.0 CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

1) The physico-chemical characteristics (temperature, pH, electrical conductivity, total dissolved solids, total hardness, total alkalinity, sulphate, dissolved oxygen and biochemical oxygen demand and phosphate-phosphorus) of surface water in the Tudun Wada-Makera drains-River Kaduna varied significantly along pollution gradient in the sampling stations. Sampling stations receiving pollutants from industries, residential areas, urban runoff and market were observed to be more polluted than those on River Kaduna, which is majorly influenced by agricultural activities and inflow of wastewater from so many other drains.

2) Periphytic algal autecology (indicator species) showed that most algal species prefer epilithic substrate, while the synecology (community structure) demonstrates that the epilithic substrate has greater species diversity and evenness, low species dominance.

Comment [MaC25]: Redundant.

3) The algal species observed were indicative of the variation in water quality status observed in the Tudun Wada-Makera drains-River Kaduna. Indicator species of the Makera drain include *Achnanthes hungarica, Aulacoseira ambigua, Epithemia* sp., *Gyrosigma* sp., *Melosira calognosa, Melosira sulcata, Melosira* sp., *Sirurella augusta, Oscillatoria limosa* and *Botryococcus* sp. Those of the Tudun Wada drain are *Nitzchia* sp., *Nostoc* sp., *Oscillatoria brevis, Oscillatoria tenuis* and *Euglena* sp., while those of the stations on River Kaduna include *Anomoneis* sp., *Aulacoseira granulata, Coconeis*

Comment [MaC26]: Write name of genus in full.

placentula, Frustulia rhomboides, Gyrosigma accumunata, Melosira distans, Pinnularia viridis, Synedra ulna, Coelastrum, all species of *Closterium,* all species of *Scenedesmus, Staurastrum* sp., *Merismopedia glaucau, Merismopedia elegans amd Oscillatoria lacustris.*

Non-metric Multidimensional Scaling (NMDS) and Cluster analysis using algal populations were successful in separating highly polluted sites from low polluted in a manner in which it groups them together or separate them in distance. While the diversity indices unraveled that the community of algae in the Tudun Wada Makera drains-River Kaduna is affected both by water quality and the activities causing physical disturbances in the vicinity of the water bodies.

4) Principal component analysis was useful in showing that the drivers of water quality in the study area are EC, TDS, pH, TA, TH, SO_4, BOD, DO and surface water temperature. It also revealed significant positive relationships among surface water physico-chemical parameters such as temperature, EC, TDS, TN, TP, TA, and TH, and among pH, NO_3-N, PO_4-P, SO_4, and BOD. EC, TDS, pH, TA, TH, SO_4, BOD, DO and surface water temperature were also positively associated with sampling stations on the Makera drains. DO was observed to positively associated with low polluted station on River Kaduna and negatively associated with EC, TDS, TN, TP, TA, and TH.

Comment [MaC27]: Replace word throughout this paragraph with between.

5) Significant positive association of EC, TDS, Total alkalinity and BOD with species such as *Aulacoseira ambigua, Euglena* sp., *Oscillatoria brevis and Sirurella ovalis* was observed. While significant negative association was observed between *Aulacoseira granulata, Closterium* sp., *Navicula cuspidate, Nitzchia* sp., *Oscillatoria limosa,*

Botryococcus sp., *Cymbella cistula, Synedra ulna, Cosmarium marigatum and C. nudum* with EC, TDS, TN, TP, TA, and TH.

Comment [MaC28]: Rephrase. Sentence is wrong. And attempt to connect with previous sentence.

6.2 Recommendations

Baseds on the findings of this work, recommendations are made thus:

a) the regulation of domestic, industrial and municipal discharges into surface water in the study area to ensure that the discharges fall within the acceptable limits.

Comment [MaC29]: Specify the nature of these discharges.

b) the combined use of epilithic and epipelic algal communities for water quality analysis.

c) The use of algae-based indices developed from other parts of the world should be applied in Nigeria with caution because of the differences species adaptations in different geographical locations and ecological differences.

d) Further studies on the determination of indicator species at a broader scale within and across ecological zones in Nigeria to establish a local indicator species assemblage in the various ecological zones the country at large should be pursued.

Comment [MaC30]: Rephrase.

References

Abagai, R. T., Tiseer F. A., Balarabe M. L., Tanimu Y. and Tanko, D. (2011) Seasonal Survey of Phytoplankton as Biondicators of Water Quality in the Streams of Kagoro Forest, Kaduna. State Northern Nigeria. Order of Proceedings of the 2011 International Symposium on Environmental Science and Technology, Dongguan, Guangdong Province, China June 1–4, 2011, pp 37-41.

Adakole, J. A. and Joshua, I.A. (2002). Phytoplankton as indicators of pollution of an urban stream, Zaria, Nigeria. *Bioscience Research Communication*, **15 (6)**:521-526.

Adakole, J.A., Mbah, C.C., and Dalla, M.A. (2003). Physico-chemical Limnology of Lake Kubanni, Zaria. Nigeria. *Proceedings of the 29th Water, Engineering and Development Centre UK (WEDC) International Conference held in Abuja, Nigeria. Published by WEDC, London.* Pp 165-168.

Adakole J.A, Abolude, D.S. and Balarabe, M.L. (2008). Assessment of Water Quality of a Man-Made Lake in Zaria, Nigeria. *Proceedings of Taal 2007: 12th World Lake Conference. Published by Ministry of Environment and Forests, India and International Lake Environment Committee Foundation (ILEC)* 1373-1382.

Adebayo, O. T., Balogun, A. M. and Olubiyi, O. A. (2007). Chemical analysis of some industrial effluents that discharge into Lagos Lagoon, Nigeria. *Research Journal of Environmental Sciences*, **1**(4):196-199.

Adebegbenro, A. O. (1970). Investigation on the seasonal changes in the phytoplankton of the NTC Lakes. BSc. Project, Department of Biological sciences, Ahmadu bello University, Zaria. 170pp.

Adeyemo, O. K., Ayodeji, I. O. and Aiki-Jaji, C. O. (2002). The water quality and sanitary conditions in a major abattoir (Bodija) in Ibadan, Nigeria. *African Journal of Biomedical Research*, **5**:51-55.

Aidar, E. and Sigand, T.C.S. (1993). The effects of chemicals on marine phytoplankton: is predation possible? In Cordeiro-marino, M., Azevedo, M.T.P., Sant'anna, C.L.,Tomita, N.Y. and Pastino, E.M. (Eds.). *Algae and environment*: a general approach. São Paulo: Sociedade Brasileira de Ficologia; CETESB. p. 65-82.

Alao O., Arojojoye, O., Ogunlaja, O., Famuyiwa, A. (2010). Impact assesment of brewery effluent on water quality in Majawe, Ibadan, Southwestern Nigeria. *Researcher*, **2**(5):21-28.

Ambrose, R.B., Martin, J. L., Wool, T. A. (2006).*WASP7 Benthic Algae -Model Theory and User's Guide Supplement to Water Quality Analysis Simulation Program (WASP) User Documentation.* Published by the U.S. Environmental Protection Agency Office of Research and Development Washington, pp26.

Ansari, A. A., Trivedi, S., Saggu, S. and Rehman, H. (2014). Mudskipper: A biological indicator for environmental monitoring and assessment of coastal waters. *Journal of Entomology and Zoology Studies*, **2**(6):22-33.

Anyam, R. W. (1980). Some aspects of the freshwater ecology of two man-made lakes near Zaria. Unpublished M. Sc. Theses, department of Biological Sciences, Ahmadu Bello University, Zaria. 110 Pp .

APHA (2005). Standard Methods for the Examination of Water and Wastewater. Published by the American Public Health Association, American Water Works Association, Water Environment Federation, Denver, USA. Dubuque, Iowa. Pp. 1287.

Auro, M. E. and Cochlan, P. C. (2013). Nitrogen utilization and toxin production by two diatoms of the pseudo-nitzschia pseudodelicatissima complex: *P. cuspidata* and *P.* fryxelliana. *Journal of Phycology*, **49**: 156–169.

Bako, S.P., Ezealor, A. U. and Tanimu, Y. (2014). Heavy Metal Deposition in Soils and Plants Impacted by Anthropogenic Modification of Two Sites in the Sudan Savanna of North Western Nigeria. In: Sariano, M. A. H. (Ed) *Environmental Risk Assessment of Soil Contamination*. InTech, Croatia. DOI: 10.5772/57299. Available from: http://www.intechopen.com/books/environmental-risk-assessment-of-soil-contamination/heavy-metal-deposition-in-soils-and-plants-impacted-by-anthropogenic-modification-of-two-sites-in-th

Barinova, S. Tavassi, M. Glassman, H. And Nevo, E. (2010). algal indication of pollution in the lower Jordan River, Israel. *Applied Ecology And Environmental Research*, **8**(1): 19-38.

Bere, T. (2007). The assessment of nutrient loading and retention in the upper segment of the Chinyika River, Harare: implications for eutrophication control. *Water SA*, **33**(2): 279-284.

Bere, T. (2011). The Diatom assemblages as indicator of field and lab conditions in lotic systems: conservation and water quality management in Sao Carlos SP catchhment, Brazil. pHD Dessertation Submitted to the Department of Biological Science, Federal University of Sao Carlos, Brazil. 221pp.

Bere, T. and Tundisi, J.G. (2011a). Influence of land-use patterns on benthic diatom communities and water quality in the tropical Monjolinho hydrological basin, São Carlos-SP, Brazil. *Water SA*, **37** (1):93-103.

Bere, T. and Tundisi, J.G. (2011b). Diatom-based water quality assessment in streams influence by urban pollution: effects of natural and two selected artificial substrates, Sao Carlos-SP, Brazil. *Brazilian Journal of aquatic Science and Technology*, **15** (1):54-63.

Bere, T. Phiri, C., Kadye, W. T. and Utete, B. (2013). Benthic diatom assemblages in mountain streams: community structure in relation to environmental and human pressures. *African Journal of Ecology*, doi: 10.1111/aje.12078.

Beyer, J., Petersen, K., Song, Y., Ruus, A., Grung, M., Bakke, T. and Tollefsen, K. E. (2014). Environmental risk assessment of combined effects in aquatic ecotoxicology: a discussion paper. *Marine Enviromental Research*, **96**:81-91.

Biggs, B.J.F. and Kilroy, C. (2000) Stream Periphyton Monitoring Manual. Published by NIWA, Christchurch, New Zealand Pp 246.

Bokulich, N. A. and Bamforth, C. W. (2013). The Microbiology of Malting and Brewing. *Microbiology and Molecular Biology Reviews* **77**(2): 157–172.

Botkin, D.B. and Keller, E.A. (1998). *Environmental Science*. John Wiley and Sons Inc. Canada. P 420.

Brabets, T.P. and Ourso, R. T. (2013).*Water Quality of Streams Draining Abandoned and Reclaimed Mined Lands in the Kantishna Hills Area, Denali National Park and Preserve, Alaska, 2008–11*. Published by the U.S. Geological Survey, Reston, Virginia, USA.pp84.

Cejudo-Figueiras, C., Avarez-Blanco, I., Becares, E. and Blanco, S. (2010). Epiphytic diatoms of shallow lakes: the neutral substrate hypothesis revised. *Marine and Freshwater Rsearch*, **61**:1457-1467.

Cheesbrough, M. (2000). District laboratory practice in tropical countries, part ii.Cambridge University press, Cambridge, Iimited Kingdom. 432pp.

Charles, D.F., Knowles, C, and Davis, R.S. (2002). Protocol for the analysis of algal samples collected as part of the U.S. Geological Survey National Water Quality Assessment Program. Published by the Academy of Natural Sciences, Philadelphia, USA. Pp 132.

Chia, A.M and Bako, S.P. (2008). Seasonal Variation of Cyanobacteria in Relation to Physico-chemical Parameters of some Fresh Water Ecosystems in the Nigerian Guinea Savanna. *Proceedings of Taal 2007: 12th World Lake*

*Conference, Published by Ministry of Environment and Forests, India and International Lake Environment Committee Foundation (ILEC). P*p.1383-1387

Chia A.M., Bako SP, Alonge S. O., Adamu A.K. (2011a). Records of Diatoms and Physico-chemical Parameters of Seasonal Ponds in Zaria- Northern Nigeria. *West African Journal of Applied Ecology*, **18**: 79-83.

Chia A.M., Bako SP, Alonge S, Adamu AK (2011b) Green algal interactions with physico-chemical parameters of some manmade ponds in Zaria, northern Nigeria. *Revista Brasilia Botanica, 34*:285–295.

Chia, A.M., Lombardi, A. T., Melão, M. G. and Parris, C.C. (2013). Lipid composition of Chlorella vulgaris (Trebouxiophyceae) as a function of different cadmium and phosphate concentrations. *Aquatic Toxicology,* **128– 129**: 171– 182.

Chindah, A.C. and Braide, S.A. (2004). The physico-chemical quality and phytoplankton community of tropical waters: a case of 4 biotopes in the lower Bonny River, Niger Delta, Nigeria. *Caderno de Pesquisa Serie Biologia*, **16**: 7-35.

Chisti, Y. (2007). Biodiesel from microalgae. *Biotechnology advances*, **25**:294-306.

Chowdhury, M., Mostafa, M.G., Biswas. T.K. and Saha, A.K. (2013) Treatment of leather industrial effluents by filtration and coagulation processes. *Water Resources and Industry*, **3**: 11–22.

Chukwu U.J., Kalagbor I.A. and Oyiborhoro B. (2012). Impact of Industrial Effluents on the Physico-chemical Properties and Some Trace Metals on Effuruntor River in Uhegheli South Lga of Delta State Nigeria. *Journal of Applied Sciences in Environmental Sanitation*, **7** (4): 275-280.

Cohn, F. (1853). Uber lebende Organismen im Trinkwasser. Z. klein. *Medizin*, **4**: 229–237.

Cohn, F. (1870). Uber den Brunnenfaden (*Crenothrix polyspora*) mit Bemerkungen uber die mikroskopische Analyse des Brunnenwassers. *Cohn's Beitrage zur Biologie der Pflanzen,* **3**: 1–108.

Cook, M.C., Vardaka, E. And Laranas, T.(2004). Toxic cyanobacteria in Greek fresh waters, 1987-2000: Occurrence, toxicity and impacts in the mediteranean. *Acta hydrochimica et hydrobiologica*, **32**(2): 107- 124.

Coring, E., Schneider, S., Hamm, A., and Hofmann, G. (1999). Durchgehendes Trophiesystem auf der Grundlage der Trophieindikation mit Kieselalgen. D*VWK Materialien,* **6**: 1–219.

Dadi-Mamud N. J, Oniye, S.J, Balarabe M.L., Auta J., Gudugi, I.A.S (2012) Toxicological Implications of Polluted Water from Makera Drain, Kaduna on Some Cereals and Horticultural Crops. *Mediterranean Journal of Social Sciences,* **3** (16): 180-185.

De La Rey, P., Roux, H., Rensburgl, L. Van and Vosloo, A. (2008). On the use of diatom-based biological monitoring Part 2: A comparison of the response of sass 5 and diatom indices to water quality and habitat variation). *Water SA*, **34**(1): 61-69.

Descy, J.P. (1979). A new approach to water quality estimation using diatoms. *Nova Hedwigia*, **64**(4): 305-323.

Dresscher, T.G.N., Van der Mark, H., (1976). A simplified method for the biological assessment of the quality of fresh and slightly brackish water. *Hydrobiologia,* **48**: 199–201.

Dufrene, M. and Lagendre, P. (1997). Species Assemblages and Indicator Species: The Need for a Flexible Asymmetrical Approach. *Ecological Monographs*, **67** (3): 345-366.

Doung, T.T., Coste, M., Feurtet-Mazel, A., Dang, D., Gold, C., Park, Y. and Boudou, A. (2006). Impact of Urban Pollution from the Hanoi Area on Benthic Diatom Communities Collected from the Red, Nhue and Tolich Rivers (Vietnam). *Hydrobiologia*, **563**(3): 201-216.

Ebuehi, E. O. A. (1988). Some aspects of the ecology of suspended algae in four ponds in Zaria. Unpublished M. Sc. Theses, department of Biological Sciences, Ahmadu Bello University, Zaria. Pp 170.

EPA/QPWS (1999).Water Quality Assessment. Retrieved June, 22, 2009 from http://www.epa.qld.gov.au/environment-management/water-quality-monitoring/assessing.

Ezra, A. G. (2007) Studies on Some Diatoms from Gubi Reservoir, Bauchi, Nigeria. *African Journal of Natural Sciences*, **10:** 7-10.

Ezra, A.G. and Nwankwo (2001). Composition of Phytoplankton Algae in Gubi Reservoir, Bauchi, Nigeria. *Journal of Aquatic Science,* **16** (2):115-118.

Fakayode, S.O. (2005). Impact Assessment of Industrial effluent on Water Quality of the Receiving Alaro River in Ibadan, NIgeria, *AJEAM-RAGEE*, **10**:1-13.

Fan, M. And Shibata, H. (2015). Simulation of watershed hydrology and stream quality under land use and climate change scenerios in Teshio river watershed, northern Japan. *Ecological indicators,* **50**:79-89.

Felfoldy, L. (1987). Abiologiai vizminosites (Biological water quality evaluation). Vizugyi Hidrobiologia 16. VGI, Budapest.

Friberg, N. (2014).Impacts and indicators of change in lotic ecosystems. *WIREs Water*, **1**:513–531.

Gara, B. D. and Stapanian, M. A. (2015). A candidate vegetative index of biological integrity based on species dominance and habitat fidelity. *Ecological Indicators*, **50**:225-232.

Geurts, J.J.M., Sarneel, J.M., Willers, B.J.C., Roelofs, J. G.M., Verhoeven, J. T.A. and Lamers, L. P.M. (2009). Interacting effects of sulphate pollution, sulphide toxicity and eutrophication on vegetation development in fens: A mesocosm experiment. *Environmental Pollution,* **157**: 2072–2081.

Government of Saskatchewan (2007). Suilphate. www.SaskH20.ca

Gupta, P.K., Nagdali, S.S., Tewari, P., Singh, N. and Gupta, R. (2008). Water Chemistry of a National Lake of India: Lake Nainital Uttarakhand. *Proceedings of Taal 2007: 12th World Lake Conference. Published by Ministry of Environment and Forests, India and International Lake Environment Committee Foundation (ILEC)*. pp 209-216.

Guo, Q., Ma, K., Yang, L., Cai, Q. and He, K. (2010). A comparative study of the impact of species composition on a freshwater phytoplankton community using two contrasting biotic indices. *Ecological Indicators* **10**: 296–302

Hamzah, A. and Hattasrul, Y. (2008). Water Quality and Bacterial Study in Tasikchini, Pahang. Proceedings of Taal 2007: 12th World Lake Conference. *Published by Ministry of Environment and Forests, India and International Lake Environment Committee Foundation (ILEC). Pp* 184-189.

Hassan, F. M., Salman, J. M., Al-Azawey, S. N. Al-Ansari, N. and Kutsson, S. (2014a). Quality, quantity and origin of PAHs (Polycyclic Aromatic Hydrocarbons) in lotic ecosystem of Al-Hilla River, Iraq. *Journal of Civil Engineering and Architecture*, **8** (8):1026-1038.

Hassan, F.M., Salman, J.M. and Abdulameer (2014b). Seasonal variation of environmental properties and phytoplankton community in Al-Hussainya River, Holly Karbala-Iraq *Mesopotamia Environmental Journal*, **1**:56-82.

Heinonen, P. (1980). Quantity and composition of phytoplankton in Finish inland waters. Publications of the Water Research Institute 37, Vesihallitus-National Board of Waters, Finland.

Hellawell, J.M. (1986). Biological indicators of freshwater pollution and environmental management.Elsevier Applied Science, London.

Herring, D. (2008). What are phytoplankton. http://earthobservatory.nasa.gov/library/phytoplankton2.

Hosmani, S. P. (2013). Fresh Water algae as indicators of water quality. *Universal Journal of Environmental Science and Technology,* **3** (4): 473-482.

Ibrahim, S. and Abdullahi, B.A. (2009). A Survey of Phytoplankton and Evaluation of some Physico-chemical Properties of Challawa River, Kano State, Nigeria. *Best Journal*, **6** (1):76-82.

Imevbore, A. M. A. (1960). Planktonic algae of Eleiyele reservoir. *Nigerian Journal of Science*, **2**: 85-90.

Inyang, U. E., Bassey, E. N. and Inyang, J. D. (2012). Characterization of brewery effluent fluid. *Journal of Engineering and Applied Sciences*, **4**: 67-77.

Jafari, N.G. and Gunale, V. R. (2006). Hydrobiological study of algae of an urban freshwater river. *Journal of applied Science, Environment and Management*, **10** (2): 153-158.

Jaweir, H. J., Salman, J. M. And Abaid, Z. H. (2014). Spatial and temporal distribution of benthic oligochaete in Euphrates river, middle of Iraq. *Mesopotamia Environmental Journal,* **1**(1):1-6.

John, J. (2000). *Diatom prediction and classification system for urban streams*. Canberra: Land and Water Resources Research and Development Corporation.pp250.

Joshi, M., Bakre, P.P.and Bhatnagar, P. (2013). Avian guano: A non-destructive biomonitoring tool for organic pollutants in Environment. *Ecological Indicators,* **24**: 284–286.

Kadiri, M.O. (1996). More desmids from the Ikpoba Reservoir, Nigeria:Comparison with other African records. *Algological Studies,* **80**: 87 - 98.

