ASSESSMENT OF SURFACE WATER QUALITY OF ONUIYIEKE RIVER IN IMO STATE, NIGERIA

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CERTIFICATION PAGE

This is to certify that this work "ASSESSMENT OF THE SURFACE WATER QUALITY OF THE ONUIYIEKE RIVER IN IMO STATE, NIGERIA" was carried out by EZE CHINWE CATHERINE with Registration Number (20154995978) in partial fulfillment for the award of the degree of Master of Science (M.Sc.) in Environmental Management, School of Environmental Sciences Federal University of Technology, Owerri.

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DEDICATION

This study is dedicated to my husband and children for their support,

understanding and care,

Charles, Charles (Jnr.), Prince, Daniel and Fortune

All glory to God, The Almighty, Who made this research possible.

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ABSTRACT

The surface water quality of Onuiyieke River was assessed for a period of six months (September, 2017 - February, 2018) at seven sampling locations (SLs) to ascertain its quality status. Measurements were made on samples collected with 500ml sample bottles according to standard methods. Samples for heavy metals were collected in 250ml bottle and fixed with concentrated $HN0_3$. Descriptive analysis, variation plots, ANOVA, Duncan Multiple Range tests, Principal Components Analysis (PCA), Pearson Correlation (r) and Water Quality Index (WQI) were used to analyze data. Mean values of the parameters obtained were: Total Suspended Solids (TSS) 198.19 ±80.93mg/L; Electrical Conductivity (EC) 331.81 ±59.78µ; Turbidity 18.84 ± 2.22 NTU; Nitrate ions 14.77 ±0.92mg/L; Dissolved Oxygen (DO) 6.58 ±O.22mg/L and Biological Oxygen Demand (BOD) 1.77±0.10mg/L. Mean values of the Trace Metals obtained were: Iron (Fe) 1.93 ±0.23mg/L; Magnesium (Mg) 0.22±0.02mg/L and Calcium (Ca) 15.15±1.87mg/L while the mean value of Faecal Coliform was 1.91±O.10MPN/100. pH, EC, TSS, BOD_5, turbidity, $N0_3$-, Ammonia, Fe and faecal coliforms exceeded the NESREA and WHO maximum permissible limits. There were significant spatial differences in levels of TDS, EC, NO_3, NH_3, DO and Faecal coliforms (Sig F=0.000 to 0.039) and significant temporal differences in levels of PO_4^{3-} (Sig F= 0.078 to 1000) between the control and other locations.at $p<0.05$. Four Principal Components (PCs) formed the extraction solution with a cumulative percentage variability of about 77.67 %. PCs 1, 2, 3, and 4 were most highly correlated with Mg^{2+} (0.925), NH_4 (0.903), TSS (0.930) and temperature (0.840) respectively. The Water Quality Index revealed that the rating for the water quality across the sampling locations was between excellent and unsuitable with SL 3 having the least water quality. Appropriate monitoring procedures for the sustainable development of the river should also be put in place.

Keywords: Pollution, Water pollution, Water Quality Index, Physicochemical Parameters, Surface Water, Biological Parameters.

CHAPTER ONE

INTRODUCTION

1.1. Background of Information

Water is necessary to live, essential for socio-economic development and maintenance of healthy ecosystems and is useful for industrial, domestic and recreational purposes (Water Research Centre, 2015). Plants and animals require water and cannot survive if their water is loaded with toxic chemicals or harmful microorganisms (Akubugwo & Duru, 2011). Polluted water can kill large numbers of fish, birds, and in some cases, all members of a species in an affected area. Water quality is evaluated relative to its intended use (Andem, Udofia, Okoroafor, Okete, & Ugwumba, 2012)

Extensive scrutiny of water used for diverse activities is necessary because numerous pathogens can live in them especially waters used as a source of drinking water like streams, lakes, ponds, and oceans. Water is undoubtedly the most precious natural resource that exists on our planet, comprising over 70% of the earth's surface. Although humans recognize this fact, they still disregard it, by polluting rivers, lakes, and oceans. The term "water pollution" can be defined as the deterioration in the chemical, physical and biological properties of water resulting from humans and their activities (Chatterjee, 2011). Increasing the human population, industrialization, intensive agricultural practices and discharges of wastewater into rivers and streams have also resulted in deterioration of water quality (Anhwange, Agbaji, & Gimba, 2012).

The impact of these anthropogenic activities has been so extensive that some water bodies have lost their self-purification capacity to a large extent (Ukiwe, Onyedika, Viven, & Iwu, 2012). Surface water pollution occurs when hazardous substances are discharged, from a channel into the water bodies or when they receive contamination from storm water runoff (Chatterjee, 2011). Water quality is commonly defined by its physical, chemical, biological and aesthetic characteristics. River pollution has become a serious problem for most commercialized and industrialized cities in Nigeria (Awomeso *et al.*, 2012) According to (National Bureau of statistics, 2011), at least 27% of Nigerians depend on streams, pond, river and rainwater as their major source of water supply. The major water pollutants are chemical, biological, or physical materials that degrade water quality. Research has shown a high prevalence of water-borne diseases such as cholera, diarrhoea, dysentery, hepatitis, etc. among Nigerians is as a result of the consumption of polluted water.

The scarcity of clean water and pollution of freshwater has led to a situation in which only one-fifth of the urban dwellers in developing countries and three quarters of their rural-dwelling counterparts do not have access to reasonably safe water supplies (Oladele, Adegbenro, & Adewole, 2011) Water pollution in Nigeria occurs in both rural and urban areas (Ukiwe *et al*., 2012). In rural areas, drinking water from natural sources such as rivers and streams is usually polluted by organic substances from upstream users who use water for agricultural activities (Osibanjo, Daso, & Gbadebo, 2011).

The most common form of stream pollution associated with forestry is increased concentrations of soil particles washed into the stream by land degradation (Odeyemi, Faweya, Agunbiade, & Ayeni, 2011). Also, the result of waste disposal in water bodies has led to the pollution of surface and groundwater. Some surface water in Nigeria is heavily polluted with human excreta, garbage and domestic sewage (Cosmas & Samuel, 2011). The National Environmental Standards and

Regulations Enforcement Agency (NESREA) was established by the Federal Government of Nigeria as a parastatal of the Federal Ministry of Environment for the protection and development of the environment, biodiversity conservation and, sustainable development of Nigeria's natural resources in general and water in particular. The function of NESREA also include the regulation of effluents discharged by industries and several other sources (NESREA, 2011). The International adoption of the Millennium Development Goals (MDG) in 2000 created a new framework for reducing deficiencies in the quality and quantity of water supply and sanitation. MDG 7 calls for ensuring environmental sustainability and, most importantly, reducing by half the number of people without sustainable access to safe drinking water (WHO, 2010). Although many countries have tried to meet the MDG drinking water target, Africa lags. The gap is most acute in Sub-Saharan Africa where only 58 percent of the population enjoys access to safe drinking water (Barnerjee & Morella, 2011).

About 47 million Nigerians still rely, exclusively, on surface water sources to meet their domestic needs. Yet, pollution discharge into the surface water by individuals and industries go on unmitigated, unregulated, and unpunished due to weaknesses in the existing laws. The involvement of the scientific community in the regular monitoring of surface water quality as a tool for managing the surface and groundwater resources, among other things, would be an advantageous tool for curbing the pollution menace.

1.2. Problem Statement

The Onuiyieke River is one of the largest rivers flowing across Obowo to Ihitte-Uboma Local Government Area of Imo State. The river drains from its source, the

Imo River, passing through many rural communities such as Ogwogoroanya, Umulogho, Umoke, Amanze, Amainyi, etc. with a drainage area of about 150000 hectares. The watershed of the river serves as the water source for the population of the bordering communities, from the source downstream. A lot of activities are carried out within and around the river banks that may affect its quality. The bordering communities wash their clothes as well as bathe inside the river. Some women use the river for the fermentation of their cassava after which they process and sell. In recent times, many rural farmers in the area make use of chemical fertilizer to improve soil quality and increase the yield of various crops such as yam, cocoyam, maize, vegetables, etc.

Due to the peculiar topographical nature of the area that accelerates the discharge of water runoff, especially during rainy season, some of these chemicals used for farming may find their way into the river. It is therefore very important to consider the analysis of the quality of the river, especially during the rainy season. The continued migration of people into the study area as a result of the 'Malaysia' market located just before Abia state, aggravated the pollution of Onuiyieke River as it forms the effluent discharge points for industrial, agricultural and household wastes (Akubugwo & Duru, 2011). Rural runoff carries all sorts of pollutants from houses and farmlands into the river.

Another activity that may contribute to the vitiation of the quality of the river water is the constant sand mining along the river. The activity carried out at the upper and middle parts of the river course has led to an increase in the turbidity of the river as it helps to raise objects deposited many years ago along the river beds. In the past few years, most communities living downstream have recorded incidents of water-borne diseases such as typhoid, diarrhoea, and dysentery. There is reported recrudescence of these diseases in the rural communities who have this river as their main source of water supply according to residents.

The increase and persistence of these diseases especially among vulnerable groups such as children and the aged has become a source of concern to the local population, public health experts and Environmentalists. According to (Nkwocha & Pat-Mbano, 2010) as societies throughout the world become more aware of the issues involved in water pollution, there has been considerable public debate about the environmental effects of effluents discharged into aquatic environments. It is based on these concerns that the present study was conducted to ascertain the level of quality of the river.

1.3. Objectives of study

The main objective of this study is to determine water quality characteristics of Onuiyieke River in Obowo- Ihitte Uboma LGAs of Imo State.

Specific

The specific objectives of the study include;

i. to determine some physicochemical and biological characteristics of Onuiyieke River;
ii. to determine spatial variations and temporal variations of the water quality parameters;
iii. to determine possible relationships among the water quality parameters and
iv. to compare levels of physicochemical and biological parameters with the control and regulatory standards.

1.4 Justification of Study

A study on Onuiyieke River will help;

i. to improve the understanding of pollution and how to prevent it as it is a direct measurement of the deleterious effect of pollution on human health. This can be achieved by knowing the channels by which pollutants enter the river;
ii. to provide up-to-date information on the water quality and pollution sources which is important for implementing sustainable water-use management strategies;
iii. to raise awareness among the residents of Obowo, Ihitte-Uboma and other rural communities living downstream who source their water from Onuiyieke on the risk in consuming polluted water;
iv. to obtain necessary data that may help public authorities in formulating policy measures that will help in ensuring safe and sustainable quality of the river and
v. to explore and develop new strategies for intervention for mitigating some easily preventable diseases, arising from continuous consumption of water from the river by bordering communities.