Karr, J.R. (1991). Biological integrity: a long-neglected aspect of water resource management. *Ecological Applications*, **1**(1): 66-84.

Kedar, G.T., Patil, G.P. and Yeole, S.M. (2005). Effect of Physico-chemical Factors on the Seasonal Abundance of Zooplankton Population in Rishi Lake. *Proceedings of Taal 2007: 12th World Lake Conference, Published by Ministry of Environment and Forests, India and International Lake Environment Committee Foundation (ILEC). P*p. 88-91.

Kelly, M. G. and Whitton, B. A. (1995). The tropic diatom index: a new index for monitoring eutrophication in rivers. *Journal of Applied Phycology*, **7**: 433-444. http://dx.doi. org/10.1007/BF00003802.

Kelly, M.G. (1996). The trophic diatom index. Bowburn Consultancy, R&D Technical Report E2, 1–148.

Kelman, D., Posner, E. K., McDermid, K. J., Tabandera, N. K., Wright, P. R. and Wright, A. D. (2012) Antioxidant Activity of Hawaiian Marine Algae. *Marine Drugs*, **10**:403-416.

Khare, K.C. and Jadva, M.S. (2008). Water Quality Assessment of Katraj Lake, Pune (Maharsshtra, India): A Case Study. *Proceedings of Taal 2007: 12th World Lake Conference, Published by Ministry of Environment and Forests, India and International Lake Environment Committee Foundation (ILEC.) P*p. 292-299.

Knopp, H., (1954). Ein neuer Weg zur Darstellung biologischer Vorfluteruntersuchungen, erlautert an einem Gutelangsschnitt des Mains. *Wasserwirtschaft*, **45**: 9–15.

Kobayasi, H. and Mayama, S. (1989). Evaluation of river water quality by diatoms. *The Korean Journal of Phicology*, **4** (2): 121-133.

Kolkwitz, R. and Marsson, M., (1902). Grundsatze fur die biologische Beurteilung des Wassers nach seiner Flora und Fauna, *Mitteilungen der Prufungsanstalt fur Wasserversorgung und Abwasserreinigung*, **1**: 33–72.

Kolkwitz, R. and Marsson, M., (1909). Okologie der tierischen Saprobien. *Internationale Revue der gesamten Hydrobiologie*, **2**: 126–152.

Kshirsagar, A. D. (2013). Use of algae as a bioindicator to determine water quality of River Mula from Pune city, Maharashtra (India). *Universal Journal of Environmental Research and Technology*, **3** (1):79-85.

Kummerlin, R., (1990). Plnakton-Gemeinschaften als bioindikatoren fur Stehgewasser. *Okologie & Naturschutz*, **3**: 227–241.

Lange-Bertalot, H. (1979). Pollution tolerance of diatoms as a criterion for water quality estimation. *Nova Hedwigia Beiheft*, **64**(1): 285-304.

Lar, U. A. (2013). Trace elements and health: an environmental risk in Nigeria. *Earth Science*, **2**(3): 66-72.

Lenntech (2008). TDS and Electrical Conductivity. Retrieved March 12, 2008 from www.lenntech.com/Tds_and_electrical_conductivity

Li, L., Zheng, B. and Liu, L.(2010). Biomonitoring and Bioindicators Used for River Ecosystems: Definitions, Approaches and Trends. *Procedia Environmental Sciences*, **2**: 1510–1524.

Linstead, C., Maltby, E. and Moss, B. (2012). Ecosystem-based Indicators for Monitoring the Status of Rivers in Ghana. *West African Journal of Applied Ecology*, **21** (3): 1-10.

Lobo, E.A., Callegaro, V.L., Hermany, G., Bes, D., Wetzel, CE. and Oliveira, M.A. (2004). Use of epilithic diatoms as bioindicator from lotic systems in southern Brazil, with special emphasis on eutrophication. *Acta Limnologica Brasiliensia*, **16**(1): 25-40.

Lobo, E.A., Salomoni, S., Rocha, O. and Callegaro, VL. (2006). Epilithic diatoms as indicatores of water quality in the Gravataí river, Rio Grande do Sul, Brazil. *Hydrobiologia*, **559**, (1-2): 233-246.

Lowe, R. L. and Gale, W.F. (1980). Monitoring of river periphyton with artificial benthic substrates. *Hydrobilogia*, **69**(3): 235-244.

Mahananda, M.R., Mohanty, B.P. and Behera, N.R. (2010). Physico-chemical analysis of surface and ground water of bargarh district, Orissa, India. *IJRRAS*, **2** (3): 285-295.

Mahesha, and Balasubramanian (2008). Hydrogeochemical Studies of Dalvoy Lake Ecosystem of Mysore city, India. *Proceedings of Taal 2007: 12th World Lake Conference:* 337-346.

Maschek, J. A. and Baker, B. J. (2008) The Chemistry of Algal Secondary Metabolism in: ansler, C. D. algal chemical ecology, Springer, Heidelberg, Germany, pp1-20.

Meays, C. and Nordin, R. (2013). Ambient Water Quality Guidelines For Sulphate. Published by Water Protection & Sustainability Branch Environmental Sustainability and Strategic Policy Division BC Ministry of Environment, USA. pp 55.

Mez, C. (1898). Mikroskopische Wasseranalyse. Springer Verlag, Berlin. In: Bere, T. and Tundisi, J.G. (2011b). Diatom-based water quality assessment in streams influence by urban pollution: effects of natural and two selected artificial substrates, Sao Carlos-SP, Brazil. *Brazilian Journal of aquatic Science and Technology*, **15** (1):54-63.

Moulton, S.R., Kennen, J.G., Goldstein, R.M. and Hambrook, J. A. (2002). Revised Protocols for Sampling Algal, Invertebrate, and Fish Communities as Part of the National Water-Quality Assessment Program. Published by the U.S. Geological Survey National Water-Quality Assessment Program, Reston, USA. Pp 87 (http://water.usgs.gov/nawqa/).

Nagare, H. and Tsuno, H. (2005). Phosphorus Budget and Effect of Phosphorus Recovery in Lake Biwa Watershed. *Proceedings of the 11th World Lake Conference, Nairobi Kenya. Published by Ministry of Work and Irrigation, Kenya and International Lake Committee.* Pp 2:356-362.

Nagorski, S. A., Engstrom, D. R., Hudson, J. P., Krabbenhoft, D. P., Hood, E., DeWild, J. F. and Aiken, G. R. (2014).Spatial distribution of mercury in southeastern Alaskan streams influenced by glaciers, wetlands, and salmon. *Environmental Pollution*, **184**: 62-72

Ndama, A. (1970). Algae from polluted situations in the Zaria area. B.Sc Project, Department of Biological Sciences, Ahmadu Bello University, Zaria. Pp35.

Nwankwo, D. I. (1996). Phytoplankton Diversity and Succession in Lagos Lagoon. *Archives of Hydroogia,* **134** (4): 529-542.

Odhiambo, W. and Gichuki, J. (2000). Seasonal Dynamics of the Phytoplankton Community in Relation to Environmental in Lake Baringo, Kenya (Impact on Lake Resource Management). *African Journal of Environmental Studies*, **9** (1&2):1-11.

Olowu, R. A, Osundiya M. O., Onwordi C.T. , Denloye, A. A., Okoro, C. G., Tovide, O. O., Majolagbe, A. O., Omoyeni, O. A. and Moronkola, B. A. (2012) Pollution status of brewery sewage sludge in Lagos, Nigeria. *IJRRAS,* **10** (1):159-165.

Olorode, O. A. and Fagade, O. E. (2012). Comparison between a brewery effluent and its receiving stream in ibadan based on their physico-chemical and microbiological analysis *International Journal of Basic and Applied Science* **1**, (2): 293-299.

Oniye, J.S., Ega, R.A.I., Ajanusi, O.J. and Agbede, R.I.S. (2002). Some Aspects of Physico-Chemical Parameters of Zaria Dam, Nigeria. *Journal of Agric. and Environment.* **3** (2): 367 – 379.

Opute, F. I. and Kadiri, M.O. (2013). *Phytoplankton algae of Nigeria, a practical guide: the desmids.* Mindex publishing company, Lagos, Nigeria. pp. 304.

Pace, G., Bella, V. D., Barile, M, Andreani, P., Mancini, A. L.and Belfiore, C, (2012). A comparison of macroinvertebrate and diatom responses to anthropogenic stress in small sized volcanic siliceous streams of Central Italy (Mediterranean Ecoregion, *Ecological Indicators*, **23**: 544–554.

Palmer, C.M. (1969). A composite rating of algae tolerating organic pollution. *Journal of Phycology*, *5*(1): 78-82.

Pan, Y., Stevenson, R.J., Hill, B.H., Herlihy, A. and Collins (1996) Using diatoms as indicators in the lotic systems: a regional assessment. *Journal of North American Benthological Society*, **15**: 481-495.

Passy S.I. (2007). Diatom ecological guilds display distinct and predictable behaviour along nutrient and disturbance gradients in running waters. *Aquatic Botany*, **86**: 171–178.

Paulose, P.V. and Maheshawr, K. (2008). Seasonal Variation in Zooplankton Community Structure of Ramgiarh Lake, Jaipur, Rajasthan. *Proceedings of Taal 2007: 12th World Lake Conference*, pp. 82-87.

Perry R. (2003). A Guide to the marine plankton of southern California. http://www.msc.ucla.edu/oceanglobe.

Pla, S., Paterson, A. M., Smol1, John P.B., Clark, J., and Ingram, R. (2005) Spatial Variability in Water Quality and Surface Sediment Diatom Assemblages in a Complex Lake Basin:Lake of the Woods, Ontario, Canada. *Journal of the Great Lakes Research*, **31**:253–266.

Plafkin, J.L., Bardour, M.T., Porter, K.D., Gross, S.K., Hughes, R.M. (1989). Rapid bioassessment protocols for use in streams and rivers. Benthic macoinvertrebrates and fish. Report No. EPA/444/4–89–001. US EPA Office of Water (WH-553), Washington DC 20460.

Potapova, M.G. and Charles, D.F. (2002). Benthic diatoms in USA Rivers: distributions along speciation and environmental gradients. *Journal of Biogeography*, **29**(2): 167-187.

Potapova, M.G. and Charles, D.F. (2003). Distribution of benthic diatoms in U.S. rivers in relation to conductivity and ionic composition. *Freshwater Biology*, **48**(8): 1311-1328.

Potapova, M. and Charles, D. F., Ponader, K.C. and Winter, D. M. (2004). Quantifying species values for trophic diatom indices: a comparison of approaches. *Hydrobiologia*, **517**: 25-41.

Potapova, M.G. and Charles, D.F. (2005). Choice of substrate in algae-based water-quality assessment. *Journal of North American Benthological Society*, **24**(2):415–427.

Prescott, G.W. (1961). *The algae of the Western Great Lakes area*. Wm. C. Brown Co., Dubuque, Iowa. Pp 950.

Prescott, G.W. (1977). *How to know the freshwater algae*. 3rd Edition. Wm. C. Brown Co. Pp 1287.

Preston, F.W. (1948). The commonness and rarity of species. *Ecology*, **29**: 254–283.

Purushothaman, P and Chakrpni, G.J. (2008). Influence of Silicon on Phosphorus Mobilisation in Lake. Proceedings of Taal 2007: 12th World Lake Conference, Jaipur Published by International Lake Environment Committee Foundation. Pp 225-230.

Rabalais, N.N. (2002). Nitrogen in Aquatic Ecosystems. *BioOne,* **31**: 102-112.

Rahman, M, Zannatul A. B. Farhana and Hossain, Y. (2014). Temporal Variation of Physico-chemical Parameters in Kaptai Lake, Bangladesh. *World Journal of Fish and Marine Sciences*, **6** (5): 475-478.

Rajasulochana, P., Dhamotharan, R., Murugesan, S. and Murthy, R. C. (2009) Bioremediation of Oil Refinery Effluent By Using Scenedesmus Obliquus, *Journal of American Science*, **5** (4):17-22.

Rawson, D.S. (1956). Algal indicators of trophic lake types. *Limnology & Oceanography*, **1**: 18–25.

Reynolds, C. S. (2006). The Ecology of Phytoplankton. Cambridge University Press Publisher, New York. Pp 353.

Rocha, A.A. (1992). Algae as indicatiors of water pollution. In CORDEIRO-MARINO, M., Azevedo, M.T.P., Sant'Anna, C.L., Tomita, N.Y. and Pastino, E.M. (Eds.). *Algae and environment*: a general approach. São Paulo: Sociedade Brasileira de Ficologia; CETESB. p. 34-55.

Rott, E., Pfister, P., Van Dam, H., Pall, K., Binder, N., Pipp, E., Ortler, K. (1999). Indikatorlisten furAufwuchsalgen. Teil 2: Trophieindikation und autokologische Anmerkungen. Wasserwirtschaftskataster. BMLF, Wien.

Round, F.E. (1991). Diatoms in river water-monitoring studies. *Journal of Applied Phycology*, **3** (1): 129-145.

Rumeau, A. and Coste, M. (1988). Initiation a la systematique des diatomees d'eau douce pour l'utilisation pratique d'un indice diatomique generique. *Bulletin de French Peche Pisciculture*, **309**:1–69.

Saad, M.A.H. and Hemeda, E.I. (2005). Impact of Agricultural Development on the Levels of Total Nitrogen and Phosphorus in Lake Gasun Egypt. *Proceedings of the 11th World Lake Conference, Nairobi Kenya. Published by Ministry of Water and Irrigation, Kenya and International Lake Committee : (*1):169-173.

Salmaso, N., Naselli-Flores, L. And Padisak, J. (2014). Functional classifications and their applications in phytoplankton ecology. *Freshwater Biology*, doi:10.1111/fwb.12520.

Salomoni, S.E., Rocha, O, Hermany, G and Lobo, E.A. *(2011).* Application of water quality biological indices using diatoms as bioindicators in the Gravataí river, RS, Brazil. *Brazilian Journal of Biology,* **71**(4): 949-959.

Salvia, M., Iffly, J.F., Borght, P.V., Sary, M. and Hoffmann, L. (1999). Application of the 'snapshot' methodology to a basin-wide analysis of phosphorus and nitrogen at stable low flow. *Hydrobiologia*, **410**: 97-102.

Schiefele, S., Kohmann, E. (1993). Bioindikation der Trophie in Fliesgewassern. Bayerisches Landesamt fur Wasserwirtschaft. Forschungsbericht Nr. 10201504.

Schmitt, A. (1998). Trophiebewertung planktondominierter Fliesgewasser – Konzept und erste Erfahrungen.Munchener Beitrage zur Abwasser-, *Fischerei- und Flussbiologie,* **51**: 394–411.

Schoemann, F.R. (1979). Diatoms as indicators of water quality in the upper Hennops River. *Journal of the Limnological Society of South Africa*, **5** (2): 73-78.

Schonfelder, I., (1997). Eine Phosphor-Diatomeen-Relation fur alkalische Seen und Flusse Brandenburgs undihre Anwendung fur die palaolimnologische Analyse von Auensedimenten der unteren Havel.Dissertationes Botanicae 283, J. Cramer, Berlin.

Sheath, R. G. and Wehr, J. D. (2003) Introduction to Freshwater Algae *in*: Wehr, J. D. and Sheath, R. G. (Eds) *Freshwater Algae of North America Ecology and Classification.* Academic Press, New York, USA. Pp 1-9.

Sheath, R. G., Hambrook, J. A. (1990). Freshwater ecology, *in*: Cole, K. M., Sheath, R. G., Eds., *Biology of the red algae*. Cambridge University Press, Cambridge, UK, pp. 423–453.

Sigler, W. A. and Bauder, J. (2015). Alkalinity, pH, and Total Dissolved Solids. Published by Montana State University Extension Water Quality Program, Department of Land Resources and Environmental Sciences, Montana, USA. pp. 1.

Sládecék, V. (1986). Diatoms as indicators of organic pollution. *Acta Hydrochimica et Hydrobiologica*, **14**(5): 555-566.

Smith, E. T. (1975). The effect of pollution in a small stream near Samaru in Northern, Nigeria. *Savannah*, **24** (2): 155-172.

Soininen, J., and Eloranta, P. (2004). Seasonal persistence and stability of diatom communities in rivers: are there habitat specific differences? *European Journal of Phycology*, **39**:153–160.

Stenger-Kovacs, C., Lengyela, E., Crossettib, L.O., Uvegesa, V. and Padisaka, J. (2013). Diatom ecological guilds as indicators of temporally changing stressors and disturbances in the small Torna-stream, Hungary. *Ecological Indicators*, **24**: 138–147.

Stoermer, E.F. and Smol, J.P. (1999). *The Diatoms*: applications for the environmental and earth sciences. Cambridge: Cambridge University Press, London. p. 467.

Sutela, T., Aroviitab, J., Keto, A. (2013): Assessing ecological status of regulated lakes with littoral macrophyte, macroinvertebrate and fish assemblages. *Ecological Indicators,* **24**: 185–192.

Tanimu, Y., Bako, S.P. and Adakole, J.A. (2011a): Effects of Domestic Waste Water on the Water Quality of three reservoirs supplying Drinking Water in Kaduna State In: Fernando S. García Einschlag. Waste Water- Management and Evaluation. Intech Publishers, Rijeka, Croatia. Pp 269-283.

Tanimu Y., Bako S. P., Adakole J. A. & Tanimu J. (2011b). Phytoplankton as Bioindicators of Water Quality in Saminaka Reservoir, Northern-Nigeria. Order of Proceedings of the 2011 International Symposium on Environmental Science and Technology, Dongguan, Guangdong Province, China.pp 318-322.

Tanimu Y., Tiseer, F.A., Ati, F.O and Ezealor, A.U. (2012) Survey of Phytoplankton in the Bauchi and Yobe State Segments of the Hadejia-Jama'are Wetlands, Northeastern Nigeria. *Ecologia*, **2** (4): 114-122 DOI: 10.3923/ecologia.2012.

Tanimu Y. and Bako S.P. (2013). Diversity and abundance of planktonic diatoms as it relates to physico-chemical characteristics of Gimbawa and Zaria reservoirs, Kaduna State, Northern-Nigeria. Proceedings of the 4th Annual Biodiversity Conference, Lagos. Published by the Nigerian Tropical Biology Association. Pp 60-66.

Tanimu, Y. and Akanta, A. A., and Amlabu, W.E. (2013). A comparative Study on Phytoplankton Abundance and Physico-chemical Characteristics between a Concrete and an Earthen Fish Pond in the Department of Biological Sciences, Ahmadu Bello University, Zaria, Kaduna State, Nigeria. *Greener Journal of Biological Sciences* **3**(3): 90-98.

Taylor, J.C., Harding, W.R. and Archibald, C.G.M. (2007). A Methods Manual for the Collection, Preparation and Analysis of Diatom Samples. Water Research Commission, Pretoria, South Africa. Pp 60.

Thangaradjou, T., Vijayabaskara, G., Sethubathi , Raja, S., Poornima , D., Shanthi, R., Balasubramanian, T., Babu, K.N., Shukla, A.K.(2012).Influence of environmental variables on phytoplankton floristic pattern along the shallow coasts of southwest Bay of Bengal. *Algal Research*, **1**: 143–154.

Tiseer, F.A., Tanimu, Y. and Chia, A.M. (2008) Seasonal Occurrence of Algae and Physico-chemical Parameters of Samaru Stream, Zaria, Nigeria. *Asian Journal of Earth Sciences,* **1** (1): 31-37.

Triest, L., Lung'ayia, H., Ndiritu, G. and Beyene, A. (2012). Epilithic diatoms as indicators in tropical African rivers (Lake Victoria catchment). *Hydrobiologia*, **695**:343–360.

Umeham, S.N. (1989). Some Aspects of the Physico-chemical Limnology of Lake Chad (Southern Sector). *Journal of Aquatic Sciences,* 4:21-26.

UNESCO/WHO/UNEP (1996). Water Quality Management Principles. WHO/UNESCO/ E and F Spon, Geneva, Switzerland. Pp 609.

Van Dover, C. L. (2014). Impacts of anthropogenic disturbances at deep-sea hydrothermal vent ecosystems: A review. *Marine Environmental Research*, **102**:59-72.

Verlencar, X.N. and Desai, S. (2004). Phytoplankton Identification Manual. National Institute of Oceanography. Dona paula, Goa India. Pp33.

Walmsley, R.D. (2000). *Perspectives on Eutrophication of Surface Waters*: Policy/Research Needs in South Africa. Pretoria: Water Research Commission. (WRC Report no. KV129/00).

Walsh, C.J., Waller, K., Gehling, J. and Mac Nally, R. (2007). Riverine invertebrate assemblages are degraded more by catchment urbanisation than by riparian deforestation. F*reshwater Biology*, **52**: 574–587.

Watanabe, T., Asai, K. and Houki, A. (1986). Numerical estimation to organic pollution of flowing water by using the epilithic diatom assemblage index (DAIpo). *Science of the Total Environment*, **55**:209–218.

Wehr, J.D. and Descy, J. (1998). Use of phytoplankton in large river management. *Journal of Phycology*, **36**(5): 741-749.

Welch, E.B. Jacuby, J.M. and May, C.W. (1998). Stream Quality in: Naiman, R.J. and Bibly, R.E. (ed) *River Ecology and Management.* Springler, Verlag. New York.

Wetzel, R.G. (2001). *Limnology Lake and River Ecosystem.* Academic Press. New York. P.72.

W.H.O (2006). Guidelines for drinking water Quality. (2ed) (dendum to vol.1). Recomendations.Geneva. Pp 595.

Wilson, J.G., McHugh, B. and Giltrap, M. (2014). Biomarkers: Are realism and control mutually exclusive in integrated pollution assessment? *Marine Environmental Research,* **102**:11-17.

Zakariya, A.M., Adelanwa, M.A. and Tanimu, Y. (2013). Physico-chemical Characteristics and Phytoplankton Diversity of the Lower Niger River in Kogi State, Nigeria. *Journal of Environmental Science Toxicology and Food Technology*, **2** (4):31-37.

Zhang, W.H. and Xu, X.Q. (2001). Determination of Trace Level Microsystem in Water using Solid-Phase Extraction and High Performance Liquid Chromatography. *Chinese J. Analytical Chemistry,* **29** (5):522-525.

Appendix I: surface water physico-chemical characteristics of Tudun Wada (TW), Makera (MK) and River Kaduna for January, 2013

Stations	Temp	pH	TDS	EC	DO	BOD	TH	TA	SO_4	PO_4	NO_3	TN	TP
TW_1	25.60	7.59	351.00	701.00	2.48	3.60	216.00	304	31.30	0.03	2.27	24.24	0.90
TW_1	24.60	7.41	353.00	705.00	2.48	0.60	228.00	324	33.39	0.04	2.19	21.22	0.97
TW_2	25.00	7.20	399.00	795.00	2.18	3.00	260.00	336	29.48	0.16	1.98	23.76	1.08
TW_2	24.40	7.04	400.00	803.00	2.15	1.50	276.00	292	32.87	0.16	2.80	22.07	1.01
TW_3	25.10	7.15	399.00	788.00	1.82	0.30	216.00	284	30.13	0.02	2.57	24.71	0.98
TW_3	24.90	7.05	398.00	797.00	2.05	0.90	228.00	256	32.74	0.04	2.52	22.07	1.11
RK_2	26.80	7.23	91.00	182.00	2.81	3.00	176.00	268	13.70	0.15	2.36	24.33	1.22
RK_2	26.60	7.21	82.00	165.00	2.61	2.70	216.00	364	20.09	0.16	2.39	21.88	1.10
RK_1	25.50	7.21	44.00	90.00	2.44	2.70	168.00	376	16.17	0.18	2.23	21.78	1.12
RK_1	25.50	7.25	51.00	102.00	2.51	3.90	188.00	328	20.09	0.17	2.27	19.99	1.23
RK_3	26.40	7.58	51.00	104.00	2.34	1.80	192.00	324	13.56	0.15	2.23	20.75	1.42
RK_3	26.20	7.50	58.00	116.00	2.48	2.40	212.00	324	14.22	0.15	2.17	22.73	1.31
MK_1	30.00	8.52	525.00	1051.00	1.83	7.20	22.00	332	145.00	2.30	8.00	27.00	1.23
MK_1	30.00	8.87	520.00	1090.00	1.45	1.80	32.00	288	145.00	1.70	7.50	25.90	1.29
MK_2	31.70	7.36	575.00	1143.00	1.85	1.20	34.00	296	145.00	1.88	1.50	24.56	1.13
MK_2	31.20	7.88	593.00	1188.00	1.83	2.55	62.00	248	130.00	2.10	6.50	23.25	1.12
MK_3	30.80	7.58	542.00	1085.00	1.49	1.35	62.00	256	145.00	1.95	7.00	22.25	1.02
MK_3	30.50	7.41	548.00	1096.00	2.10	7.95	40.00	288	160.00	1.35	7.00	23.14	1.06
RK_5	31.40	7.29	95.00	191.00	1.82	1.80	40.00	296	105.00	0.30	2.00	26.50	0.89
RK_5	30.10	7.46	77.00	154.00	1.78	7.95	38.00	216	95.00	0.73	5.00	26.56	0.90
RK_4	29.60	7.36	56.00	112.00	1.72	10.35	30.00	212	95.00	1.15	5.00	23.95	1.02
RK_4	30.50	7.44	69.00	136.00	1.78	1.20	28.00	204	105.00	0.95		22.07	1.08
RK_6	30.70	7.54	65.00	109.00	1.82	2.55	28.00	212	130.00	1.35	4.00	21.84	1.15
RK_6	29.10	7.55	55.00	110.00	2.00	3.45	20.00	60.00	130.00	1.35		21.82	1.09

(Temp = surface water temperature (°C); TDS=Total Dissolved Solids (ppm); EC= Electrical Conductivity (µS/cm); DO= Dissolved Oxygen (mg/L); BOD, Biochemical Oxygen Demand (mg/L); TH= Total Hardness (mg/L); TA= Total Alkalinity (mg/L); SO_4= sulphate (mg/L); PO_4= Phosphate-Phosphorus (mg/L); NO_3= Nitrate-Nitrogen (mg/L); TN= Total Nitrogen (mg/L); and TP= Total Phosphorus (mg/L)

Appendix II: Surface water physico-chemical characteristics of Tudun Wada (TW), Makera (MK) and River Kaduna for February, 2013

Stations	Temp	pH	TDS	EC	DO	BOD	TH	TA	SO4	PO4	NO3	TN	TP
TW_1	26.1	7.51	408	817	0.82	1.5	51	356.00	35.74	0.27	0.00	19.61	0.29
TW_1	25.7	7.36	417	834	0.82	1.8	54	368.00	34.43	0.33	0.00	19.99	0.62
TW_2	26.6	7.04	399	791	0.72	3.6	43	420.00	33.65	0.32	0.00	21.03	0.64
TW_2	26.5	7.02	438	876	0.71	0.6	45	412.00	32.61	0.31	0.00	20.56	0.84
TW_3	28.1	7.16	438	877	0.60	1.8	40	404.00	32.61	0.29	0.00	21.22	0.77
TW_3	27.5	7.06	440	879	0.68	0.6	42	412.00	31.69	0.28	0.00	21.03	0.76
RK_2	28.4	7.46	88	176	0.93	1.2	35	408.00	15.39	0.28	0.00	28.10	0.68
RK_2	28.1	7.43	88	176	0.86	1.2	36	420.00	16.70	0.28	0.00	27.91	0.80
RK_1	29.5	7.36	82	166	0.81	3.3	36	276.00	2.35	0.25	0.00	27.06	0.71
RK_1	29.6	7.3	89	194	0.83	1.8	36	292.00	3.52	0.24	0.00	27.06	0.81
RK_3	29.6	7.74	86	173	0.77	3	56	180.00	1.96	0.34	0.00	0.00	0.00
RK_3	28.6	7.48	86	173	0.82	2.1	54	196.00	2.74	0.31	0.00	0.00	0.00
MK_1	29.5	8.75	843	1705	0.60	2.7	57	500.00	28.43	0.35	2.80	19.43	1.12
MK_1	29.3	8.79	816	1638	0.48	3	55	484.00	29.74	0.32	2.78	19.71	1.12
MK_2	29.6	8.47	788	1572	0.61	2.4	45	556.00	19.69	0.23	2.20	25.08	1.09
MK_2	29.2	8.45	790	1584	0.60	3	43	548.00	20.61	0.22	2.21	28.10	1.01
MK_3	30.3	8.69	818	1635	0.49	1.5	41	488.00	34.82	0.25	1.94	25.56	0.91
MK_3	29.4	8.64	829	1681	0.69	3.3	43	476.00	37.96	0.25	1.93	19.33	0.44
RK_5	28.1	8.04	103	206	0.60	7.5	45	364.00	24.91	0.13	1.67	20.75	0.14
RK_5	29	7.77	103	207	0.59	6.3	47	376.00	22.96	0.13	1.82	22.63	0.71
RK_4	29.2	8.3	142	283	0.57	6.3	35	312.00	38.87	0.11	1.57	24.42	0.13
RK_4	28.3	8.08	116	233	0.59	5.4	34	304.00	36.39	0.12	1.49	24.52	0.18
RK_6	29.1	8.03	102	205	0.60	6.6	42	276.00	25.43	0.10	2.47	25.37	0.22
RK_6	28.9	8.3	98	197	0.66	6	45	288.00	21.26	0.09	2.48	25.56	0.19

(Temp = surface water temperature (°C); TDS=Total Dissolved Solids (ppm); EC= Electrical Conductivity (µS/cm); DO= Dissolved Oxygen (mg/L); BOD, Biochemical Oxygen Demand (mg/L); TH= Total Hardness (mg/L); TA= Total Alkalinity (mg/L); SO_4= sulphate (mg/L); PO_4= Phosphate-Phosphorus (mg/L); NO_3= Nitrate-Nitrogen (mg/L); TN= Total Nitrogen (mg/L); and TP= Total Phosphorus (mg/L)

Appendix III: Surface water physico-chemical characteristics of Tudun Wada (TW), Makera (MK) and River Kaduna March, 2013

Stations	Temp	pH	TDS	EC	DO	BOD	TH	TA	SO4	PO4	NO3	TN	TP
TW_1	30.30	7.09	363.00	764.00	1.19	5.10	135.00	356.00	0.00	0.34	1.99	20.75	0.39
TW_1	30.80	7.04	380.00	760.00	1.29	7.20	130.00	368.00	0.00	0.31	2.11	20.09	0.50
TW_2	30.50	7.12	387.00	795.00	1.35	8.40	175.00	420.00	0.00	0.33	1.45	21.31	1.10
TW_2	30.60	7.06	414.00	832.00	1.22	7.80	179.00	412.00	0.00	0.32	1.56	21.41	1.08
TW_3	30.80	7.01	398.00	796.00	1.49	6.60	131.00	404.00	0.00	0.33	2.38	23.76	0.85
TW_3	31.60	7.02	406.00	801.00	1.55	7.50	130.00	412.00	0.00	0.32	2.35	27.44	0.87
RK_2	29.70	6.88	117.00	239.00	1.35	5.40	195.00	408.00	0.00	0.16	2.81	17.82	0.81
RK_2	29.40	6.87	118.00	236.00	1.22	3.60	191.00	420.00	0.00	0.16	2.74	19.61	0.71
RK_1	28.30	7.30	22.00	44.00	1.68	9.00	85.00	276.00	0.00	0.15	1.98	19.80	0.99
RK_1	28.00	7.25	19.00	39.00	1.58	8.70	83.00	292.00	0.00	0.14	1.99	25.18	1.08
RK_3	29.20	8.16	178.00	350.00	1.58	2.70	43.00	180.00	35.22	0.17	2.01	22.35	0.54
RK_3	29.20	8.10	183.00	365.00	2.05	7.50	45.00	196.00	35.61	0.18	2.46	22.91	0.54
MK_1	32.70	8.26	600.00	1200.00	0.50	1.50	100.00	520.00	130.00	0.73	2.59	26.59	0.57
MK_1	32.30	8.23	605.00	1212.00	0.63	2.10	92.00	580.00	120.00	0.73	1.97	27.06	0.56
MK_2	32.70	7.57	664.00	1330.00	1.62	8.70	160.00	550.00	130.00	0.85	1.98	26.03	0.68
MK_2	32.50	7.53	686.00	1376.00	1.49	7.80	160.00	550.00	130.00	0.85	2.03	26.31	0.66
MK_3	33.50	7.91	763.00	1520.00	0.83	1.20	180.00	530.00	95.00	0.83	2.54	22.73	1.08
MK_3	33.10	7.93	767.00	1509.00	0.69	3.30	184.00	510.00	120.00	0.83	2.62	23.39	1.11
RK_5	32.20	7.20	89.00	178.00	1.78	8.70	80.00	110.00	105.00	0.53	1.97	26.50	0.98
RK_5	32.20	7.15	89.00	180.00	1.65	7.20	84.00	130.00	105.00	0.53	1.98	26.88	0.98
RK_4	34.80	7.58	80.00	159.00	0.99	0.90	64.00	90.00	80.00	0.65	2.14	24.80	0.94
RK_4	32.80	7.48	79.00	158.00	1.06	1.20	72.00	80.00	70.00	0.53	2.63	25.37	0.97
RK_6	34.00	9.00	75.00	148.00	1.58	9.90	72.00	60.00	40.00	0.20	1.91	22.00	0.97
RK_6	33.30	8.10	78.00	155.00	1.58	10.20	64.00	80.00	40.00	0.30	1.97	23.00	1.02

(Temp = surface water temperature (°C); TDS=Total Dissolved Solids (ppm); EC= Electrical Conductivity (μS/cm); DO= Dissolved Oxygen (mg/L); BOD, Biochemical Oxygen Demand (mg/L); TH= Total Hardness (mg/L); TA= Total Alkalinity (mg/L); SO_4= sulphate (mg/L); PO_4= Phosphate-Phosphorus (mg/L); NO_3= Nitrate-Nitrogen (mg/L); TN= Total Nitrogen (mg/L); and TP= Total Phosphorus (mg/L)

Appendix IV: surface water physico-chemical characteristics of Tudun Wada (TW), Makera (MK) and River Kaduna April, 2013

Stations	Temp	pH	TDS	EC	DO	BOD	TH	TA	SO4	PO4	NO3	TN	TP
TW_1	30.30	7.09	363.00	764.00	1.19	5.10	135.00	356.00	0.00	0.34	1.99	20.75	0.39
TW_1	30.80	7.04	380.00	760.00	1.29	7.20	130.00	368.00	0.00	0.31	2.11	20.09	0.50
TW_2	30.50	7.12	387.00	795.00	1.35	8.40	175.00	420.00	0.00	0.33	1.45	21.31	1.10
TW_2	30.60	7.06	414.00	832.00	1.22	7.80	179.00	412.00	0.00	0.32	1.56	21.41	1.08
TW_3	30.80	7.01	398.00	796.00	1.49	6.60	131.00	404.00	0.00	0.33	2.38	23.76	0.85
TW_3	31.60	7.02	406.00	801.00	1.55	7.50	130.00	412.00	0.00	0.32	2.35	27.44	0.87
RK_2	29.70	6.88	117.00	239.00	1.35	5.40	195.00	408.00	0.00	0.16	2.81	17.82	0.81
RK_2	29.40	6.87	118.00	236.00	1.22	3.60	191.00	420.00	0.00	0.16	2.74	19.61	0.71
RK_1	28.30	7.30	22.00	44.00	1.68	9.00	85.00	276.00	0.00	0.15	1.98	19.80	0.99
RK_1	28.00	7.25	19.00	39.00	1.58	8.70	83.00	292.00	0.00	0.14	1.99	25.18	1.08
RK_3	29.20	8.16	178.00	350.00	1.58	2.70	43.00	180.00	35.22	0.17	2.01	22.35	0.54
RK_3	29.20	8.10	183.00	365.00	2.05	7.50	45.00	196.00	35.61	0.18	2.46	22.91	0.54
MK_1	32.40	7.78	679.00	1359.00	1.09	3.30	180.00	250.00	70.00	0.85	10.50	16.50	7.14
MK_1	32.30	7.45	685.00	1373.00	1.16	4.20	168.00	270.00	40.00	0.85	9.00	16.22	0.59
MK_2	32.20	8.77	673.00	1344.00	1.06	2.40	60.00	500.00	160.00	0.85	9.00	19.14	0.78
MK_2	32.10	8.77	672.00	1346.00	1.16	3.90	72.00	480.00	130.00	0.95	8.50	19.14	0.83
MK_3	32.20	7.28	654.00	1310.00	1.16	3.60	172.00	320.00	210.00	0.73	9.00	22.63	1.02
MK_3	31.80	7.08	653.00	1307.00	1.09	3.60	164.00	300.00	225.00	0.85	8.00	22.44	0.90
RK_5	29.20	7.28	88.00	176.00	1.35	1.80	68.00	120.00	30.00	0.23	8.50	25.65	0.50
RK_5	28.80	7.08	90.00	180.00	1.42	3.60	76.00	100.00	30.00	0.10	8.00	25.37	0.62
RK_4	29.90	7.25	55.00	110.00	1.52	2.10	76.00	50.00	15.00	0.30	9.00	24.14	0.60
RK_4	29.70	7.11	55.00	111.00	1.49	2.70	64.00	50.00	15.00	0.10	9.00	25.18	0.49
RK_6	31.10	7.13	54.00	109.00	1.25	0.60	20.00	40.00	30.00	0.40	8.50	26.88	0.96
RK_6	30.60	6.98	54.00	109.00	1.29	1.20	16.00	30.00	15.00	0.23	9.00	26.03	1.06

(Temp = surface water temperature (°C); TDS=Total Dissolved Solids (ppm); EC= Electrical Conductivity (μS/cm); DO= Dissolved Oxygen (mg/L); BOD, Biochemical Oxygen Demand (mg/L); TH= Total Hardness (mg/L); TA= Total Alkalinity (mg/L); SO_4= sulphate (mg/L); PO_4= Phosphate-Phosphorus (mg/L); NO_3= Nitrate-Nitrogen (mg/L); TN= Total Nitrogen (mg/L); and TP= Total Phosphorus (mg/L)

Appendix V: Surface water physico-chemical characteristics of Tudun Wada (TW), Makera (MK) and River Kaduna May, 2013

Stations	Temp	pH	TDS	EC	DO	BOD	TH	TA	SO4	PO4	NO3	TN	TP
TW_1	30.30	7.09	363.00	764.00	1.19	5.10	135.00	356.00	0.00	0.34	1.99	20.75	0.39
TW_1	30.80	7.04	380.00	760.00	1.29	7.20	130.00	368.00	0.00	0.31	2.11	20.09	0.50
TW_2	30.50	7.12	387.00	795.00	1.35	8.40	175.00	420.00	0.00	0.33	1.45	21.31	1.10
TW_2	30.60	7.06	414.00	832.00	1.22	7.80	179.00	412.00	0.00	0.32	1.56	21.41	1.08
TW_3	30.80	7.01	398.00	796.00	1.49	6.60	131.00	404.00	0.00	0.33	2.38	23.76	0.85
TW_3	31.60	7.02	406.00	801.00	1.55	7.50	130.00	412.00	0.00	0.32	2.35	27.44	0.87
RK_2	29.70	6.88	117.00	239.00	1.35	5.40	195.00	408.00	0.00	0.16	2.81	17.82	0.81
RK_2	29.40	6.87	118.00	236.00	1.22	3.60	191.00	420.00	0.00	0.16	2.74	19.61	0.71
RK_1	28.30	7.30	22.00	44.00	1.68	9.00	85.00	276.00	0.00	0.15	1.98	19.80	0.99
RK_1	28.00	7.25	19.00	39.00	1.58	8.70	83.00	292.00	0.00	0.14	1.99	25.18	1.08
RK_3	29.20	8.16	178.00	350.00	1.58	2.70	43.00	180.00	35.22	0.17	2.01	22.35	0.54
RK_3	29.20	8.10	183.00	365.00	2.05	7.50	45.00	196.00	35.61	0.18	2.46	22.91	0.54
MK_1	32.40	7.78	679.00	1359.00	0.00	0.00	180.00	250.00	70.00	0.85	10.50	27.06	0.56
MK_1	32.30	7.45	685.00	1373.00	3.50	31.80	168.00	270.00	40.00	0.85	0.00	26.03	0.68
MK_2	32.20	8.77	673.00	1344.00	4.13	37.50	60.00	500.00	160.00	0.85	9.00	26.31	0.66
MK_2	32.10	8.77	672.00	1346.00	4.16	37.80	72.00	480.00	130.00	0.95	0.00	22.73	1.08
MK_3	32.20	7.28	654.00	1310.00	4.06	36.90	172.00	320.00	210.00	0.73	9.00	23.39	1.11
MK_3	31.80	7.08	653.00	1307.00	3.80	34.50	164.00	300.00	225.00	0.85	0.00	26.50	0.98
RK_5	29.20	7.28	88.00	176.00	4.13	37.50	68.00	120.00	30.00	0.23	8.50	26.88	0.98
RK_5	28.80	7.08	90.00	180.00	3.50	31.80	76.00	100.00	30.00	0.10	0.00	24.80	0.94
RK_4	29.90	7.25	55.00	110.00	4.13	37.50	76.00	50.00	15.00	0.30	9.00	25.37	0.97
RK_4	29.70	7.11	55.00	111.00	4.16	37.80	64.00	50.00	15.00	0.10	0.00	0.00	0.97
RK_6	31.10	7.13	54.00	109.00	4.13	37.50	20.00	40.00	30.00	0.40	8.50	0.00	1.02
RK_6	30.60	6.98	54.00	109.00	0.00	0.00	16.00	30.00	15.00	0.23	0.00		

(Temp = surface water temperature (°C); TDS=Total Dissolved Solids (ppm); EC= Electrical Conductivity (µS/cm); DO= Dissolved Oxygen (mg/L); BOD, Biochemical Oxygen Demand (mg/L); TH= Total Hardness (mg/L); TA= Total Alkalinity (mg/L); SO_4= sulphate (mg/L); PO_4= Phosphate-Phosphorus (mg/L); NO_3= Nitrate-Nitrogen (mg/L); TN= Total Nitrogen (mg/L); and TP= Total Phosphorus (mg/L)

Appendix VI: Surface water physico-chemical characteristics of Tudun Wada (TW), Makera (MK) and River Kaduna June and July, 2013