1.5 Scope of the Study

This study focused on the determination of major physical, chemical and biological parameters. The physical parameters analyzed include: temperature, conductivity, and turbidity to suspended solids (TSS) and total dissolved solids (TDS). The chemical parameters analyzed include pH, Chemical Oxygen Demand (COD), Biological Oxygen Demand (BOD), Dissolved Oxygen (DO), total hardness, Chloride, Nitrate, Ammonia Nitrogen, and Phosphates. Some trace metals were also analyzed which included Iron (Fe), Magnesium (Mg) Calcium (Ca) and Manganese (Mn). The biological parameter analyzed was faecal coliform count.

The Water Quality Index was equally determined. Water samples from seven sampling locations were analyzed within a period of six (6) months, (September 2017 to February 2018). The sample locations (SLs) for the study were chosen because of the observed intensive human activities that take place in those areas. It is therefore important to determine the concentration of each of these pollutants to proffer mitigation measures for improving the quality of the River on a sustainable basis.

CHAPTER TWO

LITERATURE REVIEW

2.1 Water Quality

"Water quality" is a term used here to express the suitability of water to sustain various uses or processes (Ekiye & Luo, 2010). Any particular use will have certain requirements for the physical, chemical or biological characteristics of water. Water quality can be defined by a range of variables that limit water use. There is increasing recognition that natural ecosystems have a legitimate place in the consideration of options for water quality management (Boulton, 2012). This is both for their intrinsic value and because they are sensitive indicators of changes or deterioration in overall water quality, providing a useful addition to physical, chemical and other information.

The composition of surface and underground waters is based on factors such as biological, meteorological, hydrological geological and topographical factors (Noori, Abdulrazzaq, Mohammed, & Abbas, 2017). Variations in water quality are observed even in a single watercourse. Human activities also has effect on water quality (Akubugwo & Duru, 2011). Some of these effects are the result of interventional changes, such as diversion of flow, draining of wetlands and the building of dams. More obvious are the polluting activities, such as the discharge of domestic, industrial, urban and other wastewaters into the watercourse (whether intentional or accidental) and the spreading of chemicals on agricultural land in the drainage basin (Soraya, Lakhdar, & Larbi, 2017).

Water quality is affected by a wide range of natural and human influences. The most important of the natural influences are geological, hydrological and climatic since these affect the quantity and the quality of water available (Yasi & Jimi, 2010). Their influence is generally greatest when available water quantities are low and maximum use must be made of the limited resource; The effects of human activities on water quality are both widespread and varied in the degree to which they disrupt the ecosystem and/or restrict water use (Umunnakwe & Nnaji, 2015). Pollution of water by human faeces, for example, is attributable to only one source, but the reasons for this type of pollution, its impacts on water quality and the necessary remedial or preventive measures are varied. According to Umunnakwe, Akagha, & Aharanwa (2012), faecal pollution may occur because there are no community facilities for waste disposal because collection and treatment facilities are inadequate or improperly operated, or because on-site sanitation facilities (such as latrines) drain directly into aquifers. The effects of faecal pollution vary.

In developing countries, intestinal diseases are the main problem, while organic load and eutrophication may be of greater concern in developed countries (in the rivers into which the sewage or effluent is discharged and in the sea into which the rivers flow or sewage sludge is dumped) (Nkwocha & Egejuru, 2010). A single influence may, therefore, give rise to several water quality problems, just as a problem may have some contributing influences. Eutrophication results not only from point sources, such as wastewater discharges with high nutrient loads (principally nitrogen and phosphorus), but also from diffuse sources such as run-off from livestock feedlots or agricultural land fertilized with organic and inorganic fertilizers (Huang, Wang, Lou, Zhou, & Wu, 2010). Pollution from diffuse sources, such as agricultural runoff, or numerous small inputs over a wide area, such as faecal pollution from settlements, is particularly difficult to control (Soraya *et al*., 2017). The quality of water may be described in terms of the concentration and state (dissolved or particulate) of some or all of the organic and inorganic material present in the water, together with certain physical characteristics of the water. It is determined by *in situ* measurements and by examination of water samples on-site or in the laboratory(Soraya *et al.,* 2017). The main elements of water quality monitoring are, therefore, on-site measurements, the collection and analysis of water samples, the study and evaluation of the analytical results, and the reporting of the findings. Increasing industrialization and the growth of large urban centers have been accompanied by increases in the pollution stress on the aquatic environment. Since ancient times, water in rivers, lakes, and oceans has also been considered as a convenient receiver of wastes (Barnerjee & Morella, 2011).

This use (or abuse) conflicts with almost all other uses of water and most seriously with the use of freshwater for drinking, personal hygiene, and food processing. (Akankli & Oronsaye, 2012). At a river basin scale, there is a need to establish a methodology for systematic data monitoring, for the characterization of surface water quality and the correct analysis of collected data, so that the present and expected future pressures may be identified and understood (Nibedita, 2015).

2.2 Water and its importance

Wind, fire, and water are the fundamental elements of the earth, only oxygen is more essential than water in sustaining life of all living things (Adedeji & Adetunji, 2011). On earth, water is the most abundant substance and is therefore needed by both plants and animals for survival and as such is an essential and critical element for life. It plays a vital role in nearly every function of the body, protecting the immune system, the body's natural defences and helping to remove waste matter. It is essential in maintaining and sustaining human, animal and plant life (WHO, 2010). Undoubtedly, water represents a unique and significant feature in any settlement: for drinking, sanitation, washing, planting, fishing, recreation, industrial process, etc. (Akubugwo & Duru, 2011).

Water plays a vital role in the development of a stable community since human beings can exist for days without food but the absence of water for a few days may lead to death (WHO, 2011). In the absence of which nomadic lifestyle becomes necessary and communities move from one area to another as demand for water exceeds its availability. Water is used in multiple ways, such as for domestic and industrial purposes (Water Research Center, 2015). It is also part of the larger ecosystems on which biodiversity depends. Water is a key resource and sustains both human and natural resources (Alinnor & Obiji, 2010). Water is present in the atmosphere, underground, rocks and rivers. It is useful in manufacturing, transportation, agriculture and even in the household (Ubuoh, Obeta, & Eze, 2014). Also, it is seen as the most exploited natural resource since the world began as it is used in industrial, agricultural and domestic activities.

2.3 Current Access to Safe Water

Nigeria is considered to be abundantly blessed with water resources. However, there is temporal and spatial variation in water availability, the north with low precipitation of only about 500mm in the north-eastern corner, and the south with precipitation of over 4,000mm in the southeast (Okoro, Uzoukwu, & Chemezie, 2014).. Access to safe drinking water refers to the percentage of the population that uses drinking water from improved sources; improved drinking water sources include household connection, public standpipes, boreholes, protected wells and springs (Ubuoh *et al*., 2014)

Ensuring the safety of drinking water has become a focus drawing attention. Access to safe water has been recognized as a basic human need. According to Andem, Udofia, Okoroafor, Okete, & Ugwumba, (2012) significance of safe water was recognized in the World Summit held at Johannesburg, South Africa in 2002 and later in the 3rd World water Forum held at Kyoto, Japan by mentioning that without safe water; sustainable poverty reduction in the third countries is not possible.

The issue of access to potable water supply has been a topical issue of high interest to several individuals, communities, organizations, and governments in the last three decades (Ukiwe, Onyedika, Viven, & Iwu, 2012). In developing countries, women and girls spend hours every day walking many kilometres to collect water from different sources. According to Anhwangwe *et al* (2012), women in developing countries walk an average of 6 kilometres per day to collect drinking water. On the whole, the average time lost by children and women in a day has been put at 200 million hours in search of water in developing countries daily (Ubuoh *et al.*, 2014).

According to the Water Research Center (2015), 783 million people, or 11% of the global population remain without access to an improved source of water. Such sources include; household convections, public standpipes, boreholes, protected dug wells, protected springs, and rainwater collection. In Nigeria, approximately 66 million Nigerians still do not have access to safe water (i.e. 44% of the population)(National Bureau of statistics, 2011). Only 47% in rural areas do have access while 75% in urban centres do have access. Performance on sanitation is even worse. The sanitation coverage stands at 31% representing a reversal from 37% coverage in 1990 (Water Research Center, 2015).

Consequently, when the provision of clean water is inadequate, people are compelled to use contaminated water that later result in water-related diseases and also the outbreak of these diseases (Nkwocha & Egejuru, 2010). Therefore, the provision of clean, reliable and potable water in rural areas remains a challenge because a larger percentage of the population lives in rural areas, (Amadi, Olaselinde, Okosun, & Yis., 2010). Access to water is either by construction of boreholes, digging of wells, fetching from rivers and streams or rainfall as applicable in most of our remote communities.

2.4 Water quality challenges

Water can be defined as a liquid without colour, smell or taste. It is indeed a wonderful chemical medium that has unique properties of dissolving and carrying in suspension huge varieties of chemicals (Osibanjo, Daso, & Gbadebo, 2011). The quality of water is a powerful environmental determinant of health. It is determined by the amount and level of physicochemical, microbial and heavy metals found in it. Water quality also refers to the physical, chemical and biological characteristics of water and its general composition. The quality of water is a measure of the condition of water relative to the requirements of one or more biotic species and any human need or purpose and it is frequently used by reference to a set of standards against which compliance can be assessed (WHO, 2011). The quality of any body of surface or groundwater is a function of either or both natural influences and human activities. According to Aremu, Odaofe, Ikokoh, & Yakubu, (2011), quality water must be free from high concentrations of chemicals or ions such as leads, sulphate, low pH, high turbidity, etc. Water must possess the characteristics of being aesthetically wholesome, chemically tolerable and bacteriological safe before it meets up with the requirements of the World Health Organization (WHO) as a potable water (WHO, 2011). Good quality drinking water is water free from disease-causing organisms, harmful chemical substances, and radioactive matter; it is aesthetically appealing and is free from objectionable colour or odour. Water quality is defined by the composition of water, natural processes and human activities. It is often presumed that the chemical composition of water is the only factor involved.

However, especially (micro) biological factors are of main importance when considering water quality (Barnerjee & Morella, 2011). Next to this, there are also physical factors such as sand, silt, clay, dust and plant material. Natural surface water often has impurities from various sources some of which may be suspended particles, colloidal materials and may also be dissolved cationic and anionic substances (Olajumoke, Oluwatoshin, Olumujiwa, & Abimbola, 2010). The quality of water may be described in terms of concentration and state of (dissolved and particulate) of some or all the organic and inorganic materials present in the water, together with certain physical characteristics of the water (Boulton, 2012).