Stations	Temp	pH	TDS	EC	DO	BOD	TH	TA	SO4	PO4	NO3
TW_1	26.00	7.96	321.00	644.00	3.50	6.00	184.00	87.00	30.39	0.14	3.46
TW_1	26.40	7.98	396.00	726.00	4.13	10.80	180.00	96.00	30.13	0.14	2.17
TW_2	26.40	7.97	312.00	724.00	4.16	15.00	156.00	109.00	30.26	0.27	3.49
TW_2	27.10	7.90	345.00	692.00	4.06	10.20	160.00	115.00	30.65	0.15	3.47
TW_3	26.80	7.90	344.00	688.00	3.80	13.80	132.00	91.00	24.52	0.17	4.03
TW_3	27.70	7.88	139.00	279.00	4.13	9.00	132.00	105.00	25.43	0.18	4.01
MK_1	27.60	7.90	140.00	280.00	3.50	5.10	148.00	109.00	37.17	0.08	3.39
MK_1	27.60	7.90	23.00	47.00	4.13	10.80	140.00	112.00	37.82	0.07	3.41
MK_2	27.70	7.89	23.00	46.00	4.16	34.20	188.00	173.00	38.74	0.15	3.42
MK_2	27.50	7.85	32.00	63.00	4.13	34.20	184.00	165.00	36.91	0.15	3.41
MK_3	27.60	7.84	32.00	64.00							
MK_3											
TW_1	27.00	7.30	326.00	650.00	2.15	10.20	100.00	124.00	27.91	0.18	3.42
TW_1	27.00	7.80	360.00	781.00	2.15	11.10	96.00	117.00	28.43	0.20	3.41
TW_2	27.90	7.89	367.00	745.00	2.51	6.90	124.00	122.00	25.04	0.41	3.14
TW_2	28.00	7.90	387.00	775.00	2.28	11.10	120.00	129.00	25.43	0.43	3.17
TW_3	28.50	7.04	375.00	750.00	2.81	1.20	220.00	107.00	19.56	0.22	4.03
TW_3	28.00	7.05	373.00	745.00	3.00	9.30	224.00	113.00	19.96	0.22	4.04
MK_1	31.00	9.00	444.00	888.00	1.16	22.20	160.00	151.00	77.87	0.44	3.26
MK_1	30.60	9.05	441.00	882.00	1.09	22.80	156.00	149.00	38.61	0.15	3.24
MK_2	31.40	9.05	425.00	845.00	0.99	23.10	228.00	161.00	72.26	0.32	3.77
MK_2	31.20	8.95	441.00	882.00	1.16	21.60	220.00	165.00	37.69	0.32	3.62
MK_3	31.10	8.60	480.00	960.00	0.96	20.10	188.00	157.00	73.69	0.87	3.18
MK_3	31.10	8.45	468.00	959.00	0.86	23.10	180.00	161.00	30.65	0.60	3.17

(Temp = surface water temperature (°C); TDS=Total Dissolved Solids (ppm); EC= Electrical Conductivity (µS/cm); DO= Dissolved Oxygen (mg/L); BOD, Biochemical Oxygen Demand (mg/L); TH= Total Hardness (mg/L); TA= Total Alkalinity (mg/L); SO_4= sulphate (mg/L); PO_4= Phosphate-Phosphorus (mg/L); NO_3= Nitrate-Nitrogen (mg/L); TN= Total Nitrogen (mg/L); and TP= Total Phosphorus (mg/L)

Appendix VII: Surface water physico-chemical characteristics of Tudun Wada (TW), Makera (MK) and River Kaduna August, 2013

Stations	Temp	pH	TDS	EC	DO	BOD	TH	TA	SO_4	PO_4	NO_3	TN	TP
TW_1	27.8	7.4	295	594	1.6	13	624	179	32.1	0.10	3.5	11	23
TW_1	28	7.5	313	625	1.4	15	600	175	55.2				31
TW_2	27.8	7.2	200	422	0.1	15	660	214	31.4	0.2	2.8	20	31
TW_2	27.7	7	210	586	0.2	14	640	220	44.3				31
TW_3	30.9	7.3	296	593	1.4	11	620	178	66.9	0.3	4.2	7.9	16
TW_3	38.2	7.1	236	474	1.5	11	600	180	44.3				20
RK_2	26.1	7.3	94	170	1.8	9	356	106	22.3	0.3	3.2	4.9	30
RK_2	25.6	7.1	83	193	1.8	7.2	360	105	0	0	0		29
RK_1	30.5	7.4	90	150	2.1	8.1	248	76	18.1	0.1	4.3	12	21
RK_1	29.9	7.3	92	186	2	5.7	240	75	0	0	0		22
RK_3	29.8	8.2	35	71	1.8	0.6	388	51	33.8	0.3	4.1	5	21
RK_3	28.8	8	33	61	1.7	0	380	50	0	0	0		21
MK_1	30.2	7.3	530	1055	1.8	1.2	216	322	40.6	0.2	4.2	15	20
MK_1	29.2	7.3	532	1065	1.7	1.8	220	320	95.9	0.5	0		20
MK_2	29.8	7.5	549	1115	1.1	6.6	220	297	33.9	0.3	4.5	7.7	20
MK_2	29	7.4	559	1117	1.3	7.5	216	300	92.9	0.5	0		20
MK_3	29.7	7.6	537	1070	1.4	3	448	324	32.1	0.4	3.6	7.7	28
MK_3	29	7.4	539	1074	1.3	2.7	440	320	85.3	0.2	0		29
RK_5	27.70	8.60	517.00	1035.00	0.89	1.20	63.00	392.00	31.04	0.05	2.42	0.00	0.00
RK_5	25.60	8.25	28.00	56.00	1.12	1.80	47.00	216.00	28.69	0.02	1.99	0.00	0.00
RK_4	25.60	8.27	29.00	57.00	1.22	2.10	45.00	208.00	26.35	0.01	2.03	0.00	0.00
RK_4	26.30	8.27	27.00	54.00	1.06	3.00	57.00	172.00	31.43	0.09	2.02	0.00	0.00
RK_6	26.40	8.29	26.00	53.00	1.16	1.20	52.00	180.00	28.83	0.12	2.08	0.00	0.00
RK_6	26.50	8.30	37.00	73.00	1.39	1.20	46.00	188.00	37.96	0.12	2.56	0.00	0.00

(Temp = surface water temperature (°C); TDS=Total Dissolved Solids (ppm); EC= Electrical Conductivity (µS/cm); DO= Dissolved Oxygen (mg/L); BOD, Biochemical Oxygen Demand (mg/L); TH= Total Hardness (mg/L); TA= Total Alkalinity (mg/L); SO_4= sulphate (mg/L); PO_4= Phosphate-Phosphorus (mg/L); NO_3= Nitrate-Nitrogen (mg/L); TN= Total Nitrogen (mg/L); and TP= Total Phosphorus (mg/L)

Appendix VIII: Surface water physico-chemical characteristics of Tudun Wada (TW), Makera (MK) and River Kaduna September, 2013

Stations	Temp	pH	TDS	EC	DO	BOD	TH	TA	SO_4	PO_4	NO_3	TN	TP
TW_1	28.40	6.73	173.00	348.00	2.31	2.10	232.00	75.00	44.35	0.43	1.98	27.06	0.54
TW_1	28.00	6.82	175.00	350.00	2.38	2.40	224.00	78.00	44.09	0.43	2.03	26.31	0.53
TW_2	29.50	6.92	273.00	552.00	2.38	2.10	312.00	87.00	35.48	0.00	2.18	24.24	0.37
TW_2	29.10	6.95	276.00	544.00	2.44	3.60	296.00	89.00	35.35	0.04	2.22	23.58	0.56
TW_3	29.30	7.33	248.00	496.00	2.38	2.10	320.00	96.00	33.39	0.02	2.16	28.10	0.44
TW_3	29.00	7.31	253.00	505.00	2.34	2.70	312.00	94.00	33.39	0.02	2.22	27.91	0.36
RK_2	30.70	7.34	67.00	134.00	2.15	0.60	340.00	53.00	1.30	0.15	2.18	23.01	0.18
RK_2	30.60	7.20	69.00	141.00	2.05	1.20	328.00	56.00	11.87	0.15	2.22	23.29	1.19
RK_1	30.90	6.96	166.00	331.00	2.41	2.70	344.00	89.00	21.39	0.16	2.19	21.88	1.49
RK_1	30.60	7.00	150.00	300.00	2.34	2.40	356.00	86.00	23.09	0.17	2.22	22.25	1.50
RK_3	30.50	7.20	149.00	301.00	2.48	2.10	356.00	58.00	14.22	0.13	2.46	25.46	0.22
RK_3	31.00	7.10	150.00	300.00	2.41	2.10	340.00	56.00	13.30	0.13	2.44	25.93	0.25
MK_1	31.80	9.08	557.00	1114.00	2.44	2.70	144.00	109.00	36.00	0.08	2.37	24.90	0.80
MK_1	31.30	9.10	556.00	1116.00	2.38	1.50	132.00	108.00	35.09	0.08	2.41	25.27	0.70
MK_2	31.10	9.01	544.00	1090.00	2.31	1.20	260.00	106.00	27.52	0.06	2.11	19.71	0.48
MK_2	31.10	9.15	542.00	1080.00	2.34	0.90	248.00	108.00	28.04	0.05	2.10	20.27	1.59
MK_3	31.70	9.15	556.00	1112.00	2.48	6.30	292.00	119.00	33.52	0.19	1.95	22.73	1.36
MK_3	31.10	9.16	554.00	1107.00	2.41	4.80	280.00	117.00	35.09	0.10	2.74	23.48	2.18
RK_5	29.00	8.45	31.00	63.00	2.81	6.00	288.00	66.00	16.96	0.18	1.95	20.65	0.71
RK_5	28.40	0.12	31.00	61.00	2.74	4.80	300.00	63.00	18.13	0.20	1.98	20.93	0.61
RK_4	29.30	7.75	31.00	63.00	2.41	1.20	180.00	61.00	13.30	0.19	2.35	20.65	0.49
RK_4	28.90	7.67	33.00	66.00	2.38	1.20	188.00	63.00	13.96	0.18	2.29	21.03	0.42
RK_6	28.50	7.97	29.00	60.00	2.34	1.20	236.00	41.00	13.56	0.24	2.21	18.20	0.14
RK_6	28.20	7.79	29.00	58.00	2.41	2.40	224.00	43.00	13.30	0.25	2.25	19.14	0.16

(Temp = surface water temperature (°C); TDS=Total Dissolved Solids (ppm); EC= Electrical Conductivity (µS/cm); DO= Dissolved Oxygen (mg/L); BOD, Biochemical Oxygen Demand (mg/L); TH= Total Hardness (mg/L); TA= Total Alkalinity (mg/L); SO_4= sulphate (mg/L); PO_4= Phosphate-Phosphorus (mg/L); NO_3= Nitrate-Nitrogen (mg/L); TN= Total Nitrogen (mg/L); and TP= Total Phosphorus (mg/L)

Appendix IX: Surface water physico-chemical characteristics of Tudun Wada (TW), Makera (MK) and River Kaduna for October, 2013

Stations	Temp	pH	TDS	EC	DO	BOD	TH	TA	SO_4	PO_4	NO_3	TN	TP
TW_1	23.30	7.66	315.00	627.00	2.01	1.80	168.00	45.00	6.00	0.26	1.97	4.50	21.31
TW_1	23.30	7.40	327.00	652.00	2.05	1.50	180.00	48.00	4.04	0.26	2.01	4.80	20.09
TW_2	24.40	7.26	366.00	728.00	2.28	7.20	140.00	53.00	1.30	0.31	1.88	4.90	24.90
TW_2	24.20	7.13	367.00	735.00	2.38	3.60	120.00	56.00	3.13	0.31	1.90	4.50	24.14
TW_3	25.50	7.15	360.00	719.00	1.35	0.30	184.00	42.00	13.30	0.32	2.21	3.50	18.67
TW_3	25.50	7.11	359.00	717.00	1.39	0.60	196.00	45.00	12.65	0.32	2.23	4.10	20.65
RK_2	26.90	7.80	412.00	727.00	2.48	3.00	208.00	39.00	2.74	0.17	2.76	5.20	20.27
RK_2	26.20	7.04	341.00	679.00	2.64	3.30	228.00	43.00	3.26	0.17	2.79	4.30	20.93
RK_1	27.50	7.10	109.00	219.00	2.31	0.30	168.00	38.00	4.04	0.19	1.72	3.50	19.90
RK_1	27.20	6.63	145.00	311.00	2.15	0.00	180.00	41.00	4.57	0.21	2.49	3.60	20.84
RK_3	26.10	6.81	72.00	143.00	2.64	4.20	140.00	35.00	3.00	0.26	2.26	3.90	26.03
RK_3	25.60	6.75	81.00	165.00	2.67	3.90	164.00	33.00	3.26	0.25	2.12	4.20	25.37
MK_1	28.40	9.56	499.00	1010.00	2.28	3.90	84.00	65.00	29.35	0.19	2.70	6.20	25.56
MK_1	28.00	9.60	507.00	1022.00	2.15	4.50	92.00	68.00	30.39	0.24	2.64	6.50	24.61
MK_2	28.40	9.45	449.00	893.00	2.05	2.10	100.00	55.00	37.82	0.21	2.41	4.90	19.71
MK_2	28.10	9.46	455.00	908.00	2.01	1.50	92.00	53.00	37.17	0.19	2.36	5.20	20.84
MK_3	28.50	8.94	400.00	803.00	1.85	1.20	100.00	45.00	18.13	0.33	2.71	4.50	22.54
MK_3	27.80	9.08	408.00	817.00	1.98	1.50	108.00	48.00	39.00	0.33	2.64	4.70	21.59
RK_5	26.40	7.70	40.00	80.00	1.95	2.70	124.00	47.00	26.48	0.21	2.42	4.50	21.78
RK_5	25.90	7.67	40.00	80.00	2.05	3.00	132.00	48.00	25.17	0.22	2.30	4.60	20.75
RK_4	26.70	8.06	47.00	93.00	2.77	4.20	120.00	53.00	27.65	0.20	2.26	5.10	20.65
RK_4	26.30	7.90	49.00	99.00	2.41	0.60	124.00	49.00	26.74	0.22	2.19	5.30	20.84
RK_6	27.50	8.75	39.00	79.00	2.71	3.00	140.00	45.00	16.30	0.17	2.67	4.40	19.43
RK_6	26.50	8.20	39.00	79.00	2.51	1.80	128.00	43.00	17.61	0.16	2.59	4.60	20.09

(Temp = surface water temperature (°C); TDS=Total Dissolved Solids (ppm); EC= Electrical Conductivity (µS/cm); DO= Dissolved Oxygen (mg/L); BOD, Biochemical Oxygen Demand (mg/L); TH= Total Hardness (mg/L); TA= Total Alkalinity (mg/L); SO_4= sulphate (mg/L); PO_4= Phosphate-Phosphorus (mg/L); NO_3= Nitrate-Nitrogen (mg/L); TN= Total Nitrogen (mg/L); and TP= Total Phosphorus (mg/L)

Appendix X: Surface water physico-chemical characteristics of Tudun Wada (TW), Makera (MK) and River Kaduna November, 2013

Stations	Temp	pH	TDS	EC	DO	BOD	TH	TA	SO_4	PO_4	NO_3
TW_1	26.40	7.66	454.00	909.00	1.98	0.90	128.00	47.00	18.91	0.18	2.07
TW_1	25.90	7.37	479.00	962.00	2.01	1.50	140.00	43.00	19.69	0.24	2.08
TW_2	26.00	7.22	473.00	920.00	1.68	1.20	124.00	71.00	18.26	0.18	2.04
TW_2	25.90	6.99	510.00	1018.00	1.65	0.90	132.00	72.00	19.30	0.26	2.46
TW_3	28.00	7.15	364.00	687.00	2.21	3.60	132.00	79.00	17.61	0.13	2.48
TW_3	27.20	7.08	499.00	999.00	1.65	2.10	140.00	74.00	18.65	0.24	2.23
RK_2	29.90	7.17	448.00	896.00	1.98	0.00	140.00	71.00	30.00	0.12	2.19
RK_2	28.20	6.90	507.00	1015.00	2.21	1.80	132.00	73.00	17.22	0.25	2.16
RK_1	26.20	7.34	35.00	69.00	2.41	1.50	104.00	31.00	14.61	0.20	2.56
RK_1	25.80	7.25	35.00	70.00	2.44	0.90	112.00	41.00	15.00	0.25	2.54
RK_3	29.30	6.87	220.00	440.00	2.48	3.00	164.00	44.00	18.91	0.10	2.64
RK_3	29.00	6.74	186.00	373.00	2.64	3.00	160.00	46.00	19.96	0.22	2.61
MK_1	29.60	8.52	1124.00	2253.00	1.32	2.10	84.00	175.00	33.13	0.34	2.70
MK_1	29.00	8.52	1125.00	2250.00	1.35	1.20	92.00	163.00	31.96	0.35	2.73
MK_2	29.50	8.45	1093.00	2180.00	1.55	5.10	120.00	165.00	30.13	0.28	2.52
MK_2	29.00	8.47	1095.00	2191.00	1.39	3.30	128.00	167.00	31.17	0.31	2.45
MK_3	29.60	8.20	1026.00	2044.00	1.09	3.60	168.00	175.00	31.43	0.24	2.40
MK_3	29.10	8.41	1038.00	2079.00	1.06	5.10	164.00	173.00	31.04	0.24	2.31
RK_5	27.00	7.39	80.00	163.00	2.48	5.70	124.00	41.00	30.00	0.19	2.17
RK_5	26.60	7.32	71.00	142.00	2.41	4.20	132.00	45.00	29.74	0.23	2.31
RK_4	27.60	7.63	39.00	78.00	2.44	1.50	80.00	51.00	35.35	0.18	1.96
RK_4	26.70	7.45	38.00	77.00	2.11	0.60	84.00	53.00	34.96	0.22	2.05
RK_6	27.90	7.34	40.00	82.00	2.15	2.40	92.00	23.00	34.30	0.21	2.05
RK_6	27.70	7.32	41.00	81.00	2.48	2.40	84.00	21.00	35.09	0.24	2.39

(Temp = surface water temperature (°C); TDS=Total Dissolved Solids (ppm); EC= Electrical Conductivity (µS/cm); DO= Dissolved Oxygen (mg/L); BOD, Biochemical Oxygen Demand (mg/L); TH= Total Hardness (mg/L); TA= Total Alkalinity (mg/L); SO_4= sulphate (mg/L); PO_4= Phosphate-Phosphorus (mg/L); NO_3= Nitrate-Nitrogen (mg/L); TN= Total Nitrogen (mg/L); and TP= Total Phosphorus (mg/L)

Appendix XI: Surface water physico-chemical characteristics of Tudun Wada (TW), Makera (MK) and River Kaduna for December, 2013

Stations	Temp	pH	TDS	EC	DO	BOD	TH	TA	SO_4	PO_4	NO_3	TN	TP
TW_1	25.60	7.59	351.00	701.00	2.08	3.60	216.00	0.00	31.30	0.03	2.27	24.24	0.90
TW_1	24.60	7.40	353.00	705.00	2.48	0.60	228.00	0.00	33.39	0.04	2.19	21.22	0.97
TW_2	25.00	7.23	399.00	795.00	2.18	3.00	260.00	0.00	29.48	0.16	1.98	23.76	1.08
TW_2	24.40	7.04	400.00	803.00	2.15	1.50	276.00	0.00	32.87	0.16	2.80	22.07	1.01
TW_3	25.10	7.15	399.00	788.00	1.82	0.30	216.00	0.00	30.13	0.02	2.57	24.71	0.98
TW_3	24.90	7.05	398.00	797.00	2.05	0.90	228.00	0.00	32.74	0.04	2.52	22.07	1.11
RK_2	26.80	7.23	91.00	182.00	2.81	3.00	176.00	0.00	13.70	0.15	2.36	24.33	1.22
RK_2	26.60	7.21	82.00	165.00	2.61	2.70	216.00	0.00	20.09	0.16	2.39	21.88	1.10
RK_1	25.50	7.23	44.00	90.00	2.44	2.70	168.00	0.00	16.17	0.18	2.23	21.78	1.12
RK_1	25.50	7.25	51.00	102.00	2.51	3.90	188.00	0.00	20.09	0.17	2.27	19.99	1.23
RK_3	26.40	7.60	51.00	104.00	2.34	1.80	192.00	0.00	13.56	0.15	2.23	20.75	1.42
RK_3	26.20	7.50	58.00	116.00	2.48	2.40	212.00	0.00	14.22	0.15	2.17	22.73	1.31
MK_1	29.30	7.31	612.00	1224.00	2.08	6.90	148.00	0.00	34.56	0.20	1.99	27.82	1.29
MK_1	29.00	7.20	620.00	1240.00	1.82	1.50	148.00	0.00	35.87	0.20	2.46	26.22	1.31
MK_2	28.90	7.30	580.00	1158.00	1.85	1.20	260.00	0.00	27.39	0.18	2.00	70.73	1.11
MK_2	28.70	7.28	580.00	1160.00	1.98	2.10	264.00	0.00	28.30	0.18	2.26	22.25	1.16
MK_3	28.40	7.01	590.00	1175.00	1.98	1.50	280.00	0.00	31.17	0.23	2.27	28.29	1.05
MK_3	28.20	7.05	592.00	1180.00	1.91	0.90	256.00	0.00	29.87	0.22	2.31	23.95	1.03
RK_5	27.40	7.06	82.00	163.00	1.98	0.90	184.00	0.00	15.00	0.22	1.99	26.40	0.89
RK_5	27.30	7.01	81.00	163.00	1.95	0.90	180.00	0.00	15.65	0.23	2.00	25.46	0.90
RK_4	27.60	7.41	60.00	120.00	2.15	2.70	128.00	0.00	17.48	0.21	2.12	23.58	1.04
RK_4	27.10	7.22	61.00	123.00	2.18	1.80	132.00	0.00	16.17	0.22	2.11	22.07	1.05
RK_6	27.30	7.08	60.00	122.00	2.31	2.10	120.00	0.00	14.61	0.34	2.18	20.75	1.05
RK_6	27.20	7.15	59.00	119.00	2.31	3.00	132.00	0.00	15.65	0.35	2.30	22.63	1.06