Plants and animals require moderately pure water, and they cannot survive if their water is loaded with toxic chemicals or harmful microorganisms. If severe, water pollution can kill large numbers of fish, birds, and in some cases, killing all members of a species in an affected area (Oladele, Adegbenro, & Adewole, 2011). Extensive scrutiny of water used for diverse activities is necessary because numerous pathogens can live in them especially waters used as sources of drinking water like streams, lakes, ponds, oceans, and rainwater (Aremu *et al.*, 2011). Therefore, water quality monitoring and assessment can be used to determine ambient water quality, the extent and causes of a water quality problem, or to measure the effectiveness of best management `practices. Water quality monitoring is paramount to safeguard public health and also to protect the water resource in Nigeria.

2.5 Pollution in the Environment

Pollution is the introduction, into the environment, of substances or energy liable to cause hazards to human health, harm to living resources and ecological systems, damage to structures or amenity, or interference with legitimate uses of the environment (Odeyemi, Faweya, Agunbiade, & Ayeni, 2011). *It is the introduction of contaminants into an environment causing instability, disorder, harm, or discomfort to the ecosystem (i.e. physical systems or living organisms). It can take the form of chemical substances or energy, such as noise, heat, or light* (Adedeji & Adetunji, 2011). Galadima *et al* (2011) defined pollution as the presence of undesirable substances in any segment of the environment (land, air, water, soil), primarily due to s waste products or harmful secondary products which are harmful to man and other organisms. It occurs only when the environment's capacity for dealing with additional materials is surpassed. Environmental pollution is said to occur when the undesirable substances which are admixtures and impurities are present in substantial quantities in the environment, sufficient enough to cause appreciable harm to any component (land, air, water or soil) or all the components of the environment (Ekubo & Abowei, 2011).

2.6 Water Pollution, sources and pollutants

Water pollution is the contamination of water bodies affecting plants and organisms living in these bodies of water. the effect is damaging not only to individual species and populations, but also to the natural biological communities (Adedeji & Adetunji, 2011). Water pollution occurs when pollutants are discharged on-point or diffusely into water bodies without adequate treatment to remove harmful compounds. It is the presence in water of foreign substances which could be organic, inorganic, biological or radiological in quantity high enough to lower the water quality and constitute a health hazard; because of the presence of microbiological agents, chemical agents, oxygen depleting substances, nutrient materials and suspended matter (Egereonu, Ukiwe, Edet, & Ogukwe, 2012).

Iwuoha *et al* (2010), defined pollution of the aquatic environment as the introduction of substances or energy directly or indirectly into water bodies by man, resulting in deleterious effects to living resources, hazards to human health, a hindrance to aquatic activities such as fishing, impairment of water quality and reduction of amenities. Pollution had always been misused for contamination which can be defined as the presence of elevated concentrations of a substance in the air, water, soil or any other such thing not necessarily resulting in a deleterious effect. Aquatic pollution, therefore, is the direct or indirect human introduction of substances into the aquatic environment such as to harm living resources, affect human health and water quality. Pollution is not merely the addition of a substance to the aquatic ecosystem, but its addition at a rate faster than the ecosystem can accommodate it (Ekubo & Abowei, 2011).

The pollution process is initiated when substances are released into a body of water, they become dissolved or suspended in the water or deposited on the bottom, accumulating to the extent that they overwhelm its capacity to absorb, break down, or recycle them, and thus interfering with the functioning of aquatic ecosystems (Akankli & Oronsaye, 2012). Water pollution in Nigeria occurs in both rural and urban areas. In the countryside, drinking water from natural sources such as rivers and streams is usually polluted by organic substances from upstream users who use water for various activities. The most common form of stream pollution associated with forestry activities is increased concentrations of soil particles washed into the stream by land disturbance (Iwuoha, Osuji, & Horsfall, 2012).

2.6.1 Sources of pollution in the aquatic Environment

According to Adedeji & Adetunji, (2011), two main sources of pollution exist in the aquatic environment. The two main pathways for these chemicals to enter the water system are via transport of suspended particles, in the case of insoluble chemicals and dissolution of minerals and chemicals in water, in the case of soluble chemicals. The materials get to surface water systems through point (direct) and diffuse (indirect) sources. Direct sources include effluent outfalls from factories, refineries, and waste treatment plants, etc., which emit fluids of varying quality directly into water bodies. Indirect sources include contaminants that enter the water supply from soils/groundwater systems and the atmosphere via rainwater. Soil and groundwater contain the residue of human agricultural practices (fertilizers, pesticides, etc.) and improperly disposed of industrial wastes.

Point sources refer to a point in space such as an effluent or outflow pipe like discharge of wastes from industries of definite identity with fixed volume and composition while diffuse sources refer to non-point introduction such as water flowing over field or forest surfaces, entering streams along their widely scattered and discharged margins over some considerable distance. Consequently, diffuse pollution sources are much more difficult to identify, isolate and treat, (Ochuko & Thaddeus, 2013). Aquatic environments are not holding tanks that supply water for human activities. Rather, these environments are complex matrices that require careful use for sustainability for future generations. Water pollution alters the properties of water and renders it unfit or less fit for the purpose its unaltered form was used - the use being natural or artificial. The key major sources of water pollution are oil spills, industrial refuse/toxic waste, and agricultural fertilizers (Akubugwo & Duru, 2011).

2.6.1.1 Pollution by Putrescible materials

Oxygen – demanding wastes, most of which are biodegradable like domestic sewage, animal manure, and other organic wastes do not persist in the environment (Chatterjee, 2011). This consists of foul-smelling rotting of organic materials by bacteria or materials such as waste from humans, paper pulp plants, and agricultural activities. When discharged into stream, river, or lake, the organic materials decompose by using large quantities of oxygen from water. If too much oxygen is removed and it takes too long for it to be restored, there may be serious pollution. In some rural communities and cosmopolitan cities of Nigeria, particularly in slum areas where there is an acute shortage of toilet facilities, people simply resort to open defecation thereby giving rise to land, soil and water pollution directly, as observed in areas that have streams passing through them (Cosmas & Samuel, 2011). Yet, other people decide to pass their excreta in the bush, not minding how near it is to their dwelling place. However, when such excreta are disposed of on land or stream, it eventually gets to the larger water bodies and pollutes the resources.

2.6.1.2 Pollution by heated effluents

Oxygen is readily restored to water bodies when the water is cool. The hotter it is, the lower the oxygen holding capacity of the water. The bubbles that arise from heated water demonstrate what happens to the gases in hot water (Olajumoke *et al.*, 2010). The discharge of clean hot water into an unpolluted stream is hence as harmful as the discharge of organic wastes. In these cases, the oxygen content of water is drastically reduced. It is because of all these that water pollution is a serious issue in tropical countries. The temperature is always warm that it is difficult for the streams to absorb the necessary quantities of oxygen (Oladele *et al*., 2011).

2.6.1.3 Pollution by Toxic Materials

These are toxic wastes, which do not easily settle out and are not easily broken down by biological means. Such toxic wastes such as DDT, mercury, heavy metals, herbicides, and pesticides are poisonous/toxic when consumed or contacted by plants and animals depending on the degree and rate of consumption or dosage received (Ukiwe *et al*., 2012). The important pollutants from agricultural drainage include the poisonous pesticide residues and mineral fertilizers. Unlike industrial effluents, it is very difficult to contain the transport of nutrient chemicals and pesticides through agricultural drainage, which is a non-point source of pollution. Edimeh *et al* (2011) opines that the fertilizers used in agriculture are the major contributor of residual phosphates and nitrates in surface waters. Pesticides and herbicides are used in the control of different pests and in the control of weeds that affect animals and plants. The chemicals finally end up in the aquatic environment where they enter the nutrient or water cycle (Edimeh, Eneji, Oketunde, & Sha'Ato, 2011). In Nigeria there is an increase in the use of herbicides as reported by Ukiwe *et al.*, (2012), but total quantities applied are not known. The primary agricultural pollutants are nutrients (particularly nitrogen and phosphorus), sediment, animal wastes, pesticides, and salts. Agricultural sources enter surface water through direct surface runoff or seepage to groundwater that discharges to a surface water outlet. The most common sources of excess nutrients in surface water are chemical fertilizers and manure from animal facilities (Jidauna, Dabi, Saidu, Ndabula, & Abaje, 2014). Such nutrients cause eutrophication in surface water. Eutrophication is thus depriving the river of oxygen (called oxygen debt). algae prevails and turn the water greenish, supressing the growth of other water plants which die first disrupting the food chain.

Pesticides used for pest control in farming can also contaminate water resources. Some of these pesticides contain endocrine-disrupting chemicals that can mimic or antagonize the effects of endogenous hormones could potentially have serious effects not only on the development and well-being of an individual organism, but perhaps more importantly on the ability of that organism to reproduce, and its offspring to survive and eventually reproduce (Murhekar, 2011). Nitrates also penetrate the ground and end up in drinking water.

2.6.1.4. Pollution by Inert Materials, Radioactive Elements, and Compounds

This includes those, which may affect biological conditions and equally de-oxygenate water. De-oxygenating materials include sewage and organic wastes. The choice of dumpsites close to rivers and streams is particularly becoming a major concern that merits special attention. This is essentially because most of these surface water bodies still serve as sources of water supply to many urban and rural communities down-stream (Taiwo, Olujimi, Bamgbose, & Arowolo, 2012), and are therefore expected to maintain a certain level of quality for their sustainable use by these populations. Rivers are the most important resource for man. Unfortunately, river waters are being polluted by indiscriminate disposal of sewerage, industrial waste, and the plethora of human activities, which affects their physical, chemical characteristics and microbiological quality. Industries like textile, paper and pulp, chemical, rubber, plastic, leather, and pharmaceutical usually release their toxic effluents into water bodies. Sometimes the buried industrial metals and solvents can seep through the ground to reach water bodies and cause havoc to aquatic communities. Waste management is a major problem in most developing nations of the world including Nigeria (Nkwocha, Pat-Mbano, & Okeoma, 2012). In most cases, sewage and wastewater from homes are routed into the rivers and streams. Besides, these factories use huge quantities of water for processing of products, washing, and cooling and once discharged into the environment it can reach water bodies to cause havoc to life forms. Pollution ends up reducing the quality of air, water, or land from which man draws resources. According to (Nibedita, 2015), a river may be polluted when the water in altered in composition or condition, directly or excessive nutrient enrichment of water bodies leads to Eutrophication. Where a water body has an excess of nitrogen and phosphorus from natural sources, it leads to increased nutrient loadings and increased microbiological activity. Pollution of the aquatic environment is a serious and growing problem. Significant amounts of industrial, agricultural, and commercial chemicals discharged into the aquatic environment have led to various deleterious effects on aquatic organisms. Aquatic organisms, including fish, accumulate pollutants directly from contaminated water and indirectly *via* the food chain. According to Egereonu *et al*., (2012), Nigeria's vast freshwater resources are among those most affected by environmental stress imposed by human population growth, urbanization, and industrialization (Olajumoke *et al*., 2010).