(Temp = surface water temperature (°C); TDS=Total Dissolved Solids (ppm); EC= Electrical Conductivity (µS/cm); DO= Dissolved Oxygen (mg/L); BOD, Biochemical Oxygen Demand (mg/L); TH= Total Hardness (mg/L); TA= Total Alkalinity (mg/L); SO_4= sulphate (mg/L); PO_4= Phosphate-Phosphorus (mg/L); NO_3= Nitrate-Nitrogen (mg/L); TN= Total Nitrogen (mg/L); and TP= Total Phosphorus (mg/L)

Appendix XII: Surface water physico-chemical characteristics of Tudun Wada (TW), Makera (MK) and River Kaduna for January, 2014

Stations	Temp	pH	TDS	EC	DO	BOD	TH	TA	SO_4	PO_4	NO_3	TN	TP
TW_1	24.6	7.41	353	705	2.50	0.6	57	0	33.39	0.04	2.19	21.22	0.97
TW_2	25	7.2	399	795	2.20	3	65	0	29.48	0.16	1.98	23.76	1.08
TW_2	24.4	7.04	400	803	2.17	1.5	69	0	32.87	0.16	2.80	22.07	1.01
TW_3	25.1	7.15	399	788	1.83	0.3	54	0	30.13	0.02	2.57	24.71	0.98
TW_3	24.9	7.05	398	797	2.07	0.9	57	0	32.74	0.04	2.52	22.07	1.11
RK_2	26.8	7.23	91	182	2.83	3	44	0	13.70	0.15	2.36	24.33	1.22
RK_2	26.6	7.21	82	165	2.63	2.7	54	0	20.09	0.16	2.39	21.88	1.10
RK_1	25.5	7.21	44	90	2.47	2.7	42	0	16.17	0.18	2.23	21.78	1.12
RK_1	25.5	7.25	51	102	2.53	3.9	47	0	20.09	0.17	2.27	19.99	1.23
RK_3	26.4	7.58	51	104	2.37	1.8	48	0	13.56	0.15	2.23	20.75	1.42
RK_3	26.2	7.5	58	116	2.50	2.4	53	0	14.22	0.15	2.17	22.73	1.31
MK_1	29.3	7.31	612	1224	2.17	6.9	35	0	34.69	0.20	2.00	27.44	1.23
MK_1	29	7.2	620	1240	2.10	4.2	39	0	36.00	0.21	2.54	25.93	1.29
MK_2	28.9	7.3	578	1153	1.83	1.2	68	0	27.26	0.18	2.01	25.56	1.13
MK_2	28.7	7.24	580	1160	1.90	0.6	63	0	28.56	0.18	2.34	22.25	1.12
MK_3	28.4	7.01	589	1175	1.97	0.9	69	0	31.17	0.23	2.29	22.25	1.02
MK_3	28.2	7.04	592	1183	1.93	0.9	65	0	29.87	0.22	2.18	24.14	1.06
RK_5	27.4	7.06	81	162	2.10	0.6	42	0	15.13	0.22	1.90	26.50	0.89
RK_5	27.3	6.99	81	163	2.30	3.3	49	0	15.52	0.23	2.00	25.56	0.90
RK_4	27.6	7.41	59	118	2.23	3.3	31	0	16.17	0.21	2.27	23.95	1.02
RK_4	27.1	7.22	61	123	2.10	2.4	35	0	17.48	0.22	2.07	22.07	1.08
RK_6	27.3	7.08	59	120	2.30	1.8	30	0	14.61	0.34	2.11	20.84	1.15
RK_6	27.2	7.05	59	119	2.40	0	33	0	15.78	0.35	2.18	22.82	1.09

(Temp = surface water temperature (°C); TDS=Total Dissolved Solids (ppm); EC= Electrical Conductivity (µS/cm); DO= Dissolved Oxygen (mg/L); BOD, Biochemical Oxygen Demand (mg/L); TH= Total Hardness (mg/L); TA= Total Alkalinity (mg/L); SO_4= sulphate (mg/L); PO_4= Phosphate-Phosphorus (mg/L); NO_3= Nitrate-Nitrogen (mg/L); TN= Total Nitrogen (mg/L); and TP= Total Phosphorus (mg/L)

Appendix XIII: Surface water physico-chemical characteristics of Tudun Wada (TW), Makera (MK) and River Kaduna for February, 2014

Stations	Temp	pH	TDS	EC	DO	BOD	TH	TA	SO_4	PO_4	NO_3	TN	TP
TW_1	25.7	7.36	417	834	1.089	1.8	54	0	34.43	0.33	0.00	19.99	0.62
TW_2	26.6	7.04	399	791	0.957	3.6	43	0	33.65	0.32	0.00	21.03	0.64
TW_2	26.5	7.02	438	876	0.726	0.6	45	0	32.61	0.31	0.00	20.56	0.84
TW_3	28.1	7.16	438	877	1.089	1.8	40	0	32.61	0.29	0.00	21.22	0.77
TW_3	27.5	7.06	440	879	1.122	0.6	42	0	31.69	0.28	0.00	21.03	0.76
RK_2	28.4	7.46	88	176	1.056	1.2	35	0	15.39	0.28	0.00	28.10	0.68
RK_2	28.1	7.43	88	176	1.122	1.2	36	0	16.70	0.28	0.00	27.91	0.80
RK_1	29.5	7.36	82	166	1.254	3.3	36	0	2.35	0.25	0.00	27.06	0.71
RK_1	29.6	7.3	89	194	0.957	1.8	36	0	3.52	0.24	0.00	27.06	0.81
RK_3	29.6	7.74	86	173	1.023	3	56	0	1.96	0.34	0.00	0.00	0.00
RK_3	28.6	7.48	86	173	0.99	2.1	54	0	2.74	0.31	0.00	0.00	0.00
MK_1	29.5	8.75	843	1705	0.627	2.7	67	0	27.13	0.33	2.19	21.12	0.27
MK_1	29.3	8.79	816	1638	0.495	0.6	64	0	28.17	0.32	2.23	27.16	0.34
MK_2	29.6	8.47	788	1572	0.66	2.1	53	0	18.39	0.20	1.76	27.35	0.49
MK_2	29.2	8.45	790	1584	0.561	0.6	51	0	22.43	0.21	1.84	27.25	0.57
MK_3	30.3	8.69	818	1635	0.66	3	42	0	37.43	0.25	1.70	18.01	0.20
MK_3	29.4	8.64	829	1681	0.528	0.9	43	0	34.82	0.26	1.69	18.29	0.29
RK_5	28.1	8.04	103	206	1.188	4.2	52	0	19.30	0.12	0.33	28.10	0.12
RK_5	29	7.77	103	207	1.221	4.8	51	0	20.61	0.13	0.35	23.86	0.26
RK_4	29.2	8.3	142	283	0.99	2.7	32	0	35.61	0.09	0.22	27.63	0.30
RK_4	28.3	8.08	116	233	1.089	2.7	31	0	34.17	0.10	0.23	24.61	0.42
RK_6	29.1	8.03	102	205	0.99	1.8	35	0	12.39	0.07	0.17	23.86	0.33
RK_6	28.9	8.3	98	197	1.056	3.3	33	0	13.17	0.07	0.18	25.46	0.49

(Temp = surface water temperature (°C); TDS=Total Dissolved Solids (ppm); EC= Electrical Conductivity (µS/cm); DO= Dissolved Oxygen (mg/L); BOD, Biochemical Oxygen Demand (mg/L); TH= Total Hardness (mg/L); TA= Total Alkalinity (mg/L); SO_4= sulphate (mg/L); PO_4= Phosphate-Phosphorus (mg/L); NO_3= Nitrate-Nitrogen (mg/L); TN= Total Nitrogen (mg/L); and TP= Total Phosphorus (mg/L)

Appendix XIV: Surface water physico-chemical characteristics of Tudun Wada (TW), Makera (MK) and River Kaduna for March, 2014

Stations	Temp	pH	TDS	EC	DO	BOD	TH	TA	SO_4	PO_4	NO_3	TN	TP
TW_1	31.3	6.98	526	1050	1.122	1.5	53	304	28.43	0.30	1.91	19.61	0.55
TW_2	31.5	6.9	496	990	0.99	2.7	43	324	32.35	0.23	2.29	22.82	0.18
TW_2	31.2	6.94	499	1001	1.056	2.7	45	336	28.43	0.23	2.31	23.39	0.14
TW_3	31.8	6.94	498	999	1.056	0.9	36	292	31.04	0.22	1.93	23.86	0.71
TW_3	30.5	6.9	496	997	1.089	0.6	38	284	32.35	0.22	1.95	17.45	0.78
RK_2	30.2	7.27	134	188	1.221	2.4	52	256	16.30	0.04	2.22	11.88	0.53
RK_2	30.8	7.12	94	267	1.353	2.4	55	268	17.61	0.05	2.20	13.77	0.69
RK_1	30.8	7.31	36	138	1.452	5.1	41	364	14.09	0.03	1.92	19.14	0.47
RK_1	30.1	7.3	32	135	1.485	4.8	43	376	15.78	0.03	1.90	19.71	0.51
RK_3	28.9	7.45	84	169	1.287	4.8	47	328	3.00	0.02	2.23	15.94	0.39
RK_3	30.3	7.25	89	177	1.353	4.8	46	324	4.30	0.03	2.19	17.82	0.51
MK_1	32.8	7.21	707	1414	1.023	2.7	57	324	28.43	0.35	2.80	19.43	1.12
MK_1	31.8	7.71	701	1399	0.99	3	55	332	29.74	0.32	2.78	19.71	1.12
MK_2	33.2	7.71	711	1422	1.023	2.4	45	288	19.69	0.23	2.20	25.08	1.09
MK_2	33.3	7.66	711	1424	1.023	3	43	296	20.61	0.22	2.21	28.10	1.01
MK_3	33	7.4	690	1345	0.825	1.5	41	248	34.82	0.25	1.94	25.56	0.91
MK_3	33.1	7.42	688	1389	1.056	3.3	43	256	37.96	0.25	1.93	19.33	0.44
RK_5	31.5	7.45	108	212	1.782	7.5	45	288	24.91	0.13	1.67	20.75	0.14
RK_5	31.1	7.35	108	211	1.584	6.3	47	296	22.96	0.13	1.82	22.63	0.71
RK_4	30.2	7.89	81	162	1.419	6.3	35	216	38.87	0.11	1.57	24.42	0.13
RK_4	30.5	7.52	80	161	1.386	5.4	34	212	36.39	0.12	1.49	24.52	0.18
RK_6	32	7.45	69	139	1.518	6.6	42	204	25.43	0.10	2.47	25.37	0.22
RK_6	31.2	7.48	73	147	1.386	6	45	212	21.26	0.09	2.48	25.56	0.19

(Temp = surface water temperature (°C); TDS=Total Dissolved Solids (ppm); EC= Electrical Conductivity (µS/cm); DO= Dissolved Oxygen (mg/L); BOD, Biochemical Oxygen Demand (mg/L); TH= Total Hardness (mg/L); TA= Total Alkalinity (mg/L); SO_4= sulphate (mg/L); PO_4= Phosphate-Phosphorus (mg/L); NO_3= Nitrate-Nitrogen (mg/L); TN= Total Nitrogen (mg/L); and TP= Total Phosphorus (mg/L)

Appendix XV: Surface water physico-chemical characteristics of Tudun Wada (TW), Makera (MK) and River Kaduna for April, 2014

Stations	Temp	pH	TDS	EC	DO	BOD	TH	TA	SO_4	PO_4	NO_3	TN	TP
TW_1	30.30	7.09	363.00	764.00	1.19	5.10	135.00	356.00	0.00	0.34	1.99	20.75	0.39
TW_1	30.80	7.04	380.00	760.00	1.29	7.20	130.00	368.00	0.00	0.31	2.11	20.09	0.50
TW_2	30.50	7.12	387.00	795.00	1.35	8.40	175.00	420.00	0.00	0.33	1.45	21.31	1.10
TW_2	30.60	7.06	414.00	832.00	1.22	7.80	179.00	412.00	0.00	0.32	1.56	21.41	1.08
TW_3	30.80	7.01	398.00	796.00	1.49	6.60	131.00	404.00	0.00	0.33	2.38	23.76	0.85
TW_3	31.60	7.02	406.00	801.00	1.55	7.50	130.00	412.00	0.00	0.32	2.35	27.44	0.87
RK_2	29.70	6.88	117.00	239.00	1.35	5.40	195.00	408.00	0.00	0.16	2.81	17.82	0.81
RK_2	29.40	6.87	118.00	236.00	1.22	3.60	191.00	420.00	0.00	0.16	2.74	19.61	0.71
RK_1	28.30	7.30	22.00	44.00	1.68	9.00	85.00	276.00	0.00	0.15	1.98	19.80	0.99
RK_1	28.00	7.25	19.00	39.00	1.58	8.70	83.00	292.00	0.00	0.14	1.99	25.18	1.08
RK_3	29.20	8.16	178.00	350.00	1.58	2.70	43.00	180.00	35.22	0.17	2.01	22.35	0.54
RK_3	29.20	8.10	183.00	365.00	2.05	7.50	45.00	196.00	35.61	0.18	2.46	22.91	0.54
MK_1	32.50	9.50	582.00	1165.00	1.09	3.30	185.00	500.00	0.00	0.35	2.66	16.50	7.14
MK_1	32.70	9.53	585.00	1175.00	1.16	4.20	193.00	484.00	0.00	0.34	2.72	16.22	0.59
MK_2	33.30	9.35	570.00	1140.00	1.06	2.40	199.00	556.00	0.00	0.33	1.11	19.14	0.78
MK_2	33.40	9.36	566.00	1120.00	1.16	3.90	223.00	548.00	0.00	0.34	1.21	19.14	0.83
MK_3	32.80	9.38	586.00	1172.00	1.16	3.60	161.00	488.00	0.00	0.32	1.83	22.63	1.02
MK_3	32.60	9.44	582.00	1107.00	1.09	3.60	165.00	476.00	0.00	0.32	1.85	22.44	0.90
RK_5	29.20	9.80	101.00	202.00	1.35	1.80	132.00	364.00	0.00	0.23	2.32	25.65	0.50
RK_5	32.20	8.20	95.00	186.00	1.42	3.60	135.00	376.00	0.00	0.23	2.34	25.37	0.62
RK_4	29.00	8.05	52.00	106.00	1.52	2.10	119.00	312.00	0.00	0.27	1.74	24.14	0.60
RK_4	28.70	8.03	54.00	107.00	1.49	2.70	121.00	304.00	0.00	0.28	1.78	25.18	0.49
RK_6	29.40	7.95	26.00	56.00	1.25	0.60	111.00	276.00	0.00	0.34	1.48	26.88	0.96
RK_6	29.00	8.03	26.00	53.00	1.29	1.20	115.00	288.00	0.00	0.25	1.50	26.03	1.06

(Temp = surface water temperature (°C); TDS=Total Dissolved Solids (ppm); EC= Electrical Conductivity (µS/cm); DO= Dissolved Oxygen (mg/L); BOD, Biochemical Oxygen Demand (mg/L); TH= Total Hardness (mg/L); TA= Total Alkalinity (mg/L); SO_4= sulphate (mg/L); PO_4= Phosphate-Phosphorus (mg/L); NO_3= Nitrate-Nitrogen (mg/L); TN= Total Nitrogen (mg/L); and TP= Total Phosphorus (mg/L)

Appendix XVI: Surface water physico-chemical characteristics of Tudun Wada (TW), Makera (MK) and River Kaduna for May, 2014

Stations	Temp	pH	TDS	EC	DO	BOD	TH	TA	SO_4	PO_4	NO_3	TN	TP
TW_1	31.50	9.20	394.00	789.00	0.53	0.30	45.00	460.00	30.26	0.08	2.30	28.29	0.92
TW_2	31.20	9.09	399.00	798.00	0.40	0.60	41.00	356.00	38.87	0.13	2.17	25.18	0.62
TW_2	31.60	9.13	399.00	792.00	0.59	0.90	43.00	380.00	38.09	0.13	2.37	25.56	0.66
TW_3	31.50	8.64	461.00	910.00	0.59	0.90	34.00	324.00	28.83	0.09	2.59	21.12	1.06
TW_3	31.60	8.66	441.00	881.00	0.63	0.30	39.00	356.00	29.09	0.11	2.26	21.78	1.10
RK_2	29.50	8.56	242.00	489.00	1.02	0.30	46.00	228.00	21.65	0.09	2.31	22.73	0.92
RK_2	29.30	8.54	233.00	467.00	1.02	0.30	49.00	260.00	21.00	0.10	2.65	21.69	0.88
RK_1	29.00	7.81	30.00	63.00	1.91	1.80	35.00	208.00	25.17	0.25	2.53	26.03	0.53
RK_1	29.10	7.80	28.00	56.00	1.68	0.30	41.00	236.00	24.78	0.25	1.98	21.69	0.55
RK_3	29.20	8.16	178.00	350.00	1.58	2.70	43.00	180.00	35.22	0.17	2.01	22.35	0.54
RK_3	29.20	8.10	183.00	365.00	2.05	7.50	45.00	196.00	35.61	0.18	2.46	22.91	0.54
MK_1	30.00	6.71	406.00	815.00	1.09	6.69	55.00	476.00	37.56	0.03	2.59	26.59	0.57
MK_1	29.00	6.80	406.00	812.00	0.89	4.50	57.00	500.00	36.65	0.03	1.97	27.06	0.56
MK_2	30.20	7.10	415.00	829.00	0.99	5.70	59.00	460.00	30.00	0.07	1.98	26.03	0.68
MK_2	30.00	7.20	414.00	827.00	0.96	4.20	56.00	476.00	30.13	0.08	2.03	26.31	0.66
MK_3	30.70	7.01	399.00	798.00	0.69	0.30	39.00	500.00	30.65	0.03	2.54	22.73	1.08
MK_3	30.90	7.02	399.00	798.00	0.43	0.90	42.00	516.00	30.00	0.03	2.62	23.39	1.11
RK_5	30.00		86.00	174.00	1.29	2.70	29.00	260.00	29.74	0.13	1.97	26.50	0.98
RK_5	30.00		84.00	168.00	1.35	1.80	32.00	292.00	28.83	0.14	1.98	26.88	0.98
RK_4	30.20	7.40	111.00	221.00	1.19	1.80	44.00	212.00	32.35	0.13	2.14	24.80	0.94
RK_4	30.10	7.42	110.00	221.00	1.02	0.30	46.00	208.00	31.43	0.13	2.63	25.37	0.97
RK_6	30.10	7.19	37.00	75.00	0.99	0.00	49.00	208.00	29.22	0.20	1.91	0.00	0.97
RK_6	30.20	7.20	37.00	74.00	1.16	1.50	47.00	200.00	28.69	0.20	1.97	0.00	1.02

(Temp = surface water temperature (°C); TDS=Total Dissolved Solids (ppm); EC= Electrical Conductivity (µS/cm); DO= Dissolved Oxygen (mg/L); BOD, Biochemical Oxygen Demand (mg/L); TH= Total Hardness (mg/L); TA= Total Alkalinity (mg/L); SO_4= sulphate (mg/L); PO_4= Phosphate-Phosphorus (mg/L); NO_3= Nitrate-Nitrogen (mg/L); TN= Total Nitrogen (mg/L); and TP= Total Phosphorus (mg/L)

Appendix XVII: Surface water physico-chemical characteristics of Tudun Wada (TW), Makera (MK) and River Kaduna for June, 2014

Stations	Temp	pH	TDS	EC	DO	BOD	TH	TA	SO_4	PO_4	NO_3	TN	TP
TW_1	26	7.96	321	644	0.83	1.50	49.00	356.00	32.61	0.07	0.00	26.03	0.74
TW_2	26.4	7.98	396	726	0.66	1.50	35.00	348.00	36.39	0.04	0.00	27.54	0.44
TW_2	26.4	7.97	312	724	0.69	0.30	36.00	332.00	36.52	0.07	0.00	25.18	0.61
TW_3	27.1	7.9	345	692	0.66	0.00	41.00	292.00	4.83	0.06	0.00	21.22	0.68
TW_3	26.8	7.9	344	688	0.76	0.90	41.00	304.00	5.22	0.07	0.00	20.18	0.56
RK_2	27.7	7.88	139	279	0.69	0.30	46.00	312.00	1.43	0.04	0.00	20.46	0.32
RK_2	27.6	7.9	140	280	0.69	0.30	43.00	300.00	1.30	0.04	0.00	19.90	0.48
RK_1	27.6	7.9	23	47	2.15	4.20	51.00	224.00	10.04	0.25	0.00	23.29	0.48
RK_1	27.7	7.89	23	46	1.72	0.30	49.00	236.00	10.43	0.25	0.00	22.25	0.32
RK_3	27.5	7.85	32	63	1.82	2.40	42.00	188.00	12.78	0.26	0.00	22.44	0.75
RK_3	27.6	7.84	32	64	1.78	3.30	41.00	180.00	11.74	0.26	0.00	21.50	0.66
MK_1	29.2	7.9	430	860	0.73	0.60	34.00	348.00	15.13	0.09	0.00	27.44	1.45
MK_1	29	7.87	420	840	1.06	0.60	37.00	344.00	15.39	0.09	0.00	27.06	1.46
MK_2	29	7.79	405	811	1.06	0.60	37.00	364.00	2.09	0.08	0.00	25.18	1.10
MK_2	29	7.78	405	810	0.86	1.80	41.00	356.00	1.96	0.04	0.00	26.50	1.16
MK_3	28.9	7.78	403	807	0.73	0.60	41.00	348.00	23.35	0.05	0.00	23.20	1.87
MK_3	27.9	7.78	400	800	0.66	0.00	42.00	340.00	23.48	0.05	0.00	23.48	1.90
RK_5	27.9	7.97	81	164	1.82	1.50	37.00	160.00	5.09	0.13	0.00	23.48	1.18
RK_5	27.8	7.69	81	162	1.62	2.70	41.00	168.00	52.17	0.02	0.00	24.99	1.21
RK_4	27.9	7.8	24	49	1.49	1.50	45.00	184.00	10.30	0.23	0.00	22.54	1.57
RK_4	27.9	7.97	25	50	1.82	1.50	47.00	168.00	10.43	0.11	0.00	22.73	1.60
RK_6	28.6	7.99	23	46	1.42	0.90	34.00	156.00	11.35	0.26	0.00	21.69	1.02
RK_6	27.9	8	22	44	1.42	0.90	37.00	164.00	11.48	0.26	0.00	21.97	1.08