The transfer of unfavorable releases from industries is detrimental to human and animal health and safety. Disposal of sewage wastes into a large volume of water could increase the biological oxygen demands to such a high level that all the available oxygen may be removed, consequently causing the death of aerobes. Pollutants of water, according to Awomeso *et al*.,(2012), include sewage and other oxygen demanding wastes, infectious agents, organic chemicals, other chemicals, and mineral substances, sediments (turbidity), radioactive substances and thermal pollution. Additionally, several human activities that may result in water pollution include the following, agriculture, irrigation, urbanization, mining, fire, and industrialization (Taiwo *et al.*, 2012).

2.7 Bacteriological Examination of surface Water

Some harmful diseases are transmitted by water-borne organisms. An example is Bilharzias caused by Schistosoma. Apart from the problem of accessibility of clean water, pollution of water could lead to health hazard, sanitary nuisance, and severe economic and social consequences. Incidence of diseases such as typhoid, paratyphoid, giardiasis, infectious hepatitis, leptospirosis, schistosomiasis, shigellosis, amoebiasis, etc. could be inherent from the consumption of contaminated water. According to WHO, (2011), associated pathogens of these diseases are linked with contaminated water.

2.7.1 Faecal Coliforms

Human and animal wastes carried to stream systems are sources of pathogenic or disease-causing, bacteria and viruses. The disease-causing organisms are accompanied by other common types of non-pathogenic bacteria found in animal intestines, such as faecal coliform bacteria, enterococci bacteria, and Escherichia coli (E. coli) bacteria (WHO, 2011). Faecal coliforms and enterococci are not usually disease-causing agents themselves but high concentrations suggest the presence of pathogens. Faecal coliform, enterococci, and *E. coli* bacteria are therefore used as indicator organisms indicating the probability of finding pathogenic organisms in a stream. To measure indicator bacteria, water samples must be collected in sterilized containers, forced through a filter, and incubated at a specific temperature for a certain amount of time. The resulting colonies that form during incubation are counted and recorded as the number of CFU units per 100 ml of water.

2.7.2 Total coliforms

The term "total coliforms" refers to a large group of Gram-negative, rod-shaped bacteria that share several characteristics. The group includes thermotolerant coliforms and bacteria of faecal origin, as well as some bacteria that may be isolated from environmental sources. Thus, the presence of total coliforms may or may not indicate faecal contamination. In extreme cases, a high count for the total coliform group may be associated with a low, or even zero, count for thermotolerant coliforms. Such a result would not necessarily indicate the presence of faecal contamination. According to Oladele *et al.*,(2011), it might be caused by the entry of soil or organic matter into the water or by conditions suitable for the growth of other types of coliform. Total coliforms are grown in or on an appropriate medium, at a temperature of 35 or 37 °C. They are provisionally identified by the production of acid and gas from the fermentation of lactose. The term "faecal coliform" has been used in water microbiology to denote coliform organisms, which grow at 44 or 44.5°C and ferment lactose to produce acid and gas.

Water that flows over the land and runs into rivers, lakes, ponds, and impounded reservoirs is known as surface water (NESREA, 2011). Surface water is exposed to contamination such as organic impurities, inorganic impurities, gases, and microorganisms therefore; it must be treated before use. There is a need to intensify efforts in the routine monitoring of activities going on within the surface water vicinities. Rivers are the most important freshwater resources for man. Unfortunately, river waters are being polluted by indiscriminate disposal of sewage, industrial waste and a plethora of human activities, which affects their physicochemical characteristics and microbiological quality (AIRBDA, 2014). Most of the surface water sources in Nigeria recorded both total coliform and faecal coliform counts high above the limits of WHO Maximum Contamination Levels of drinking water.

High faecal coliform is an indication of possible pollution by human excreta. The presence of this indicator bacterium suggests the possible presence of pathogens causing cholera; typhoid and gastroenteritis, thus calling initial disinfection and treatment which renders pathogens ineffective before such water are consumed. Pollution of the aquatic environment is therefore, a serious and growing problem. Odeyemi *et al*., (2011) insists that in most countries, the principal risks to human health associated with the consumption of polluted water are microbiological in nature. The bacteriological examination of water has a special significance in pollution studies, as it is a direct measurement of the deleterious effect of pollution on human health. Coliforms are the major microbial indicator in the monitoring water quality. Onuiyieke River is a major river of economic, agricultural and environmental significance in Obowo LGA of, Imo State, Nigeria.

The river receives effluents from local industries located along its course, apart from domestic wastes and other activities carried out along it that contribute to its pollution. Therefore, the river is subject to a high level of eutrophication due to the organic matter and industrial effluents discharged into it (Iwuoha *et al*., 2012). In addition, industrial wastes that alter the water pH and provide excessive bacterial nutrients often compromise the ability of natural processes to inactivate and destroy the pathogen. The extent of discharge of domestic and industrial effluents is such that rivers receiving untreated effluent cannot provide the dilution necessary for the survival of resident organisms as good quality water sources. Water contaminated by microbes remains the greatest single cause of human illness and death on a global scale. According to Ideriah *et al* (2010), high nutrient loads lead to eutrophication of downstream and coastal waters and loss of beneficial human uses. High levels of pollutants in river water systems causes an increase in biological oxygen demand (BOD), chemical oxygen demand (COD), total dissolved solids (TDS), total suspended solids (TSS), toxic metals such as Cadmium, Chromium, Nickel and lead and faecal coliform and hence make such water unsuitable for living. Industrial wastewaters range from human sewage, pulp and paper industries, slaughterhouses, tanneries and chemical industry.

2.8. Parameters of Water Quality

2.8.1 Turbidity

Turbidity refers to the cloudiness of water due to fine suspended colloidal particles of clay or silt, waste effluents or microorganisms and is measured in turbidity units (NTU) (Egereonu *et al.*, 2012). Suspended solids, microscopic plants and animals that are suspended in the water column cause cloudiness. It is an important indicator of suspended sediment and erosion levels (Murhekar, 2011). Typically, it will increase sharply during and after a rainfall, which causes sediment to be carried into the river. Elevated turbidity will also raise water temperature, lower dissolved oxygen (Ekubo & Abowei, 2011), prevent light from reaching aquatic plants which reduces their ability to photosynthesize and harm fish gills and eggs. However, high turbidity in drinking water which correlates positively with TDS can cause colour/odour problems (Edimeh *et al.*, 2011). The measurement of turbidity is a key test of quality. The source of these sediments includes natural and anthropogenic (human) activities in the watershed, such as natural or excessive soil erosion from agriculture, forestry or construction, urban runoff, industrial effluents, or excess phytoplankton growth.

2.8.2 pH

The pH of water determines the solubility, biological availability of chemical constituents such as nutrients and heavy metal. pH is defined as degree of the activity of the hydrogen ion. It can be defined as the decimal logarithm of the reciprocal of the hydrogen ion activity in a solution. The pH of pure water decreases with increasing temperatures. For example, the pH of pure water at 50 °C is 6.55, but at 25°C, it has a pH very close to 7. Water that has been exposed to air is mildly acidic being that water absorbs carbon dioxide from the air, which is then then converted into bicarbonate and hydrogen ions. Solutions with a pH less than 7 are said to be acidic and solutions with a pH greater than 7 are basic or alkaline. Measurement of pH for aqueous solutions can be done with a glass electrode and a pH meter or using indicators (WHO, 2011)

2.8.3 Total Dissolved Solids

Total Dissolved Solids (TDS) is a measure of the content of inorganic and organic substances contained in a liquid in micro-granular or molecular, ionized suspended form (Dibafor, Amalo, & Clement, 2011). Therefore, the solids must be small enough to survive filtration through a sieve the size of two micrometres. Suspended solids refer to small solid particles which remain in suspension in water as a colloid or due to the motion of the water. It is used as one indicator of water quality. Suspended solids are important as pollutants and pathogens are carried on the surface of particles. The smaller the particle size, the greater the total surface area per unit mass of the particle, and so the higher the pollutant load that is likely to be carried.

2.8.4 Temperature

Temperature is important because the rate of chemical reactions increases at higher temperatures, which in turn affects biological activities and growth of aquatic organisms (WHO, 2011). Temperature is measured in °C and is a good measure for assessing the effects of temperature changes on living organisms. Many factors can influence stream temperature. Water temperatures can change. Temperature affects the concentration of dissolved oxygen in a water body. According to (Boulton, 2012), increases in temperatures that may occur due to climate change have the potential to result in shifts in species composition and loss of endemic species. Water temperature is a controlling factor for aquatic life: it controls the rate of metabolic activities, reproductive activities, and therefore, life cycles. If stream temperatures increase, decrease or fluctuate too widely, metabolic activities may speed up, slow down, malfunction, or stop altogether.

2.8.5 Colour, Taste, and Odour

Colour, taste, odour are subjectively determined properties. They are caused by dissolved impurities either from natural sources or from the discharge of noxious substances.

2.8.6 Electrical conductivity (EC)

Electrical conductivity (EC) is a physical property of water, which is dependent on the level of dissolved salts. It is measured in micro Siemens per centimetre (μScm-1), giving a good estimate of the dissolved salt content of water (WHO, 2011). It is a measure of how well water can pass an electrical current and an indirect measure of the presence of inorganic dissolved solids such as chloride, nitrate, sulphate, phosphate, sodium, magnesium, calcium, iron, and aluminium. Such substances increase the conductivity of a body of water. Substances (organic) like sugar, oil and alcohol do not conduct electricity very well having a low conductivity in water. Water with absolutely no impurities (which does not exist) conducts water very poorly. The impurities in water increase its conductivity.

2.8.7 Dissolved Oxygen (DO)

The amount of dissolved oxygen is a measure of the biological activity of the water masse (Ademoroti, 1996). Dissolved Oxygen (DO) is widely used in water quality studies. The amount of dissolved oxygen gas depends highly on temperature and somewhat on atmospheric pressure. Salinity also influences dissolved oxygen concentrations, such that oxygen is low in highly saline waters and vice versa. The amount of any gas, including oxygen, dissolved in water is inversely proportional to the temperature of the water; as temperature increases, the amount of dissolved oxygen (gas) decreases

Water at higher temperatures and altitudes will have less dissolved oxygen (Boulton, 2012). Dissolved oxygen reaches its peak during the day. At night, it decreases as photosynthesis has stopped while oxygen-consuming processes such as respiration, oxidation, and respiration continue, until shortly before dawn. (Umunnakwe & Nnaji, 2015) maintain that DO plays a key role in the assessment of water quality. It affects the taste of water and high concentrations of dissolved oxygen in domestic supplies are encouraged by aeration. Dissolved Oxygen is measured in $mg1^{-1}$ (WHO, 2011).

2.8.8 Biochemical Oxygen Demand (BOD):

This is the amount of DO needed by aerobic biological organisms in a body of water to break down substances present in a given water sample at a certain temperature over a specific period (WHO, 2011). The term also refers to the amount of oxygen required for microbial metabolism of organic compounds in water. The BOD value is expressed in milligrams of oxygen consumed per liter of sample during 5 days of incubation at 20°C and is often used as a measure of organic pollution of water. The difference between the physical concentration of oxygen in the water and the actual concentration of oxygen is defined as the biochemical demand in oxygen (Ademoroti, 1996)

2.8.9 Chemical Oxygen Demand (COD)

This is a measure of the oxygen equivalent of the organic matter in a water sample that is susceptible to oxidation by a strong chemical oxidant, such as dichromate (WHO, 2011). In environmental chemistry, the COD test is commonly used to indirectly measure the amount of organic compounds in water. It is expressed in milligrams per liter (mg/l) also referred to as ppm (parts per million), which indicates the mass of oxygen consumed per liter of solution (Ademoroti, 1996).

2.8.10 Phosphates

Sources of phosphate include road salts, animal wastes, fertilizer, disturbed land, detergent and sewage. According to (WHO, 2011), Phosphates do not pose a human or health risk except in very high concentrations. It is measured in mg/L.

2.8.11 Nitrogen

Nitrogen may be present in the form of organic compounds usually from domestic wastes. Examples of these compounds are ammonia or ammonium salts. Nitrogen could be in the form of nitrites or fully oxidized nitrates. Measures of nitrogen indicate the state of pollution by organic wastes. It is measured in mg 1^{-1}(N) (Boulton, 2012).

2.8.12 Chlorides

Chlorides are found in brackish water bodies contaminated by seawater or in groundwater aquifers with high salt-water content. The presence of chlorides (mg 1-^{1}Cl) in a river is an indication of sewage pollution from other chloride compounds.

2.9 Effects of Fresh Water Pollution on the Environment

Various pollutants entering surface water either naturally or through human beings have human and environmental consequences. Apart from the economic implications like spending money to buy water from water vendors, medical expenses incurred for treating patients of water-borne diseases and the hours dissipated in search of safe water, there are many negative effects. The effect of uncontrolled pollution as seen all over Nigeria renders stream channels and waterways unsafe for human, agriculture and recreational uses; destroys biotic life, poisons the natural ecosystems, poses a threat to human life and is, therefore, against the principles of sustainable development (Chatterjee, 2011).

2.9.1 Health Hazards

Water polluted with human and animal faeces often contain different forms of bacteria, viruses, protozoa, and helminths which can cause diseases like dysentery, typhoid, and infectious hepatitis (Desai & Tank, 2010). The implication of contracting the diseases is that one becomes sick, debilitated, and weak and may even die. Effluent flowing from factories and fields containing cadmium, mercury, lead, nickel, antimony, and arsenic can get to the natural water and be assimilated at low concentrations by aquatic organisms over time (Olajumoke *et al*., 2010). Fish caught and eaten from such contaminated bodies of water pose health hazards to both children and adults. Infants often suffer severe brain damage and nervous system damage from methyl mercury when passed from the fish to the mother through the placenta to the foetus (WHO, 2010). The symptoms include breathing difficulty, blue skin; colouring and suffocation while lead poisoning in human beings generally range from anaemia, headache, sore muscles (when in small concentrations), to malfunctioning of kidney, reproductive system, liver, and central nervous system.

2.9.2 Death of Water-related Birds and fishes

Organic matter which includes dead leaves, human and animal excreta are mainly from fields, homes, and factories. The presence of these pollutants in water results in a reduction of dissolved oxygen, leading to an increase in the amount of oxygen needed (Akubugwo & Duru, 2011). The resulting anaerobic condition produces foul smell due to the accumulation of ammonia and hydrogen sulphide. This can eventually lead to the death of many aquatic fauna not adapted to low oxygen concentration (Alinnor & Obiji, 2010). Aquatic organisms are greatly affected, including birds of the air. Fishing is a popular activity in Nigeria where many ethnic groups in riverine areas engage in it for livelihood. Pollution of water bodies implies a reduction in fish catch and may put the local fishermen out of business (Aremu *et al*., 2011). The presence of toxic pollutants in water bodies often soften**s** the exo-skeleton or carapace of fish-like creatures and exposes them to various disease conditions and a considerable number may die. The death of aquatic organisms does not only throw fishermen and other water-related business activities out of jobs but reduces fish supply generally (Alinnor & Obiji, 2010).

The absence of these proteinous foods from people's tables has a direct effect on their health by exposing them to protein deficiency disease conditions.

2.9.3 Change in Species Composition

Some industries such as thermal power plants and nuclear reactors withdraw water from freshwater for cooling purposes but return same at higher temperature with deleterious consequences (Boulton, 2012). The heated water dissolves oxygen at the faster rates than cool water and increases the rate of chemical reaction including decomposition, thereby leading to depletion of oxygen. In a thermal-polluted water, oxygen is depleted but the growth of thermophilic species is enhanced hence upsets species composition.

2.9.4 Floral Photosynthesis Impaired

The presence of insoluble particles suspended in water bodies makes water cloudy and murky. These solid particles which are mostly derived from cultivated lands, overgrazed lands, degraded stream banks, strip mines, and construction sites make the water dark hence reduces light penetration (Ekiye & Luo, 2010). As a result of light reduction, the normal photosynthesis of under-water plants will be impaired to the disadvantage of aquatic animals that depend on such plants for livelihood. According to Ekubo & Abowei (2011), impaired photosynthesis by aquatic plants reduces the concentration of dissolved oxygen in the water body. Under conditions of low dissolved oxygen, anaerobic reactions for the degradation of pollutants begin to occur hence, it may lead to the deterioration of the water body beyond recovery.

2.9.5 Ecological Succession

The concentration of nutrients in natural water from wash-down sources usually increases the growth and number of aquatic organisms (Jidauna *et al.*, 2014). The presence of these pollutants, particularly nitrogen compounds, sulphur, phosphorus and metal ions creates a new environment hence the physical, chemical and biological properties change; leading to new organisms getting into the system while others will disappear. Since there is dense growth in algae bloom and other aquatic plants that now cover the water surface, photosynthesis is prevented thus, the feeding habits of aquatic animals may change from simple autotrophic to heterotrophic mode known as eutrophication, which is a natural process of ecological succession (Nasehi, 2012).

2.9.6 Loss of Aesthetic and Recreational Value of Water Fronts

Polluted water body emits bad smell and is clogged with debris or covered with algae bloom which can be offensive, hence unpleasant to visit. The stench can also arise from decaying organic matter and sewage which may replace the natural state of water (Ubuoh *et al.*, 2014). The implication is that such a body of water that emits foul odour to cause noxious smell will certainly lead to loss of the beautiful sites for recreation and tourism.

Table 2.1 WHO and NESREA Regulatory Limits for Water Quality Parameters

PARAMETERS	WHO (2011)	NESREA(2011)
PH	6.5-9.5	6.5-8.5
Temperature (ºC)	-	-
Alkalinity (mg/L)	120.00	-
Total Hardness (mg/L)	<200.00	-
Total Solids(mg/L)	<1500.00	-
TDS(mg/L)	<1000.00	500.00
DO(mg/L)	6.00	≥6.00
BOD(mg/L)	3.00	≥3.00
COD(mg/L)	-	30.00
Nitrate(mg/L)	50.00	9.10
Sulphate (mg/L)	500	100
Phosphate (mg/L)	-	3.50
Ammonia (mg/L)	<1.50	0.05
Iron (mg/L)	0.30	0.30
Chloride (mg/L)	-	300.00
Conductivity (mg/L)	300	-

TDS =Total Dissolved Solids, DO= Dissolved Oxygen, BOD= Biological Oxygen Demand, COD= Chemical Oxygen Demand, WHO= World Health Organisation, NESREA = National Environmental Standards and Regulatory Enforcement Agency. Sources: WHO (2011), NESREA (2011)

2.10 Water Quality Index (WQI)

Water Quality Index is one of the most effective tools to communicate information on the quality of water to the concerned citizens and policymakers (WHO, 2011). Water quality index is an important parameter for the assessment of surface water. It is defined as a rating showing the composite influence of various water quality parameters. WQI is calculated from the suitability of surface water for human consumption (Chatterjee & Raziuddin, 2002).WQI provides a single number (like a grade) that expresses the overall quality of water at a certain location and time based on several water quality parameters (AIRBDA, 2014). Singh, Tiwari, & Mahato, (2013) defined WQI as a technique of rating that provides the composite influence of individual water quality parameters on the overall quality of water.

One of the major advantages of WQI is that it integrates data from many water quality parameters into a mathematical equation that evaluates the health of water quality with number, (Douglas, Stephen, & Kenneth, 2015). The weights for various water quality parameters are assumed to be inversely proportional to the regulated standards for the equivalent parameters. According to Brown, McClellan, Deininger, & O'Connor, (1972), the progressive search on how to improve polluted water quality led to the development of models for the determination of water quality known as Water Quality Index (WQI). Nine parameters were finally accepted to summarize the composite effect on water quality using a single numerical expression (Chandra, 2017). The single numerical index helps to classify the water into five different classes*(Brown et al.*, 1972; Horton, 1965; Said & Stevens, 2014). Such grouping helps to identify river water requiring prompt action on a regular basis.

CHAPTER THREE

MATERIALS AND METHODS

3.1 Study Area

3.1.1 Location and Site

Imo is one of the 36 states of Nigeria and lies in the South East of Nigeria. Owerri is its capital and largest city. Its other major cities are Orlu and Okigwe Located in the south-eastern region of Nigeria, it occupies the area between the lower River Niger and the upper and middle, Imo River (National Bureau of statistics, 2011).

Obowo is a Local Government Area in Imo State. It is bounded on the north by Ihitte; in the southeast by the Imo River; in the southwest by Mbaise and in the North West by Ehime. Its headquarters is located in Otoko. The area is right across the Imo River and Onuiyieke River is a first stream order, a tributary of Imo River (one of the five sub-basins of Imo State) having its source from Imo River then course through Isi-Nweke to Seven and half, Obowo-Umuahia boundary. It is characterized by relatively low elevation and near flat topography which enhances its runoff. Micro cliffs appear along the river showing the extent of the scouring damage caused by sheet erosion. The hydraulic gradient increases in line with the topography thus the river is recharged by natural precipitation and groundwater.