(Temp = surface water temperature (°C); TDS=Total Dissolved Solids (ppm); EC= Electrical Conductivity (µS/cm); DO= Dissolved Oxygen (mg/L); BOD, Biochemical Oxygen Demand (mg/L); TH= Total Hardness (mg/L); TA= Total Alkalinity (mg/L); SO_4= sulphate (mg/L); PO_4= Phosphate-Phosphorus (mg/L); NO_3= Nitrate-Nitrogen (mg/L); TN= Total Nitrogen (mg/L); and TP= Total Phosphorus (mg/L)

Appendix XVIII: Surface water physico-chemical characteristics of Tudun Wada (TW), Makera (MK) and River Kaduna for July, 2014

Stations	Temp	pH	TDS	EC	DO	BOD	TH	TA	SO4	PO4	NO3	TN	TP
TW_1	25.70	8.15	305.00	609.00	0.83	1.50	52.00	92.00	34.82	0.25	3.62	27.25	0.82
TW_2	26.00	8.18	353.00	707.00	0.73	1.50	43.00	116.00	37.04	0.24	2.60	27.25	0.34
TW_2	26.10	8.19	350.00	707.00	0.66	0.60	41.00	104.00	35.35	0.24	2.58	26.88	0.21
TW_3	26.50	8.15	315.00	630.00	0.83	1.80	40.00	120.00	36.65	0.24	3.44	22.16	0.33
TW_3	26.20	8.14	314.00	629.00	0.69	0.60	38.00	120.00	36.00	0.13	3.46	22.54	0.49
RK_2	26.60	8.60	22.00	44.00	0.86	1.80	35.00	144.00	15.65	0.24	2.07	21.31	0.44
RK_2	26.50	8.65	23.00	45.00	0.92	2.40	32.00	136.00	15.13	0.24	2.10	23.20	0.61
RK_1	26.40	8.40	18.00	36.00	1.32	3.60	29.00	132.00	13.56	0.29	2.51	22.35	0.44
RK_1	26.50	8.35	17.00	35.00	1.35	4.50	31.00	140.00	13.83	0.28	2.50	23.29	0.30
RK_3	26.40	8.29	22.00	44.00	1.16	1.80	45.00	156.00	13.83	0.28	2.49	23.39	0.36
RK_3	26.50	8.30	22.00	43.00	1.39	3.00	42.00	140.00	14.09	0.29	2.54	22.54	0.50
MK_1	29.00	8.33	420.00	840.00	1.49	12.00	67.00	148.00	28.17	0.30	3.56	23.01	1.37
MK_1	28.90	8.31	420.00	840.00	1.85	13.20	59.00	140.00	28.56	0.31	3.48	22.07	1.39
MK_2	28.70	9.45	456.00	903.00	1.12	8.70	75.00	156.00	18.13	0.12	2.71	24.61	1.38
MK_2	28.90	9.30	440.00	890.00	1.29	9.00	72.00	116.00	18.39	0.12	2.63	24.99	1.36
MK_3	29.00	8.09	410.00	819.00	0.96	6.90	73.00	172.00	36.91	0.16	2.68	26.22	1.19
MK_3	28.40	8.14	413.00	825.00	0.73	3.90	70.00	188.00	37.43	0.17	2.60	25.56	1.28
RK_5	27.50	8.33	25.00	50.00	0.89	0.60	56.00	216.00	35.61	0.14	2.75	22.91	1.33
RK_5	27.40	8.30	24.00	49.00	1.02	0.30	52.00	232.00	36.13	0.15	2.71	22.73	1.36
RK_4	26.70	8.03	22.00	44.00	0.83	1.50	43.00	136.00	34.43	0.16	2.65	23.48	1.08
RK_4	26.50	8.01	23.00	45.00	0.89	2.10	41.00	148.00	34.69	0.16	2.69	22.63	1.18
RK_6	27.90	8.12	22.00	44.00	1.16	0.30	48.00	124.00	31.56	0.15	2.60	22.73	1.13
RK_6	27.50	8.10	23.00	43.00	1.22	0.60	40.00	132.00	31.30	0.15	2.58	22.54	1.19

(Temp = surface water temperature (°C); TDS=Total Dissolved Solids (ppm); EC= Electrical Conductivity (µS/cm); DO= Dissolved Oxygen (mg/L); BOD, Biochemical Oxygen Demand (mg/L); TH= Total Hardness (mg/L); TA= Total Alkalinity (mg/L); SO_4= sulphate (mg/L); PO_4= Phosphate-Phosphorus (mg/L); NO_3= Nitrate-Nitrogen (mg/L); TN= Total Nitrogen (mg/L); and TP= Total Phosphorus (mg/L)

Appendix XIX: Surface water physico-chemical characteristics of Tudun Wada (TW), Makera (MK) and River Kaduna for August, 2014

Stations	Temp	pH	TDS	EC	DO	BOD	TH	TA	SO_4	PO_4	NO_3	TN	TP
TW_1	27.80	8.37	418.00	837.00	1.25	3.90	75.00	388.00	23.48	0.05	2.16	26.03	0.74
TW_2	27.90	8.47	405.00	811.00	0.89	0.60	35.00	356.00	29.22	0.01	3.11	27.54	0.44
TW_2	27.90	8.47	415.00	830.00	0.63	1.20	40.00	344.00	30.52	0.02	2.81	25.18	0.61
TW_3	28.20	8.43	449.00	899.00	0.89	3.60	37.00	408.00	36.00	0.07	2.34	21.22	0.68
TW_3	28.00	8.40	450.00	900.00	0.73	0.60	39.00	396.00	30.26	0.02	2.41	20.18	0.56
RK_2	27.20	8.33	199.00	399.00	1.12	0.60	65.00	260.00	41.22	0.02	2.11	20.46	0.32
RK_2	27.30	8.43	204.00	408.00	1.02	0.30	67.00	268.00	39.26	0.06	2.13	19.90	0.48
RK_1	26.10	8.35	31.00	61.00	0.79	1.20	43.00	180.00	43.69	0.11	2.58	23.29	0.48
RK_1	26.00	8.34	30.00	29.00	1.06	6.00	45.00	184.00	41.22	0.10	2.39	22.25	0.32
RK_3	26.20	8.33	50.00	100.00	1.12	3.00	46.00	252.00	28.83	0.08	1.90	22.44	0.75
RK_3	26.10	8.30	49.00	99.00	1.06	4.50	48.00	256.00	27.65	0.03	2.03	21.50	0.66
MK_1	27.70	8.79	549.00	1090.00	0.89	0.60	45.00	460.00	30.26	0.10	2.52	27.44	1.45
MK_1	27.80	8.79	545.00	1090.00	0.83	0.30	49.00	448.00	29.09	0.12	2.52	27.06	1.46
MK_2	27.70	8.72	522.00	1036.00	0.73	1.20	46.00	420.00	28.69	0.05	3.13	25.18	1.10
MK_2	27.70	8.73	518.00	1044.00	0.69	1.50	48.00	408.00	30.26	0.02	3.05	26.50	1.16
MK_3	27.80	8.61	523.00	1047.00	0.76	1.20	65.00	412.00	34.96	0.06	2.32	23.20	1.87
MK_3	27.70	8.60	517.00	1035.00	0.89	1.20	63.00	392.00	31.04	0.05	2.42	23.48	1.90
RK_5	25.60	8.25	28.00	56.00	1.12	1.80	47.00	216.00	28.69	0.02	1.99	23.48	1.18
RK_5	25.60	8.27	29.00	57.00	1.22	2.10	45.00	208.00	26.35	0.01	2.03	24.99	1.21
RK_4	26.30	8.27	27.00	54.00	1.06	3.00	57.00	172.00	31.43	0.09	2.02	22.54	1.57
RK_4	26.40	8.29	26.00	53.00	1.16	1.20	52.00	180.00	28.83	0.12	2.08	22.73	1.60
RK_6	26.50	8.30	37.00	73.00	1.39	1.20	46.00	188.00	37.96	0.12	2.56	21.69	1.02
RK_6	26.80	8.33	38.00	74.00	1.32	0.00	45.00	172.00	34.04	0.11	2.64	21.97	1.08

(Temp = surface water temperature (°C); TDS=Total Dissolved Solids (ppm); EC= Electrical Conductivity (µS/cm); DO= Dissolved Oxygen (mg/L); BOD, Biochemical Oxygen Demand (mg/L); TH= Total Hardness (mg/L); TA= Total Alkalinity (mg/L); SO_4= sulphate (mg/L); PO_4= Phosphate-Phosphorus (mg/L); NO_3= Nitrate-Nitrogen (mg/L); TN= Total Nitrogen (mg/L); and TP= Total Phosphorus (mg/L)

Appendix XX: Surface water physico-chemical characteristics of Tudun Wada (TW), Makera (MK) and River Kaduna for September, 2014

Stations	Temp	pH	TDS	EC	DO	BOD	TH	TA	SO4	PO4	NO3	TN	TP
TW_1	29.00	8.47	339.00	680.00	0.96	1.20	22.00	292.00	14.48	0.14	2.33	0.00	0.00
TW_2	29.90	8.56	386.00	773.00	0.76	0.90	27.00	224.00	14.09	0.06	2.27	0.00	0.00
TW_2	29.90	8.52	386.00	772.00	0.89	1.80	24.00	220.00	14.35	0.07	2.31	0.00	0.00
TW_3	29.90	8.51	384.00	758.00	1.09	3.60	37.00	328.00	15.00	0.15	2.46	0.00	0.00
TW_3	30.00	8.55	382.00	764.00	1.16	3.60	35.00	320.00	14.74	0.14	2.52	0.00	0.00
RK_2	31.00	8.45	139.00	278.00	1.12	2.70	29.00	172.00	27.39	0.11	2.32	0.00	0.00
RK_2	31.50	8.43	140.00	280.00	1.02	1.50	27.00	164.00	24.91	0.12	2.29	0.00	0.00
RK_1	31.50	8.41	106.00	212.00	1.45	3.00	35.00	140.00	31.43	0.14	2.37	0.00	0.00
RK_1	31.00	8.32	104.00	230.00	1.52	4.50	37.00	144.00	26.22	0.13	2.40	0.00	0.00
RK_3	31.05	8.34	325.00	650.00	0.92	0.90	42.00	212.00	33.00	0.13	2.39	0.00	0.00
RK_3	31.06	8.32	323.00	648.00	0.86	1.20	42.00	208.00	31.43	0.12	2.43	0.00	0.00
MK_1	31.80	10.51	508.00	1016.00	0.73	0.60	16.00	300.00	37.69	0.05	2.27	0.00	0.00
MK_1	31.80	10.79	502.00	1005.00	0.69	0.90	14.00	284.00	33.78	0.04	2.35	0.00	0.00
MK_2	31.90	10.09	466.00	932.00	0.69	0.30	15.00	260.00	23.74	0.06	2.40	0.00	0.00
MK_2	31.90	10.22	465.00	938.00	0.83	1.20	14.00	252.00	25.69	0.06	2.43	0.00	0.00
MK_3	31.80	8.38	488.00	978.00	0.59	2.10	41.00	196.00	31.17	0.04	2.47	0.00	0.00
MK_3	31.80	8.33	486.00	968.00	0.69	1.80	40.00	208.00	32.22	0.03	2.53	0.00	0.00
RK_5	27.20	9.20	36.00	73.00	0.92	2.40	19.00	268.00	36.78	0.05	2.57	0.00	0.00
RK_5	27.90	9.01	36.00	73.00	0.96	2.10	21.00	264.00	34.69	0.05	2.61	0.00	0.00
RK_4	29.90	8.90	35.00	71.00	1.02	0.90	21.00	156.00	21.00	0.06	2.60	0.00	0.00
RK_4	27.80	8.70	34.00	69.00	1.06	2.10	24.00	144.00	16.70	0.06	2.62	0.00	0.00
RK_6	27.80	9.83	30.00	60.00	0.89	1.80	32.00	180.00	18.13	0.03	2.03	0.00	0.00
RK_6	27.90	9.43	35.00	70.00	0.79	1.20	30.00	172.00	22.43	0.04	2.00	0.00	0.00

(Temp = surface water temperature (°C); TDS=Total Dissolved Solids (ppm); EC= Electrical Conductivity (µS/cm); DO= Dissolved Oxygen (mg/L); BOD, Biochemical Oxygen Demand (mg/L); TH= Total Hardness (mg/L); TA= Total Alkalinity (mg/L); SO_4= sulphate (mg/L); PO_4= Phosphate-Phosphorus (mg/L); NO_3= Nitrate-Nitrogen (mg/L); TN= Total Nitrogen (mg/L); and TP= Total Phosphorus (mg/L)

Appendix XXI: Surface water physico-chemical characteristics of Tudun Wada (TW), Makera (MK) and River Kaduna for October, 2014

Stations	Temp	pH	TDS	EC	DO	BOD	TH	TA	SO_4	PO_4	NO_3	TN	TP
TW_1	27.40	7.06	378.00	760.00	1.06	2.40	12.00	456.00	16.30	0.05	2.18	27.25	0.82
TW_2	28.40	7.06	391.00	792.00	0.73	0.60	10.00	476.00	15.00	0.05	2.08	27.25	0.34
TW_2	28.60	7.09	297.00	605.00	0.76	1.20	12.00	464.00	15.91	0.05	2.07	26.88	0.21
TW_3	28.80	7.00	364.00	730.00	0.83	1.50	32.00	444.00	15.65	0.05	2.03	22.16	0.33
TW_3	28.70	6.98	360.00	721.00	0.79	2.10	31.00	460.00	18.91	0.05	2.05	22.54	0.49
RK_2	30.20	6.87	269.00	604.00	0.79	3.00	12.00	440.00	24.91	0.05	2.11	21.31	0.44
RK_2	29.90	6.82	276.00	583.00	0.89	3.00	13.00	432.00	25.69	0.06	2.18	23.20	0.61
RK_1	30.10	7.00	92.00	192.00	0.89	1.80	19.00	148.00	14.35	0.05	2.01	22.35	0.44
RK_1	30.90	7.02	91.00	181.00	1.16	4.50	16.00	156.00	15.26	0.05	2.05	23.29	0.30
RK_3	30.40	6.81	130.00	260.00	0.92	2.10	21.00	244.00	1.57	0.07	2.07	23.39	0.36
RK_3	30.10	6.80	128.00	255.00	1.12	3.00	23.00	256.00	2.48	0.08	2.10	22.54	0.50
MK_1	30.80	6.15	443.00	876.00	0.56	2.10	21.00	508.00	27.91	0.04	2.18	23.01	1.37
MK_1	30.70	6.12	432.00	865.00	0.53	1.50	22.00	516.00	25.83	0.05	2.10	22.07	1.39
MK_2	31.00	6.17	459.00	908.00	0.36	0.30	23.00	504.00	30.65	0.05	2.11	24.61	1.38
MK_2	30.80	6.21	449.00	901.00	0.23	0.30	21.00	496.00	30.00	0.06	2.08	24.99	1.36
MK_3	30.60	6.55	466.00	920.00	0.23	0.30	27.00	472.00	37.96	0.04	2.19	26.22	1.19
MK_3	30.70	6.45	468.00	939.00	0.26	0.30	24.00	500.00	36.65	0.04	2.18	25.56	1.28
RK_5	28.40	6.73	76.00	144.00	1.12	7.50	23.00	140.00	36.91	0.02	2.29	22.91	1.33
RK_5	28.50	6.65	73.00	158.00	1.16	7.50	25.00	132.00	35.09	0.02	2.26	22.73	1.36
RK_4	29.90	6.82	46.00	92.00	0.73	0.90	31.00	144.00	32.22	0.05	2.19	23.48	1.08
RK_4	29.60	6.73	50.00	101.00	1.12	3.30	30.00	136.00	30.13	0.04	2.17	22.63	1.18
RK_6	29.90	6.80	43.00	85.00	1.16	1.50	39.00	84.00	25.30	0.03	1.93	22.73	1.13
RK_6	29.60	6.73	38.00	77.00	1.16	1.80	36.00	80.00	24.91	0.03	1.97	22.54	1.19

(Temp = surface water temperature (°C); TDS=Total Dissolved Solids (ppm); EC= Electrical Conductivity (µS/cm); DO= Dissolved Oxygen (mg/L); BOD, Biochemical Oxygen Demand (mg/L); TH= Total Hardness (mg/L); TA= Total Alkalinity (mg/L); SO_4= sulphate (mg/L); PO_4= Phosphate-Phosphorus (mg/L); NO_3= Nitrate-Nitrogen (mg/L); TN= Total Nitrogen (mg/L); and TP= Total Phosphorus (mg/L)

Appendix XXII: Surface water physico-chemical characteristics of Tudun Wada (TW), Makera (MK) and River Kaduna for November, 2014

Stations	Temp	pH	TDS	EC	DO	BOD	TH	TA	SO_4	PO_4	NO_3	TN	TP
TW_1	25.30	6.99	345.00	690.00	0.96	4.20	15.00	300.00	16.30	0.04	2.04	2.07	0.90
TW_2	25.90	6.99	304.00	608.00	0.73	3.00	14.00	316.00	17.09	0.02	2.07	2.08	0.97
TW_2	25.60	6.96	344.00	688.00	0.69	2.40	16.00	304.00	16.96	0.03	2.07	2.04	1.08
TW_3	26.60	7.03	343.00	686.00	0.69	2.10	32.00	276.00	24.91	0.02	2.26	2.46	1.01
TW_3	26.60	6.93	345.00	691.00	0.66	2.10	30.00	268.00	23.35	0.02	2.11	2.48	0.98
RK_2	26.00	7.23	131.00	262.00	0.63	1.20	17.00	132.00	12.78	0.05	2.26	2.23	1.11
RK_2	25.80	7.03	132.00	263.00	0.59	1.20	19.00	144.00	12.39	0.06	2.25	2.19	1.22
RK_1	25.20	7.20	48.00	95.00	0.86	0.30	19.00	100.00	14.22	0.06	2.18	2.16	1.10
RK_1	25.20	7.03	60.00	120.00	0.92	1.20	20.00	108.00	13.83	0.07	2.22	2.56	1.12
RK_3	26.30	7.23	52.00	104.00	0.89	1.80	29.00	108.00	15.52	0.06	2.10	2.54	1.23
RK_3	26.50	7.06	55.00	110.00	0.92	2.40	27.00	104.00	13.96	0.06	2.08	2.64	1.42
MK_1	29.80	9.75	650.00	1302.00	0.30	1.80	21.00	532.00	26.22	0.01	2.02	2.61	1.31
MK_1	30.10	9.60	647.00	1295.00	0.23	1.20	20.00	548.00	27.52	0.02	2.11	2.70	1.29
MK_2	29.30	9.65	632.00	1264.00	0.63	4.20	22.00	580.00	25.69	0.02	2.11	2.73	1.31
MK_2	29.50	9.63	630.00	1260.00	0.56	3.30	20.00	596.00	26.22	0.02	2.08	2.52	1.11
MK_3	29.50	8.55	560.00	1124.00	0.33	1.80	29.00	488.00	27.65	0.01	2.21	2.45	1.16
MK_3	29.30	8.70	560.00	1123.00	0.43	2.40	29.00	500.00	28.17	0.02	2.14	2.40	1.05
RK_5	26.60	8.00	71.00	141.00	0.83	0.30	21.00	116.00	29.35	0.04	2.22	2.31	1.03
RK_5	26.80	8.04	71.00	140.00	0.96	1.50	23.00	108.00	28.04	0.04	2.18	2.17	0.89
RK_4	26.30	8.06	46.00	92.00	0.96	2.10	30.00	128.00	27.39	0.02	2.25	2.31	0.90
RK_4	25.30	7.79	47.00	94.00	0.89	1.20	31.00	136.00	26.22	0.03	2.18	1.96	1.04
RK_6	25.60	7.73	46.00	91.00	0.89	0.30	37.00	100.00	28.04	0.05	1.90	2.05	1.05
RK_6	25.90	7.68	46.00	92.00	0.89	0.90	33.00	104.00	26.74	0.05	1.99	2.05	1.05
												2.39	1.06