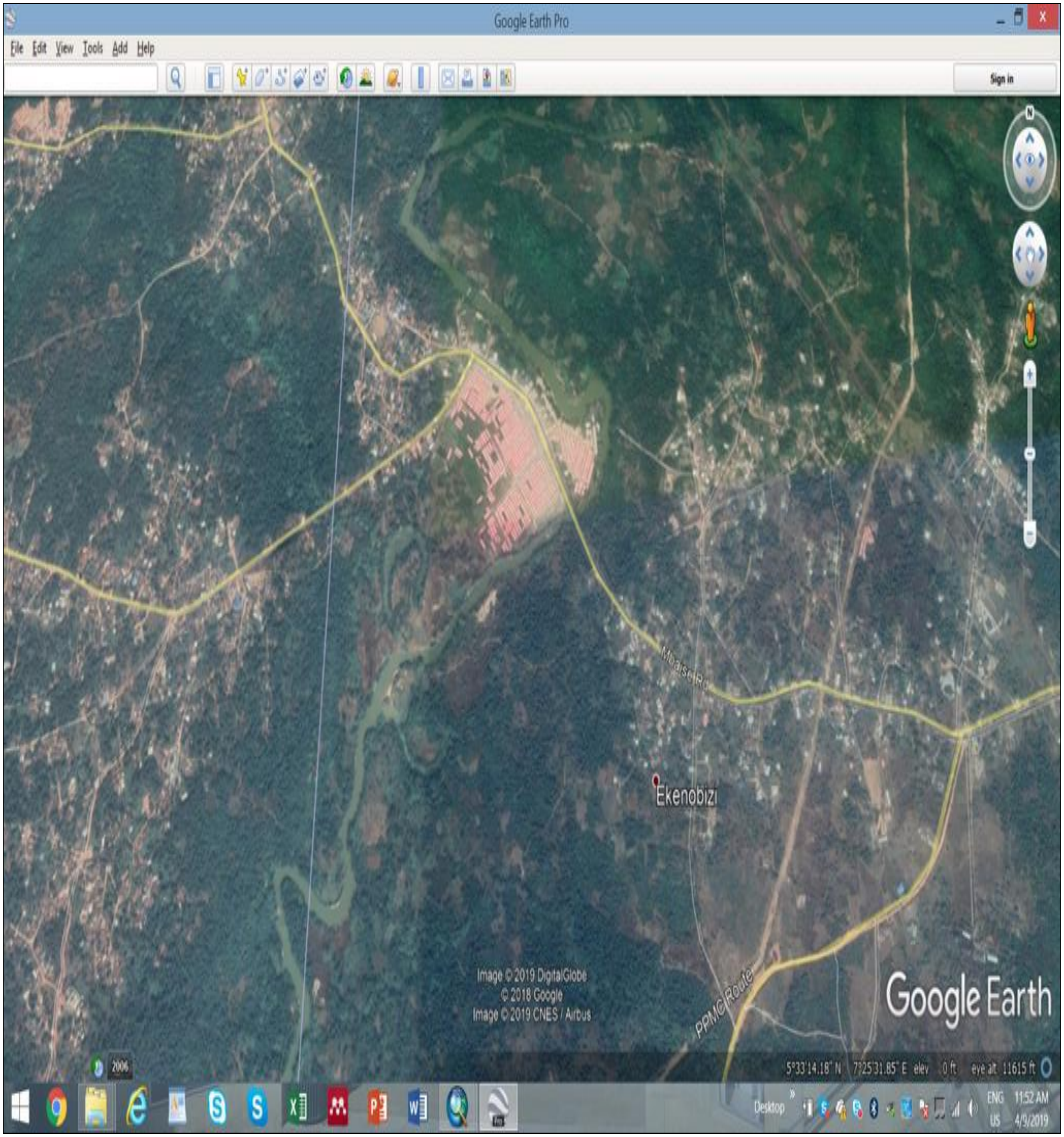

Fig 3.1 Imaging Presentation of the study area (*Source, Google Earth*)

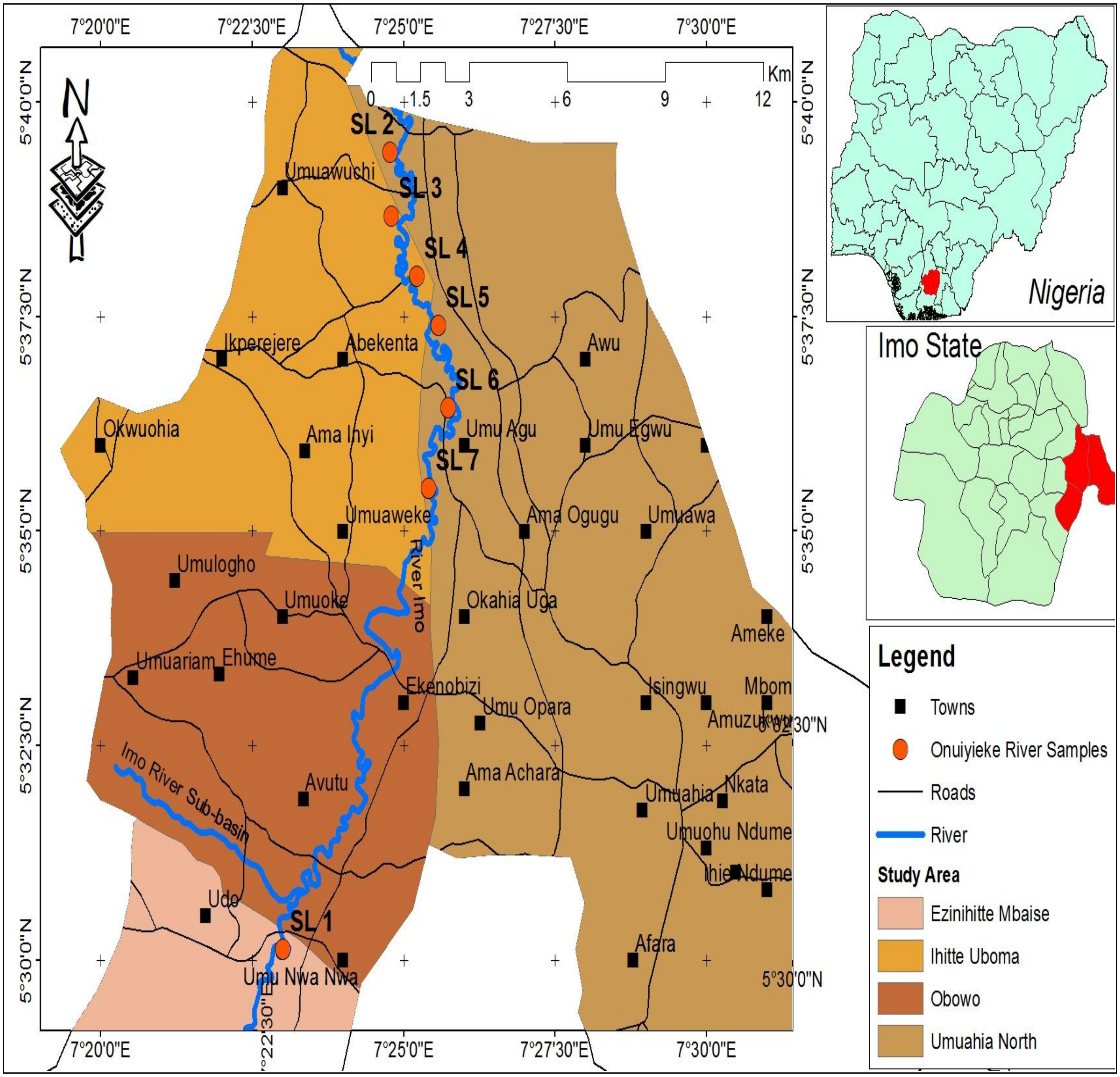

Fig 3.2 Map showing sampling points in the study area.

3.1.2 Climate, Vegetation, and Drainage

The notable rivers and streams that are found in the state include; Imo, Nwaorie, Otamiri, and Njaba. The study area lies within the tropical region and the Imo River Basin hydrological province of Nigeria. Early rainfalls usually start in January/February with full commencement of rainy season in March and ends in November of each year. The climate of Imo State is humid, semi equatorial type (Boulton, 2012). The State experiences heavy rainfall, with an average annual rainfall of 2000- 2400 mm/yr. and an average number of 152 rain/ days particularly during the rainy seasons (April– October) the superficial rainfall distribution is bimodal, with peaks in July and September and a two weeks break in August. The rainy season begins in March and lasts till October or early November.

Rainfall is often at its maximum at night and during the early morning hours. The higher annual rainfall depths and rainfall days encourage large volumes of runoff. However, variations occur in rainfall amount from year to year, usually between 1,990 mm and 2,200 mm. Temperatures are similar all over the State; the hottest months are January to March. The study area falls within the humid tropical rainforest region characterized by depleted rainforest vegetation, with mean temperatures of 27ºC throughout the year. The rainy season begins in April and lasts until October. An average annual temperature above 20 °C (68.0 °F) creates an annual relative humidity of 75% with humidity reaching 90% in the rainy season. The dry season experiences two months of Harmattan from late December to late February. The watershed covers about 10,000 km^2 and has a mean slope of 38.5% draining about 18700 hectares of land.

Plate 3.1: Sand mining along Onuiyieke River at Ogwogoroanya (near Site Location 3)

3.1.3 Population and activities

Obowo has an area of 90.0 km² and a population of 171, 342 at the 2006 census (NBS, 2011). The current estimated population is put at 188,612 inhabitants with the majority of the area's dwellers being members of the Igbo Ethnic group (National Population Commission of Nigeria, Web).

The towns and activities that make up Obowo LGA include Umuokeh, Amuzi, Umulogho, Otoko and Umungwa.

The river is of a very great significance to the people as it serves as a major source of water supply for domestic and other purposes. Most of the inhabitants are engaged in subsistence agriculture, fishing and trading with a few percent in white-collar jobs. Farming and fishing are key features of the economy of Obowo LGA with the area hosting several markets where a variety of commodities are bought and sold. Other economic activities of the people include food processing, lumbering, and welding.

The bank of the Onuiyieke River is used for various human activities such as fishing, car washing, solid waste disposal, and agro products processing (NBS, 2011) According to Kumar & Prabhabar, (2012), turbidity and phosphorus concentration increases while other parameters decrease. Rainfall produces runoff and increase of various pollutants including TSS, nutrients, microorganisms and nitrogen concentration to water bodies. Wet season has more water volume but dry season has less volume of water for dilution leading to higher concentrations of nutrients downstream (Kumar & Prabhabar, 2012). There are lower flows, reduced velocities and higher water resident times in the river enhancing the potential for toxic algal blooms and reduced oxygen levels. Higher water temperature leads to low levels of oxygen and the study area falls within the humid tropical rainforest region. The rainfall regime is bimodal and peaks between July and September with a little break known as August Break in between. The annual mean rainfall of Imo State is between 2550mm and 2990mm. Temperature is generally high and uniform throughout the year. The mean maximum air temperature of the area is 22.8°C. The hottest months are between January and March. The cooling influence of the Harmattan winds last from December to February. Palm trees, raffia palms, bananas, plantain, cassava, yarn, cocoyam, and maize are grown along the river basin as abundant rainfall and high temperatures in the area favour their growth. The vegetation appears more luxuriant along river channels and due to intense fanning in the area.