(Temp = surface water temperature (°C); TDS=Total Dissolved Solids (ppm); EC= Electrical Conductivity (µS/cm); DO= Dissolved Oxygen (mg/L); BOD, Biochemical Oxygen Demand (mg/L); TH= Total Hardness (mg/L); TA= Total Alkalinity (mg/L); SO_4= sulphate (mg/L); PO_4= Phosphate-Phosphorus (mg/L); NO_3= Nitrate-Nitrogen (mg/L); TN= Total Nitrogen (mg/L); and TP= Total Phosphorus (mg/L)

Appendix XXIII: Surface water physico-chemical characteristics of Tudun Wada (TW), Makera (MK) and River Kaduna for December, 2014

Stations	Temp	pH	TDS	EC	DO	BOD	TH	TA	SO_4	PO_4	NO_3	TN	TP
TW_1	20.60	7.01	403.00	798.00	0.73	0.60	12.00	1120.00	22.17	0.18	2.13	24.24	0.18
TW_2	22.80	7.10	247.00	498.00	0.76	1.20	13.00	1280.00	21.52	0.16	1.74	21.22	0.24
TW_2	22.40	7.03	259.00	518.00	0.69	0.90	12.00	1360.00	20.87	0.16	1.70	23.76	0.18
TW_3	21.90	6.81	359.00	731.00	0.83	0.90	15.00	752.00	24.65	0.14	2.18	22.07	0.26
TW_3	21.70	6.78	365.00	730.00	0.73	0.30	14.00	720.00	24.78	0.13	2.17	24.71	0.13
RK_2	22.40	7.26	80.00	162.00	0.99	0.30	12.00	180.00	14.35	0.11	1.58	22.07	0.24
RK_2	22.10	7.13	58.00	125.00	1.06	0.60	11.00	160.00	13.04	0.11	1.52	24.33	0.12
RK_1	22.20	7.27	48.00	99.00	1.09	0.90	14.00	200.00	16.70	0.13	1.37	21.88	0.25
RK_1	22.10	7.24	51.00	102.00	1.16	1.20	12.00	192.00	16.30	0.12	1.32	21.78	0.20
RK_3	22.10	7.07	58.00	117.00	1.06	0.60	13.00	196.00	15.26	0.12	1.68	19.99	0.25
RK_3	21.30	7.00	52.00	108.00	1.16	1.50	12.00	180.00	15.00	0.12	1.65	20.75	0.10
MK_1	26.90	8.15	451.00	904.00	0.69	0.30	11.00	1520.00	37.17	0.22	2.59	22.73	0.22
MK_1	26.30	8.38	455.00	911.00	0.76	0.60	10.00	1440.00	36.52	0.22	2.60	27.82	0.34
MK_2	26.40	7.25	460.00	922.00	0.66	0.90	12.00	1680.00	29.22	0.21	2.76	26.22	0.35
MK_2	26.30	7.62	456.00	914.00	0.63	0.30	11.00	1600.00	28.96	0.21	2.73	70.73	0.28
MK_3	26.30	8.21	561.00	1122.00	0.69	0.60	13.00	2000.00	33.78	0.27	2.69	22.25	0.31
MK_3	27.00	8.15	590.00	1184.00	0.66	0.90	12.00	1920.00	33.91	0.27	2.64	28.29	0.24
RK_5	24.80	7.45	79.00	164.00	1.02	0.60	10.00	236.00	14.61	0.13	1.74	23.95	0.24
RK_5	23.40	7.17	77.00	156.00	1.12	1.20	11.00	220.00	14.35	0.11	1.70	26.40	0.19
RK_4	22.90	7.41	54.00	109.00	0.89	0.90	10.00	224.00	13.17	0.11	1.74	25.46	0.23
RK_4	22.80	7.37	55.00	111.00	0.79	2.40	11.00	216.00	13.04	0.11	1.70	23.58	0.18
RK_6	24.00	7.48	53.00	108.00	0.86	0.90	10.00	208.00	15.00	0.09	1.66	22.07	0.22
RK_6	22.90	7.39	52.00	105.00	0.83	1.50	11.00	200.00	18.78	0.10	1.60	20.75	0.21

(Temp = surface water temperature (°C); TDS=Total Dissolved Solids (ppm); EC= Electrical Conductivity (µS/cm); DO= Dissolved Oxygen (mg/L); BOD, Biochemical Oxygen Demand (mg/L); TH= Total Hardness (mg/L); TA= Total Alkalinity (mg/L); SO_4= sulphate (mg/L); PO_4= Phosphate-Phosphorus (mg/L); NO_3= Nitrate-Nitrogen (mg/L); TN= Total Nitrogen (mg/L); and TP= Total Phosphorus (mg/L)

Appendix XXIV: Two Way Analysis of Variance for surface water physico-chemical characteristics in Tudun Wada (TW), Makera (MK) drainages and River Kaduna lotic systems

Source	Dependent Variable	Type III Sum of Squares	Df	Mean Square	F	Sig.
Corrected Model	Temp	191.647[a]	23	8.332	1.849	.017
	pH	37.979[b]	23	1.651	2.035	.007
	TDS	6.780E6[c]	23	294786.182	34.860	.000
	EC	2.712E7[d]	23	1179254.284	35.712	.000
	DO	54.831[e]	23	2.384	6.946	.000
	BOD	844.134[f]	23	36.701	.761	.773
	Hardness	1.221E6[g]	23	53082.518	6.970	.000
	Alkalinity	1.648E6[h]	23	71667.792	3.369	.000
	SO4	91242.567[i]	23	3967.068	3.541	.000
	PO4	6.097[j]	23	.265	2.086	.005
	NO3	258.484[k]	23	11.238	2.293	.002
	TN	5550.659[l]	23	241.333	4.047	.000
	TP	9.638[m]	23	.419	1.084	.372
Intercept	Temp	117491.043	1	117491.043	2.607E4	.000
	pH	8253.462	1	8253.462	1.017E4	.000
	TDS	9716135.259	1	9716135.259	1.149E3	.000
	EC	3.881E7	1	3.881E7	1.175E3	.000
	DO	376.162	1	376.162	1.096E3	.000
	BOD	2460.862	1	2460.862	51.026	.000
	Hardness	2172194.006	1	2172194.006	285.235	.000
	Alkalinity	5433328.017	1	5433328.017	255.446	.000

	SO4	170943.683	1	170943.683	152.604	.000
	PO4	9.775	1	9.775	76.924	.000
	NO3	1317.985	1	1317.985	268.924	.000
	TN	54524.519	1	54524.519	914.231	.000
	TP	95.792	1	95.792	247.838	.000
Stations	Temp	134.871	11	12.261	2.721	.003
	pH	10.421	11	.947	1.167	.316
	TDS	5922036.663	11	538366.969	63.664	.000
	EC	2.375E7	11	2159066.239	65.385	.000
	DO	6.207	11	.564	1.644	.094
	BOD	270.418	11	24.583	.510	.894
	Hardness	246267.558	11	22387.960	2.940	.002
	Alkalinity	960196.625	11	87290.602	4.104	.000
	SO4	36118.267	11	3283.479	2.931	.002
	PO4	1.583	11	.144	1.132	.342
	NO3	63.987	11	5.817	1.187	.303
	TN	1476.700	11	134.245	2.251	.016
	TP	2.163	11	.197	.509	.895
Year	Temp	19.971	1	19.971	4.431	.037
	pH	2.101	1	2.101	2.590	.110
	TDS	611.178	1	611.178	.072	.788
	EC	4088.771	1	4088.771	.124	.726
	DO	41.377	1	41.377	120.552	.000
	BOD	175.342	1	175.342	3.636	.059

	Hardness	857970.354	1	857970.354	112.662	.000
	Alkalinity	399840.492	1	399840.492	18.798	.000
	SO4	7513.439	1	7513.439	6.707	.011
	PO4	1.429	1	1.429	11.247	.001
	NO3	65.489	1	65.489	13.362	.000
	TN	1079.436	1	1079.436	18.099	.000
	TP	1.162	1	1.162	3.006	.085
Stations * Year	Temp	48.299	11	4.391	.974	.473
	pH	21.294	11	1.936	2.386	.010
	TDS	229484.573	11	20862.234	2.467	.008
	EC	870735.036	11	79157.731	2.397	.010
	DO	1.393	11	.127	.369	.966
	BOD	268.028	11	24.366	.505	.897
	Hardness	293849.038	11	26713.549	3.508	.000
	Alkalinity	277676.452	11	25243.314	1.187	.303
	SO4	27321.154	11	2483.741	2.217	.017
	PO4	1.571	11	.143	1.124	.348
	NO3	67.998	11	6.182	1.261	.254
	TN	1728.006	11	157.091	2.634	.005
	TP	6.623	11	.602	1.558	.119
Error	Temp	567.863	126	4.507		
	pH	102.241	126	.811		
	TDS	1065502.197	126	8456.367		
	EC	4160648.728	126	33021.022		

	DO	43.247	126	.343		
	BOD	6076.639	126	48.227		
	Hardness	959546.756	126	7615.450		
	Alkalinity	2680013.547	126	21269.949		
	SO4	141142.623	126	1120.180		
	PO4	16.011	126	.127		
	NO3	617.521	126	4.901		
	TN	7514.613	126	59.640		
	TP	48.700	126	.387		
Total	Temp	129925.930	150			
	pH	9274.177	150			
	TDS	2.035E7	150			
	EC	8.132E7	150			
	DO	530.594	150			
	BOD	10054.331	150			
	Hardness	4279205.000	150			
	Alkalinity	1.102E7	150			
	SO4	479871.478	150			
	PO4	36.214	150			
	NO3	2576.121	150			
	TN	64735.458	150			
	TP	153.724	150			
Corrected Total	Temp	759.511	149			
	pH	140.220	149			

	TDS	7845584.373	149			
	EC	3.128E7	149			
	DO	98.078	149			
	BOD	6920.773	149			
	Hardness	2180444.673	149			
	Alkalinity	4328372.773	149			
	SO4	232385.189	149			
	PO4	22.108	149			
	NO3	876.006	149			
	TN	13065.271	149			
	TP	58.338	149			

Appendix XXV: One Way Analysis of Variance for surface water physico-chemical characteristics in Tudun Wada (TW), Makera (MK) drainages and River Kaduna lotic systems (Years)

ANOVA

		Sum of Squares	Df	Mean Square	F	Sig.
Temp	Between Groups	3.495	1	3.495	.723	.395
	Within Groups	2144.720	444	4.830		
	Total	2148.214	445			
pH	Between Groups	7.820	1	7.820	10.785	.001
	Within Groups	320.462	442	.725		
	Total	328.282	443			
TDS	Between Groups	306173.257	1	306173.257	5.063	.025
	Within Groups	2.685E7	444	60474.128		
	Total	2.716E7	445			
EC	Between Groups	1215988.728	1	1215988.728	5.036	.025
	Within Groups	1.072E8	444	241452.961		
	Total	1.084E8	445			
DO	Between Groups	119.494	1	119.494	264.934	.000
	Within Groups	204.769	454	.451		
	Total	324.263	455			
BOD	Between Groups	1813.669	1	1813.669	50.050	.000
	Within Groups	16161.796	446	36.237		
	Total	17975.464	447			
Hardness	Between Groups	1638687.897	1	1638687.897	235.185	.000
	Within Groups	3177253.876	456	6967.662		
	Total	4815941.773	457			
Alkalinity	Between Groups	1171833.030	1	1171833.030	48.714	.000
	Within Groups	9237243.851	384	24055.323		
	Total	1.041E7	385			
SO4	Between Groups	62713.199	1	62713.199	59.369	.000
	Within Groups	455281.564	431	1056.338		
	Total	517994.762	432			

PO4	Between Groups	6.036	1	6.036	91.001	.000
	Within Groups	29.847	450	.066		
	Total	35.883	451			
NO3	Between Groups	211.767	1	211.767	71.088	.000
	Within Groups	1146.894	385	2.979		
	Total	1358.662	386			
TN	Between Groups	11193.383	1	11193.383	114.313	.000
	Within Groups	39559.007	404	97.918		
	Total	50752.390	405			
TP	Between Groups	6.651	1	6.651	14.967	.000
	Within Groups	179.534	404	.444		
	Total	186.185	405			

Appendix XXVI: Canonical Correspondence analysis Axes Extraction for periphytic algae in Tudun Wada (TW), Makera (MK) drainages and River Kaduna lotic systems

	1	2	3	4	5	6	7	8	9
Osla	-0.20	-0.44	0.10	-0.04	-0.01	-0.02	-0.04	-0.01	-0.01
Oste	1.81	0.49	-0.32	-0.07	-0.10	-0.25	0.18	-0.12	0.01
Eusp	0.21	1.73	0.73	-0.05	0.51	0.06	-0.01	0.04	-0.01
Osbr	-3.33	1.80	-0.41	0.13	-0.49	0.14	0.18	-0.24	-0.02
Augr	1.84	1.06	-0.58	0.51	-0.47	0.46	-0.55	0.04	-0.02
Siau	-0.11	-0.14	-0.34	-0.52	0.15	0.49	0.12	0.07	0.26
Nosp	-1.81	0.75	-1.75	0.08	0.68	-0.66	-0.25	0.31	0.01
Syul	0.82	-0.56	-1.20	-0.59	0.40	0.86	0.60	0.23	-0.24
Auva	-0.04	1.02	0.78	0.00	-1.39	-0.30	0.36	0.68	0.02
Siov	0.03	-0.95	0.04	2.66	0.44	0.16	0.46	0.06	0.06
TW_1	0.18	0.33	-1.58	-0.50	0.37	0.74	0.91	0.47	-0.25
TW_2	-0.12	-0.79	0.44	2.21	0.35	0.22	0.30	-0.13	-0.04
TW_3	-0.18	-0.67	0.53	-0.45	0.04	0.05	-1.08	-0.42	0.72
RK_2	0.36	1.11	1.23	-0.42	1.76	0.27	0.67	0.47	-0.50
RK_1	0.18	0.02	0.42	-0.20	-1.51	-1.38	0.86	1.31	-0.92
RK_3	1.13	0.26	-0.97	-0.47	-0.83	-3.77	3.66	-6.06	2.04
MK_1	-0.06	1.27	-0.48	0.37	-5.46	-1.41	3.75	2.53	0.17
MK_2	-0.77	2.46	0.80	0.17	-0.50	-0.05	2.66	0.56	-2.45
MK_3	-0.29	0.65	-3.55	0.00	1.60	-6.04	-0.45	2.42	1.62
RK_5	1.05	0.96	-0.70	0.50	-2.03	1.04	-2.20	1.20	3.78
RK_4	0.38	-0.12	-1.30	-0.31	0.09	-0.67	0.30	0.08	-5.02
RK_6	0.81	0.66	-1.41	0.99	-2.46	1.44	-4.01	-3.02	-1.69
Tempt	-4.88	5.38	-0.99	0.24	-0.95	-0.89	0.28	0.50	-0.02
pH	-5.01	5.90	-0.47	0.72	-1.59	-0.34	0.49	0.46	0.01
TDS	-8.78	2.16	-0.51	0.34	-0.20	-0.79	0.74	0.60	0.03
EC	-8.78	2.17	-0.50	0.34	-0.20	-0.79	0.74	0.60	0.03
DO	5.72	3.48	-0.64	-0.78	-0.37	0.29	-0.33	-0.27	-0.16
BOD	-6.30	5.31	-0.18	0.75	-0.16	-0.03	0.40	0.40	-0.22
Hardness	-6.24	-3.09	-0.20	-0.67	1.85	-0.87	0.18	0.35	0.04
Alkalinity	-8.68	2.43	-0.60	0.42	-0.10	-0.82	0.81	0.61	0.02
SO4	-5.30	4.34	-2.05	0.48	-0.58	-0.78	0.09	0.57	-0.07
PO4	-4.24	6.02	-1.56	0.30	-1.03	-0.65	0.33	0.47	0.00
NO3	-3.74	2.99	-2.43	0.19	-0.74	-0.87	-0.14	0.60	0.03
TN	-5.57	1.66	-1.67	1.41	-0.63	0.14	-0.17	0.57	-0.12
TP	-4.17	-0.11	-0.33	2.24	-0.03	0.72	-0.68	0.41	-0.07

Appendix XXVII: Canonical Correspondence Analysis Extraction for Phytoplankton in Tudun Wada (TW), Makera (MK) drainages and River Kaduna

	1	2	3	4	5	6	7	8	9
Osla	-0.19681	-0.44013	0.09943	-0.03563	-0.01128	-0.01662	-0.03742	-0.0087	-0.00793
Oste	1.81408	0.486319	-0.31948	-0.06834	-0.09511	-0.2479	0.179681	-0.11689	0.014558
Eusp	0.214968	1.72754	0.733443	-0.05079	0.510656	0.061849	-0.01311	0.044634	-0.01364
Osbr	-3.32997	1.80307	-0.41031	0.125598	-0.49413	0.142882	0.182371	-0.23675	-0.01631
Augr	1.83537	1.05531	-0.57876	0.505948	-0.46583	0.460602	-0.55454	0.040348	-0.01948
Siau	-0.10937	-0.13886	-0.34483	-0.51811	0.145479	0.486869	0.119419	0.071917	0.261853
Nosp	-1.8065	0.753642	-1.75099	0.078511	0.682722	-0.65641	-0.24733	0.307306	0.014697
Syul	0.824377	-0.55782	-1.19939	-0.58886	0.396362	0.855928	0.597561	0.225363	-0.24068
Auva	-0.0359	1.02081	0.782071	0.001247	-1.39204	-0.30291	0.361615	0.677846	0.016882
Siov	0.03239	-0.95007	0.040003	2.66431	0.44034	0.160088	0.459945	0.05719	0.064644
TW_1	0.17885	0.327597	-1.58415	-0.50246	0.36644	0.736374	0.90766	0.47315	-0.2515
TW_2	-0.11692	-0.79291	0.439716	2.21241	0.353613	0.21917	0.297859	-0.13267	-0.03506
TW_3	-0.18055	-0.66918	0.529513	-0.45154	0.039985	0.051487	-1.07951	-0.42421	0.724965
RK_2	0.364837	1.11423	1.22502	-0.4218	1.76023	0.267813	0.671367	0.471447	-0.49721
RK_1	0.180234	0.019837	0.416527	-0.1979	-1.51002	-1.38377	0.856979	1.31312	-0.91586
RK_3	1.12505	0.259426	-0.97199	-0.46976	-0.82532	-3.76811	3.65697	-6.06453	2.04157
MK_1	-0.06393	1.27326	-0.48245	0.367571	-5.45893	-1.41007	3.75149	2.53168	0.169972
MK_2	-0.76981	2.45916	0.796371	0.172948	-0.49786	-0.04758	2.65605	0.558285	-2.44504
MK_3	-0.28751	0.651896	-3.54692	-0.00089	1.60407	-6.04283	-0.45454	2.41596	1.62225
RK_5	1.04783	0.962211	-0.70052	0.501447	-2.0318	1.03804	-2.2019	1.20433	3.78424
RK_4	0.375344	-0.12305	-1.30421	-0.31041	0.090152	-0.67347	0.299393	0.084652	-5.01674
RK_6	0.808532	0.658134	-1.41169	0.98868	-2.45813	1.44174	-4.01138	-3.0183	-1.69165
Tempt	-4.88246	5.3764	-0.99394	0.236763	-0.948	-0.88944	0.284273	0.502285	-0.01527
pH	-5.01309	5.89856	-0.4671	0.723921	-1.58653	-0.33888	0.486137	0.455895	0.007056
TDS	-8.77683	2.15857	-0.51363	0.34092	-0.20094	-0.78636	0.735799	0.600992	0.032526
EC	-8.78105	2.16856	-0.50362	0.344246	-0.20191	-0.78519	0.738737	0.602244	0.032344
DO	5.72111	3.48245	-0.64252	-0.78226	-0.36703	0.287153	-0.33137	-0.26587	-0.16079
BOD	-6.30345	5.31354	-0.18042	0.751778	-0.15895	-0.03159	0.403703	0.403818	-0.21607
Hardness	-6.24372	-3.08649	-0.19552	-0.66546	1.8543	-0.86778	0.177329	0.353335	0.037392
Alkalinity	-8.68322	2.43011	-0.60257	0.424596	-0.09592	-0.81543	0.811029	0.606147	0.016057
SO4	-5.29872	4.33704	-2.04964	0.479148	-0.58232	-0.7832	0.090796	0.571939	-0.06859
PO4	-4.2436	6.02361	-1.559	0.304119	-1.02912	-0.6503	0.332487	0.473126	-0.0039
NO3	-3.7372	2.99112	-2.42823	0.194425	-0.74352	-0.86955	-0.13911	0.596917	0.028561
TN	-5.57123	1.65698	-1.66566	1.40988	-0.63214	0.135593	-0.16814	0.572157	-0.12218
TP	-4.16744	-0.1065	-0.32535	2.24187	-0.02681	0.722601	-0.68035	0.412273	-0.06838

Appendix XXVIII: Principal component Analysis Extraction for surface water physico-chemical characteristics in Tudun Wada (TW), Makera (MK) drainages and River Kaduna

	AXIS											
	1	2	3	4	5	6	7	8	9		10	11
Tempt	-1.14	0.40	-0.02	0.06	-0.08	0.00	0.00	0.00	0.00	0.00	0.00	0.00
pH	-1.90	-0.19	0.03	-0.02	-0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TDS	3.03	-0.96	0.00	0.01	0.00	-0.01	-0.02	0.00	0.00	0.00	0.00	0.00
EC	8.28	-1.48	0.01	0.03	0.00	0.01	0.01	0.00	0.00	0.00	0.00	0.00
DO	-2.13	-0.36	0.04	-0.05	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00
BOD	-2.06	-0.31	0.02	-0.05	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Hardness	0.54	1.35	0.34	0.17	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Alkalinity	4.70	2.34	-0.08	-0.15	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SO4	-1.07	0.47	-0.39	0.15	0.02	0.01	0.00	0.00	0.00	0.00	0.00	0.00
PO4	-2.18	-0.40	0.05	-0.06	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00
NO3	-2.09	-0.33	0.03	-0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TN	-1.82	-0.13	-0.07	0.01	0.01	-0.03	0.01	0.00	0.00	0.00	0.00	0.00
TP	-2.17	-0.39	0.04	-0.05	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00