3.2. Sources of Data

The data used in this research work are in two categories. They are the primary and secondary data.

3.2.1 Primary Data

The primary data are the set of data collected from the study area through sampling of the river, observations made during the sampling periods and laboratory results from sample analysis as well as responses from oral interviews carried out among people living around the river banks.

3.2.2 Secondary Data

Secondary data includes all published materials used in this study. These are information and data obtained from textbooks, monographs, lecture notes, scientific journals, and the internet.

3.3 Research Design

The study is an experimental research design. The research was conducted in two phases: field sampling and laboratory analysis. A systematic point sampling design was adopted by selecting sampling locations at regular intervals as they are encountered. This approach often provides greater information because the sample is distributed uniformly over the entire study area and because of its ease of use in field studies. One sample was collected at a time from each of the seven sampling locations. One of the locations was the upstream of the river which served as the control point while six other locations served as the downstream of the river.

3.4 Field Sampling

3.4.1 Sampling Location (SLs)

Samples used for this study were collected from seven different locations namely SL 1, SL 2, SL 3, SL 4,SL 5, SL 6,SL 7. In all SL 1 served as the control sample while SL 7 served as the downstream. SL 1-, the upstream of Onuiyieke River (close to the source)

4° ' 53" 07 N

7° 20' 59" E

SL 2, section of the river where laundry activities take place

4° 8' 36" N

7^{o}21' 20" E

SL 3- Section of the river near a large poultry

4^{0} 8’ 28.902” E

7^{0} 22’ 1.618” E

SL 4- Section of the river where agro products are processed

4° 7' 58.33'' N

7^0 22’ 30.79” E

SL 5- Waterside section of the river where farmers wash their implements

4° 7' 10.456" N

$7^0$22' 46.849" E

SL 6 where locals bathe

4° 6' 38.604" N

7^0 22' 52.582"E

SL 7 - Section of the river which served as the downstream.

4° 6' 15.67" N

7 23' 4.686" E

3.4.2 Insitu Measurements

Surface water temperature, conductivity, pH, Dissolved Oxygen (DO), Turbidity and Total Dissolved Solids (TDS) were determined electromagnetically with the HANNAH HI 9828 VI PH/OR/EC/DO meter. The metre was pre-calibrated with the standard HI 9828-25 Calibration solution. The desired physicochemical parameters were read off the LCD.

3.4.3 Collection of Water Samples

Samples were collected at seven different points along the river using the conventional (WHO, 2011) methods. Water samples were collected from the early hours of the day under aseptic conditions using disposable sterile hand gloves. Bottles were rinsed with the river water before sampling. The containers were unscrewed at a depth of 15-30cm below the surface of the water, facing the upstream direction and corked when filled while still under water to prevent oxidation. A small air space of 2 to 3 cm above the sample was left in the container for proper mixing of the sample before analysis. Collected water samples were subjected to filtration after collection. All the different dilutions were properly labelled and used for total plate count.

The standards reagents used in the analysis were prepared using double distilled water. Water samples for trace metals were collected in 250mls plastic bottles and fixed with concentrated H_2SO_4 in the ratio of 2:500. Water samples for other parameters were collected in 500mls sterile plastic containers. It was tightly closed and labelled. These were stored in the icebox to retard the biochemical activities and promptly transported to the laboratory. Water samples were taken to the laboratory as soon as possible to maintain their integrity. A total of 129 samples were collected from the seven sampling locations in triplicates for six months from September 2017 to February 2018.

3.5 Laboratory Analyses

The samples were analysed as per standard methods mentioned in (Ademoroti, 1996). Serial dilution of the water samples were carried out using sterile distilled water on the following water parameters:

3.5.1 Nitrate

This was determined by the spectrophotometric method. A nitrate (NO_3-) stock was prepared by dissolving 0.7222 g of potassium nitrate (KNO_3) into 1000 ml of distilled water giving 100 ppm of NO_3-N. After preparing the nitrogen stock, standard preparations were made by adding 40 ml of distilled water to 550 ml centrifuge tubes. 0, 0.5, 1.0, 1.5 and 2.0 ml were then subtracted from the 5 tubes respectively, and the same amounts of 100 ppm of the NO_3-N initially prepared. The individual tube will contain 0, 1.25, 2.50, 3.75 and 5.00 ppm of the NO_3-N. 1 ml of the sample to be tested was taken into a cuvette and 4 ml of distilled water is added. The same is also done for the standard samples. Both the sample and the standards are read in a spectrophotometer at wavelength 210 nm after which a standard curve is plotted and the reading gotten from the standard curve's plot is multiplied by 4.

3.5.2 Phosphate

The phosphate was measured using the Vanado-molybdo-phosphate acid colorimetric method. The reagent used was vanadate-molybdate reagent. 25 ml of the sample was poured into a 50 ml volumetric flask. 10 ml of the vanadate-molybdate reagent was then added to the sample giving a mixture of 35 ml. 15 ml of distilled water was added to give 50 ml. The dilution factor (the volume initially diluted to give 50 ml i.e. 25 ml). A blank sample was prepared using 25 ml of distilled water to substitute for the sample in another volumetric flask. Both the standard and blank samples were then read in a spectrophotometer after 10 minutes at wavelength 470 nm and the curve plotted. The phosphate values were gotten from the equation 3.1

$$\text{Phosphate}\left({}^{mg}/_{1PO_4^{3-}}\right) = \frac{Reading\ from\ curve\ x\ 1{,}000\ x\ D}{ml\ sample} \qquad 3.1$$

Where D=dilution factor.

3.5.3 Temperature.

This was determined at the point of sample collection by dipping the bulb of mercury-in-glass thermometer into the soil suspension and recording the readings.

Reading was taken when there was a steady temperature from the calibration on the capillary tube.

3.5.4 Conductivity

This was measured using the suntex conductivity meter (DD 193). After it was calibrated, the electrode was inserted into the portion of the sample and the conductivity button was pressed. The valve was then read.

3.5.5Total Solids (TS)

This was determined gravimetrically with the aid of silica crucible, furnace, Desiccator, weighing balance and measuring cylinder. A silica crucible was heated to about 550^0C in the furnace for about 30mins, cooled in a desiccator and then weighed. This process was repeated until a constant weight was obtained. Then 50ml of the unfiltered water sample was taken in the crucible and evaporated on a water bath. The solid residue was heated and cooled in a desiccator and then weighed. This process was repeated until a constant weight was obtained. The difference in two weights gave the weight of solid obtained from the evaporated of 50ml sample.

$$\text{Total solids in mg/L} = \frac{W\ x\ 1000\ x\ 1000}{V} \qquad 3.2$$

Where W = Weight of the solids after evaporated.

V =volume of the water sample used for evaporation.

3.5.6 Total Suspended Solids (TSS)

The amount of suspended or particulate matter was obtained by subtracting Total Dissolved Solids from Total Solids. T.S.S =T.S – T.D.S in mg/L

3.5.7 Total Hardness

This was determined by the titrimetric method using a conical flask, burette, and funnel. EDTA 0.01m solution (3.723g) was dissolved in one litre distilled water.

- Buffer solution (7g of NH_4Cl was dissolved in 60ml of concentrated 15m ammonia.
- Indicator (0.4g of Eriochrome black T was ground with 100g analytical reagent sodium chloride (NaCl)

  Calcium and Magnesium reacted with the Erichrome black T (indicator) at pH of about 10 to form a wine red coloured complex. EDTA was added breaking it down and a blue coloured indicator was produced so that at the endpoint the colour changes from red to blue.
- 50ml of the water sample taken in the conical flask
- 1ml of buffer solution was added to the content
- Two drops of Eriochrome Black T indicator was also added
- The content in the conical flask was titrated with EDTA until the solution turns blue.

$$Total\ Hardness\ in\ mg/L = m/s\ of\ \frac{0.01M\ EDTA\ x\ 1000\ x\ A}{V} \qquad 3.3$$

Where A = $MgCaCo_3$ equivalent to 1ml of EDTA Titrant

V = Volume of the sample

3.5.8 Dissolved Oxygen (DO)

The audiometric method and its aside modification as described by Prescott *et al.*, (2002) was used. A clean 250 ml BOD bottle, previously sterilized and labelled was lowered at each sampling point such that the influent gently flowed into the bottle until it was filled up, avoiding air bubbles. 1ml of $MnSO_4$ solution was added to each sample followed by 1ml Sodium-iodide-aside solution and the bottle was stoppered. The content, the brown precipitate of hydrated manganese hydroxide MN $(OH)_2$ was allowed to settle down. 1ml concentrated H_2SO_4 was and the stopper was replaced and, the bottle was inverted again until the brown precipitate was completely dissolved leaving a golden yellow solution that was used for titration. 200 ml of each sample was titrated with 0.025 M NaS_2O_3 solution until a pale straw colour was noticed. A few drops of 1% starch solution were added to the flask and the titration was continued until the blue-black coloration disappeared at the endpoint living a colourless solution in the flask. The volume of $Na_2S_2O_3$ used for the titration was then recorded which was equal to the concentration of DO. The entire procedure was ensured to complete within about 2 h after $MnSO_4$ solution, sodium iodide- azide and concentrated H_2SO_4 were added. The initial DO (D1) was estimated by determining the differences between the final burette reading and the initial burette reading.