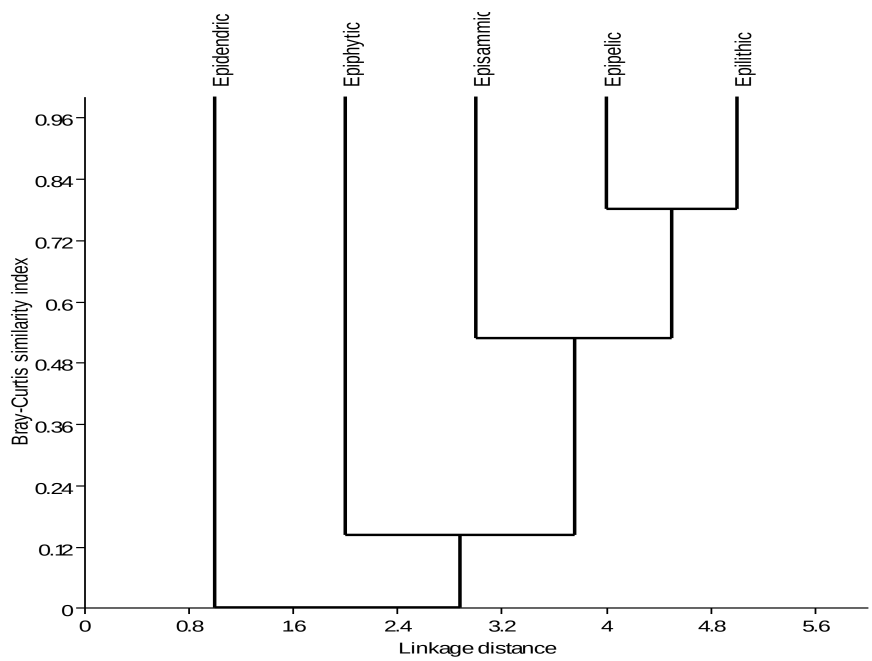
Appendix XXIX: Diversity Indices of Phytoplankton in Tudun Wada (TW), Makera (MK) drainages and River Kaduna

	TW_1	TW_2	TW_3	RK_1	RK_2	RK_3	MK_1	MK_2	MK_3	RK_4	RK_5	RK_6
Taxa_S	13	13	9	11	14	5	8	9	5	9	10	5
Individuals	6170	3450	9484	1300	1825	350	384	1300	342	525	563	463
Dominance_D	0.15	0.45	0.64	0.35	0.25	0.35	0.15	0.24	0.25	0.28	0.16	0.28
Shannon_H	2.13	1.20	0.75	1.58	1.75	1.27	1.98	1.71	1.46	1.68	2.03	1.39
Simpson_1-D	0.85	0.55	0.36	0.65	0.75	0.65	0.85	0.76	0.75	0.72	0.84	0.72
Evenness_e^H/S	0.65	0.25	0.23	0.44	0.41	0.71	0.91	0.61	0.86	0.60	0.76	0.80
Menhinick	0.17	0.22	0.09	0.31	0.33	0.27	0.41	0.25	0.27	0.39	0.42	0.23
Margalef	1.38	1.47	0.87	1.40	1.73	0.68	1.18	1.12	0.69	1.28	1.42	0.65
Equitability_J	0.83	0.47	0.34	0.66	0.66	0.79	0.95	0.78	0.90	0.77	0.88	0.86
Fisher_alpha	1.57	1.71	0.98	1.65	2.06	0.83	1.43	1.30	0.83	1.54	1.73	0.78
Berger-Parker	0.24	0.64	0.79	0.56	0.34	0.50	0.23	0.38	0.29	0.48	0.27	0.35

Appendix XXX: Diversity Indices of Periphyton algae in Tudun Wada (TW), Makera (MK) drainages and River Kaduna

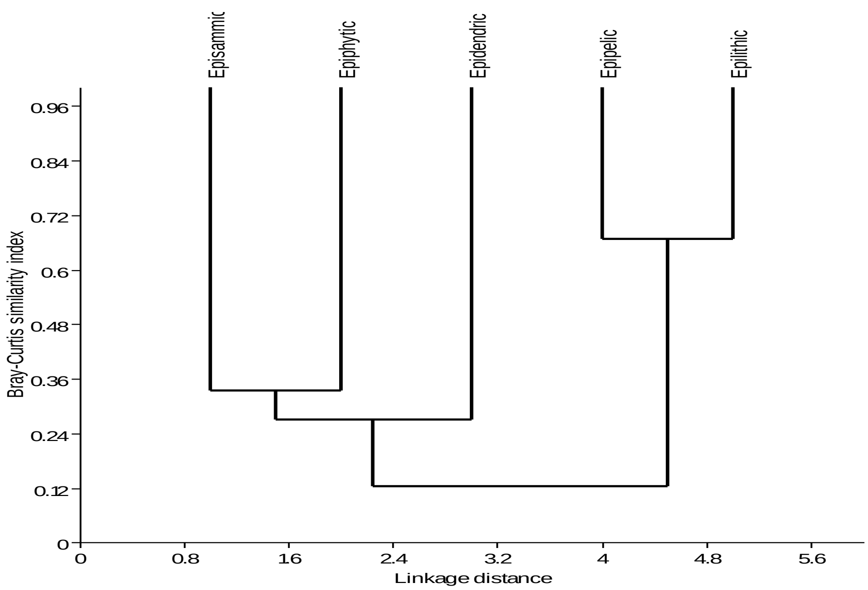
	TW_1	TW_2	TW_3	RK_2	RK_1	RK_3	MK_1	MK_2	MK_3	RK_5	RK_4	RK_6
Taxa_S	6	4	5	18	3	9	12	13	10	12	28	37
Individuals	3212	463	1273	7200	1230	1565	959	1629	540	724	618	1869
Dominance_D	0.22	0.85	0.27	0.06	0.34	0.46	0.15	0.22	0.21	0.20	0.09	0.17
Shannon_H	1.65	0.35	1.37	2.89	1.10	0.97	2.08	1.84	1.85	1.93	2.83	2.35
Simpson_1-D	0.78	0.15	0.73	0.94	0.66	0.54	0.85	0.78	0.79	0.80	0.91	0.83
Evenness_e^H/S	0.86	0.36	0.79	1.00	1.00	0.29	0.67	0.49	0.63	0.58	0.60	0.28
Menhinick	0.11	0.19	0.14	0.21	0.09	0.23	0.39	0.32	0.43	0.45	1.13	0.86
Margalef	0.62	0.49	0.56	1.91	0.28	1.09	1.60	1.62	1.43	1.67	4.20	4.78
Equitability_J	0.92	0.26	0.85	1.00	1.00	0.44	0.84	0.72	0.80	0.78	0.85	0.65
Fisher_alpha	0.71	0.60	0.66	2.23	0.37	1.26	1.93	1.93	1.74	2.04	6.04	6.54
Berger-Parker	0.31	0.92	0.31	0.06	0.37	0.58	0.23	0.34	0.37	0.36	0.19	0.30

Appendix XXXI



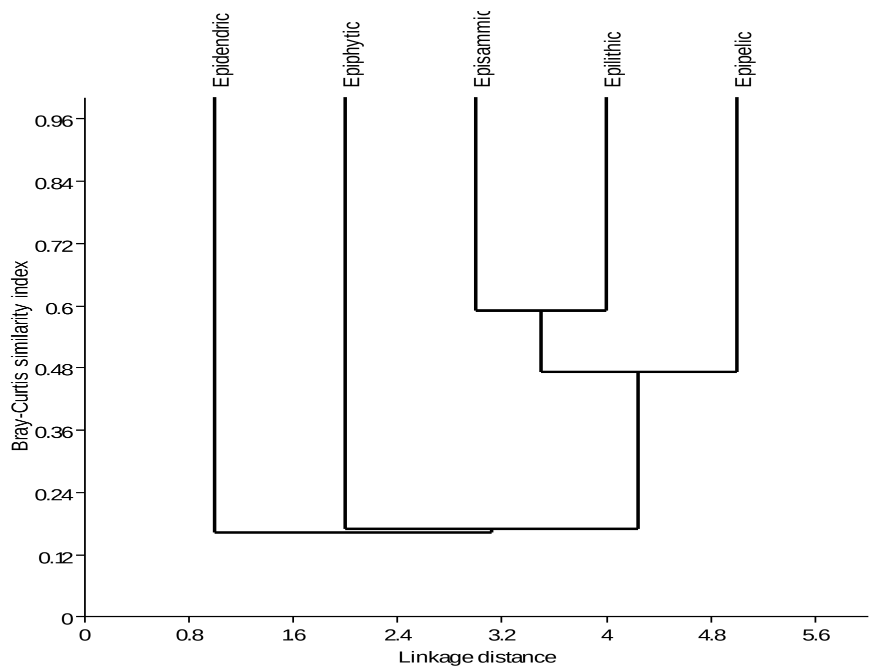
Cluster analysis for periphytic cyanobacteria on substrate in Tudun Wada (TW), Makera (MK) drainages and River Kaduna

Appendix XXXII



Cluster analysis for periphytic chorophyta on substrate in Tudun Wada (TW), Makera (MK) drainages and River Kaduna

Appendix XXXIII



Cluster analysis for periphytic diatoms on substrate in Tudun Wada (TW), Makera (MK) drainages and River Kaduna

Appendix XXXIV: Absorbance and concentrations for the determination of calibration curve of NO_3-N

Concentration of standards mg/L	Absorbance of standards
1	0.13
2	0.25
3	0.35
4	0.4
5	0.46

Appendix XXXV: Absorbance and concentrations for the determination of calibration curve PO_4-P

Concentration of standards mg/L	Absorbance of standards
0.05	0.024
0.1	0.066
0.15	0.14
0.25	0.24

Appendix XXXVI: Absorbance and concentrations for the determination of calibration curve SO_4

Concentration of standards mg/L	Absorbance of standards
8	0.06
16	0.13
24	0.17
32	0.25
40	0.31

Appendix XXXVII: Abundance and distribution of phytoplankton algae in Station 1 of Tudun Wada drain (TW_1), Kaduna

Species	Year	January	February	March	April	May	June	July	August	September	October	November	December	Total
Oscillatoria lacustries	2013	5	4	7	6	4	2	1	3	3	4	1	4	44
	2014		20		30		52	0	0	6	0	0		108
O. tenuis	2013	3		3		3					3	3		15
	2014		5									5	5	15
O. Limosa	2013											1		1
	2014											0		0
O. brevis	2013							8						8
	2014							0						0
***Spirulina* sp.**	2013						1							1
	2014						0							0
***Nostoc* sp.**	2013	3		7		5		5						20
	2014							0						0
***Synedra* sp.**	2013										1			1
	2014										0			0
Sirurella augusta	2013											1		1
	2014											0		0
Aulacoseira granulate	2013											1		1
	2014											0		0
***Euglena* sp.**	2013			4				4						8
	2014							0						0
uk5	2013								1					1
	2014								0					0
***Closterium* sp.**	2013											0		0
	2014											1		1
***Oscillatoria* sp.**	2013											0		0
	2014											6		6
uk7	2013											41		41
	2014											7		7
uk1	2013		7		5		10			5				27
	2014	12		2			7					1		22

Appendix XXXVIII: Abundance and distribution of phytoplankton algae in Tudun Wada drain (TW_2), Kaduna

	Year	January	February	March	April	May	June	July	August	September	October	November	December	Total
Oscillatoria lacustris	2013							14	82		35			131
	2014		200		140			9	300		118			767
***Euglena* sp.**	2013							4	1					5
	2014							3	0					3
uk2	2013							0	0					0
	2014							2	1					3
uk4	2013								0					0
	2014								1					1
Sirurella augusta	2013											11		11
	2014											1		1
Oscillatoria tenuis	2013											1	0	1
	2014											0	1	1
uk10	2013												23	23
	2014												32	32
uk11	2013												1	1
	2014												0	0
uk12	2013												1	1
	2014												1	1

Appendix XXXIX: Abundance and distribution of phytoplankton algae in Tudun wada (TW_3), Kaduna

	Year	January	February	March	April	May	June	July	August	September	October	November	December	Total
Oscillatoria lacustris	2013							14	82		35			131
	2014		200		140			9	300		118			767
Euglena sp.	2013							4	1					5
	2014							3	0					3
uk2	2013							0	0					0
	2014							2	1					3
uk4	2013								0					0
	2014								1					1
Sirurella augusta	2013											11		11
	2014											1		1
Oscillatoria tenuis	2013											1	0	1
	2014											0	1	1
uk10	2013												23	23
	2014												32	32
uk11	2013												1	1
	2014												0	0
uk12	2013												1	1
	2014												1	1

Appendix XL: Abundance and distribution of phytoplankton algae in River Kaduna (RK_1), Kaduna

	Year	January	February	March	April	May	June	July	August	September	October	November	December	Total
Oscillatoria brevis	2013											1		1
	2014											0		0
Oscillatoria lacustris	2013	3		3		3	3		3	3				18
	2014		3		4					1		1	1	10
uk5	2013									1				1
	2014									1				1
Oscillatoria tenuis	2013		3			4					3	1		11
	2014	1		2	2			2			2	1		10
Aulacoseira granulata	2013										1			1
	2014										0			0
***Nitzchia* sp**	2013													
	2014													
Melosira sulcata	2013										1			1
	2014										1			1
Aulacoseira varians	2013										1			1
	2014										2			2
***Phacus* sp.**	2013									1				1
	2014									1				1
Frustulia rhomboides	2013										0			0
	2014										1			1

Oscillaria limosa	2013	1	1
	2014	0	0

Appendix XXXLI: Abundance and distribution of phytoplankton algae in River Kaduna drain (RK_2), Kaduna

	Year	January	February	March	April	May	June	July	August	September	October	November	December	Total
Sirurella augusta	2013											1		1
	2014											1		1
***Euglena* sp.**	2013											0		0
	2014	5		3	7							7	3	25
uk13	2013											0		0
	2014											1		1
Oscillatoria brevis	2013											0		0
	2014											1		1
Oscillatoria lacustris	2013									5				5
	2014		9					3		6				18
uk5	2013									1				1
	2014									0				0
Oscillatoria tenuis	2013	3					3				3			9
	2014					3					2			5
Aulacosiera granulata	2013										1			1
	2014										1			1
***Nitzchia* sp.**	2013										1			1
	2014										0			0
Melosira sulcata	2013										1			1
	2014										0			0
Synedra ulna	2013										1			1
	2014										0			0
***Navicula* sp.**	2013										1			1

	2014	0		0
Aulacoseira varians	2013	1		1
	2014	0		0
Oscillatoria limosa	2013		0	0

Appendix XLII: Abundance and distribution of phytoplankton algae in River Kaduna (RK_3), Kaduna

	Year	January	February	March	April	May	June	July	August	September	October	November	December	Total
Sirurella augusta	2013													
	2014													
***Euglena* sp.**	2013										1			1
	2014										1			1
Oscillatoria lacustris	2013									1				1
	2014	1								2				3
uk5	2013													
	2014													
Oscillatoria tenuis	2013			2							2			4
	2014		1								1		1	3
Oscillatoria limosa	2013										1			1
	2014										1			1

Appendix XLIII: Abundance and distribution of phytoplankton algae in Station of Makera drain (MK_1), Kaduna

	Year	January	February	March	April	May	June	July	August	September	October	November	December	Total
Aulacoseira numuloides	2013						1							1
	2014						0							0
Melosira sulcata	2013	1					1							2
	2014						0							0
Oscillatoria brevis	2013						1				2			3
	2014						0				1			1
Oscillatoria lacustris	2013	2		2			2		1	1	0		2	10
	2014						0		0	1	1			2
Aulacoseira granulate	2013						1				1			2
	2014						0				0			0
uk6	2013								1					1
	2014								0					0
Oscillatoria tenuis	2013										1	1		2
	2014		1	1		1					1	1	1	6
Cosmarium marigatius	2013										1			1
	2014										0			0
Aulacoseira varians	2013											1		1
	2014											1		1

Appendix XLIV: Abundance and distribution of phytoplankton algae in Station 2 of Makera drain (MK_2), Kaduna

	Year	January	February	March	April	May	June	July	August	September	October	November	December	Total
Aulacoseira numuloides	2013													

	2014													
Melosira sulcata	2013						1					1		2
	2014						0					0		0
Oscillatoria brevis	2013	2	4	2	1		1			1	1			12
	2014		4	1	1	1	6	3			0			16
Oscillatoria lacustris	2013								1	2			1	4
	2014								0	0				0
Aulacoseira granulate	2013						1		1	1				3
	2014						0		0	0				0
uk6	2013													
	2014								0		3			3
Oscillatoria tenuis	2013										3		2	5
	2014													
Cosmarium marigatius	2013													
	2014													
Aulacoseira varians	2013											1		1
	2014											1	2	3
***Euglena* sp.**	2013	2		3		2		3	10					20
	2014								0					0
***Nostoc* sp.**	2013								2					2
	2014								0					0

Appendix XLV: Abundance and distribution of phytoplankton algae in Station 3 of Makera drain (MK_3), Kaduna

	Year	January	February	March	April	May	June	July	August	September	October	November	December	Total
Aulacoseira numuloides	2013									0				
	2014									1				1
Melosira sulcata	2013													
	2014													
Oscillatoria brevis	2013										0			0
	2014										1			1
Oscillatoria lacustris	2013								1	1				2
	2014	1					1		0	1				3
Aulacoseira granulate	2013													
	2014													
uk6	2013													
	2014													
Oscillatoria tenuis	2013										1			1
	2014		1				1				1			3
Cosmarium marigatius	2013													
	2014													

Aulacoseira varians	2013													
	2014													
***Euglena* sp.**	2013													
	2014													
***Nostoc* sp.**	2013	1		2					1	3	1	1		9
	2014	2	1	2			2		2	6	4	1		20

Appendix XLVI: Abundance and distribution of phytoplankton algae in Station 4 of River Kaduna (RK_4), Kaduna

	Year	January	February	March	April	May	June	July	August	September	October	November	December	Total
Aulacoseira numuloides	2013													
	2014													
Melosira sulcata	2013													
	2014													
Oscillatoria brevis	2013													
	2014													
Oscillatoria lacustris	2013								1					1
	2014	1		1					1					3
Aulacoseira granulate	2013									3	0			3
	2014									2	1			3
uk6	2013													
	2014													
Oscillatoria tenuis	2013	1	2		1	1				2		1		8
	2014			1		1				1	1	1		5
Cosmarium marigatius	2013													
	2014													
Aulacoseira varians	2013									1	1			2
	2014									0	0			0
***Euglena* sp.**	2013									0				0
	2014	1								1				2
***Nostoc* sp.**	2013													

	Year	January	February	March	April	May	June	July	August	September	October	November	December	Total
	2014													
***Navicula* sp1**	2013									1				1
	2014									0				0
***Navicula* sp 2**	2013									0				0
	2014									1				1
***Nitzchia* sp**	2013									0				0
	2014									1				1
Sirurella augusta	2013										0			0
	2014										1			1
***Navicula* sp3**	2013		1								1		1	3
	2014										0			0
***Pleurosigma* sp.**	2013										1			1
	2014										0			0

Appendix XLVII: Abundance and distribution of phytoplankton algae in Station 5 of Makera drain (RK_5), Kaduna

	Year	January	February	March	April	May	June	July	August	September	October	November	December	Total

Aulacoseira numuloides	2013								0	0
	2014								1	1
Melosira sulcata	2013									
	2014									
Oscillatoria brevis	2013									
	2014									
Oscillatoria lacustris	2013	1		1		1	1			4
	2014		2		2		2			6
Aulacoseira granulate	2013							0		0
	2014							1		1
uk6	2013									
	2014									
Oscillatoria tenuis	2013							0	2	2
	2014							1	3	4
Cosmarium marigatius	2013									
	2014								1	1
Aulacoseira varians	2013								0	0
	2014									
***Euglena* sp.**	2013									
	2014									
***Spirulina* sp.**	2014								0	0
	2013								1	1
Synedra ulna	2014							1		1
	2013							0		0
***Staurastrum* sp.**	2014								0	0
	2013								1	1

Appendix XLVIII: Abundance and distribution of phytoplankton algae in River Kaduna (RK_6), Kaduna

	Year	January	February	March	April	May	June	July	August	September	October	November	December	Total
Aulacoseira numuloides	2013													
	2014													
Melosira sulcata	2013													
	2014													
Oscillatoria brevis	2013											0		0
	2014											1		1
Oscillatoria lacustris	2013	1			2			`		`	1			4
	2014		1	1			1			1	0			4
Aulacoseira granulata	2013										4	0		4
	2014										1	1		2
uk6	2013													
	2014													
Oscillatoria tenuis	2013	2		2				1		1	1	1	1	9
	2014										1	0		1
Cosmarium marigatius	2013													

	2014		
Aulacoseira varians	2013		
	2014		
***Euglena* sp.**	2013		
	2014		
***Navicula* sp2**	2014	0	0
	2013	1	1