3.5.9 Chloride

This is determined by a titrimetric method using a micropipette, micro conical flask. The reagents used include Mercuric Nitrate Solution) 0.1N 25g Hg $(NO_3)_2.H_2O$ in 900ml distilled water containing 5ml concentrated HNO_3 diluted to 1 litre), Nitric acid solution 0.14N. Chloride is determined by mercuric nitrate titration. The pH is lowered to approximately 3 by nitric acid addition. Mercuric ions react with chloride ions to form mercuric chloride. When excess mercuric ions are present in complexes with diphenylcarbazone it forms a purple solution. The colour changes from yellow to purple.

i. 50ml of the water sample was taken in the flask
ii. Two drops of diphenylcarbazone indicator was added and mixed by swirling.
iii. While swirling, nitric acid was added dropwise until the solution turns yellow.
iv. Titrate with 0.1N mercuric Nitrate until purple coloration appeared.
v. Chloride in mg/L was calculated by multiplying the of 0.1N mercuric nitrate used to titrate the sample with 100

Cl mg/L = mercuric Nitrate x 100

3.5.10 Chemical Oxygen Demand (COD)

This is determined by the Oxidation reaction method using retort stand, heating mantle, round bottom flask, condenser, conical flask, burette, and beaker. Reagents include 0.25N potassium dichromate (12.25g dried $K_2Cr_20_7$ in 1litre distilled water 0.1N ferrous ammonium sulphate, Ferrous indicator solution (1.485g of 1, 10-phenanthradine and o.695g ferrous sulphate in distilled water and diluted to 100mls). Concentrated Hydrogen tetraoxosulphate VI acid, (specific gravity 1.84), solid mercuric sulphate and silver sulphate including 20 ml of water sample was introduced into a 250ml round bottom flask with ground glass joint for fixing a reflux condenser.

i. 10mls of 0.25N $K_2Cr_20_7$, 0.4g of Ag_2S0_4 and H_2S0_4 was added to the round bottom flask.
ii. 20ml of concentrated H_2S0_4 was also added and the content of the flask reflux for 2-3 hours.
iii. After refluxing, it was cooled and diluted to 150ml using distilled water.

iv. The diluted sample was titrated with 0.1N ferrous ammonium sulphate solution using the ferroin indicator until colour changes from blue to red.

v. Blank was run along using distilled water.

vi. The volume of 0.1N ferrous ammonium sulphate solution was noted and recorded.

$$\text{COD mg/L} = \frac{(b-a)x\ Normality\ of\ titrant\ x\ 1000\ x\ 8}{Volume} \qquad 3.4$$

a = Volume of the titrant with the sample

b = Volume of the Titrant with the blank

3.5.11 Media for Analyses

The media used in this study were Nutrient agar (Fluka Biochemica, Germany), MacConkey agar (Antec), Sabourand dextrose agar (Fluka Biochemica, Germany), Eosin Methylene Blue (EMB), MF-Endo agar medium, KF- streptococcus agar, thiosulphate and citrate bile sucrose agar (TCBS). Nutrient agar medium was used for isolation of aerobic heterotrophic bacteria while total coliform isolates were obtained using the MF-Endo agar medium. KF- streptococcus agar was used for faecal streptococci while thiosulphate citrate bile sucrose agar (TCBS) was used to isolate *Vibrio* species. The enumeration of *Salmonella* species was carried out using the bismuth sulphate agar method. Media preparations were according to manufacturer's instructions and incubation generally, except for faecal coliform, was at 35 -37°C for 24 hrs. All the media were prepared and sterilized according to the manufacturer's specifications. All glassware and media used were sterilized by autoclaving at 121^{0}C for 15 min,15 pounds pressure and air-drying in the hot air oven at 160^{0}C (2 hrs).

3.5.11.1 Faecal Coliform Bacteria Count

About 100ml of the water samples were filtered through a membrane filter with the aid of a vacuum pump. The filter membrane was placed on a MacConkey agar plate. This was then incubated using an incubator pre-set to 44.5 ± 2^0C for 24hrs. Observation was made for colony development on the filter membrane. The colonies were then counted as colony-forming units per 100ml.

3.6 Validation of the Instrument

Validity is concerned with the issue of whether or not one is measuring a variable or a set of variables that are intended for measurement. It is this concern that underlies the importance of instrument validation in any research. Validity encompasses the entire experimental concept and establishes whether the results obtained meet all the requirements of the research method .content and construct validity was considered in that instrument measures were drawn equitably and the data generated were true scores of the instruments chosen. A control (SLI) was used over 4 months to eliminate other potential causal relationships. External ecological validity was ensured in that fast-changing parameters such as biochemical oxidation demand (BOD) and dissolved oxygen (DO) determination including temperature was tested on-location sites.

3.7 Reliability of the instrument

Various methods are concerned with the degree of consistency in the data gathering process. Water samples were collected from the early hours of the day the same way, each time to minimize environmental changes. Successive Triplicate grab samples (samples, collected at no set time or flow rate) of water were also taken. That is, Samples were collected thrice from each sampling site, randomly and mixed thoroughly to minimize the chances of malfunction of instruments and researcher error. Test-retest reliability was conducted on separate days. The scores between the two sets were calculated and there was a strong relationship. So the instruments were considered reliable.

3.8 Calculation of Water Quality Index

Generally, Water quality is estimated using four different methods. This includes the National Sanitation Foundation Water Quality Index (NSFWQI), the Canadian Council of Ministries of the Environment Water Quality Index (CCMEWQI), the Oregon Water Quality Index (OWQI) and Weighted Arithmetic Water Quality Index Method (WAWQI). The present study determined the water quality index using a weighted arithmetic water quality index method. The reason for choosing the WAWQI method according to Douglas, Stephen, & Kenneth (2015) and Soraya, Lakhdar, & Larbi (2017) is that it has an edge over other methods as some parameters are incorporated into a mathematical equation that rates the health of water body through a number called water quality index. It also describes the suitability of water sources for human consumption. In this study, for the calculation of the water quality index, nine important parameters were chosen. The WQI has been calculated using the standards of drinking water quality recommended by the World Health Organisation (WHO) and the National Environmental Standards and Regulatory Agency (NESREA). The weighted arithmetic index method ((Brown, McClellan, Deininger, & O'Connor, 1972) has been used for the calculation of WQI of the water body. Further, quality rating or sub-index (q_n) was calculated using the following expression.

$$q_n = 100 \frac{[V_n - V_{io}]}{[S_n - V_{io}]} \qquad 3.5$$

let there be n water quality parameters and quality rating or sub index (q_n) corresponding to n^{th} parameter is a number reflecting the relative value of this parameter in the polluted water concerning its standard permissible value

q_n =Quality rating for the n^{th} water quality parameter.

V_n = Estimated value of the n^{th} parameter at a given sampling station

S_n = Standard permissible value of the *nth* parameter

V_{io} = Ideal value of nth parameter in pure water (i.e., 0 for all other parameters except the parameter pH and Dissolved oxygen (7.0 and 14.6 mg/L, respectively)

Unit weight was calculated by a value inversely proportional to the recommended standard value *Sn* of the corresponding parameter.

$$Wn = K/Sn \qquad 3.6$$

Wn = unit weight for the nth parameters.

Sn = Standard value for nth parameters

K =Constant for proportionality

The overall Water Quality Index was calculated by aggregating the quality rating with the unit weight linearly.

$$WQI = \frac{\sum_{qn} W_n}{\sum \mathrm{W}_n} \qquad 3.7$$

Table 3.1 WHO and NESREA Regulatory Limits for Water Quality Parameters

Parameters	Standards	Recommended Agency	Unit Weight
pH	6.5-8.5	WHO/ NESREA	0.2190
Electrical Conductivity (µS/cm)	300	WHO/ NESREA	0.371
Total Hardness(mg/L)	300.00	WHO/ NESREA	0.0062
TSS(mg/L)	30	WHO/ NESREA	0.0037
TDS(mg/L)	50	WHO	0.0037
DO(mg/L)	6.00	WHO/ NESREA	0.3723
BOD(mg/L)	6-9	WHO/ NESREA	0.3723
Nitrate(mg/L)	50	WHO/ NESREA	0.0412
Calcium(mg/L)	50	WHO/ NESREA	0.025
Chloride (mg/L)	300	WHO/ NESREA	0.0074
Magnesium (mg/L)	0.20	WHO/ NESREA	0.061

TDS =Total Dissolved Solids, DO= Dissolved Oxygen, BOD= Biological Oxygen Demand, WHO= World Health Organisation, NESREA = National Environmental Standards and Regulatory Enforcement Agency. Sources: WHO (2010), NESREA (2011)

Table 3.2 Classification of water quality based on weighted arithmetic WQI method

Water quality Index level	Water Quality Status
0-25	Excellent water quality
26-50	Good water quality
51-75	Medium
76-100	Very Poor water quality
>100	Unsuitable for drinking

Source: Brown *et al* (1972), (Douglas *et al.*, 2015)

3.9 Statistical analyses

Statistical analyses were performed with SPSS v 22.0 and MS Excel version 2010 was utilized in the analyses of data. The probability level (α) for rejection of the null hypothesis was 0.05. Descriptive statistics used to explore minimum and maximum values as well as ranges, means and Standard Errors of the Data Set. Variation plots were used to represent the mean values of the physical and chemical attributes of the river. The test of homogeneity in mean-variance of the quality parameters was explored with a one-way Analysis of Variance (ANOVA) and the structure of group means detected with the post-hoc means plot at 95% confidence limit.

The factor analysis procedure, using the Principal Components Analysis (PCA) method of extraction for data reduction was used to remove highly correlated (redundant) variables from the data file with a smaller number of uncorrelated variables (factors). Factor rotations for the transformation of extracted factors to a new position for interpretation were achieved with the Varimax method. The Pearson correlation was used to determine possible relationships between the physical and chemical attributes of the river.

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 Presentation of Results

4.1.1 *Results on physical, chemical and biological Parameters of Onuiyieke River*

The results of the levels of the quality parameters of the Onuiyieke River obtained during the sampling period are shown in Appendices 1a-1f. The parameters analysed presented the following;

Physical parameters, Total Suspended Solids (TSS) (Range =3006.00). Electrical Conductivity (EC) (Range =1361.00), Total Dissolved Solids (TDS) (Range= 826.00), Total Solids (TS) (Range=3660.00), this value far exceeds NESREA regulatory standard value of 500mg/l. Total Hardness (Range= 195.80) these parameters have comparatively wider variations than the other parameters however pH, Turbidity and Dissolved Oxygen varied from 5.40- 7.00 (6.18 ± 0.06), 4.50 – 53.00 (18.84 ± 2.22) and 3.00- 8.30 (6.58 ± 0.22) mg/l respectively. Temperature was at 26.00 – 29.00 (27.67 ± 0.14) ^{0}C. The values for Turbidity and Dissolved Oxygen also exceeded the WHO standards of 10mg/l and 6.00mg/l respectively.

Chemical parameters, Calcium ion concentration ranged from 3.00 to 39.00 mg/l with a mean value of 15.15 ± 1.87 mg/l, Magnesium ion concentration 0.09 -0.46 (0.22 ± 0.02) mg/l, nitrate 4.50 – 28.10mg/l (14.77 ± 0.92) mg/l, phosphate ion concentration 0.17 - 4.00 (2.08 ± 0.18)mg/l, biochemical oxygen demand (BOD) values 0.70 – 3.30 (1.77 ± 0.10) mg/l., Ammonia (NH_3) chloride ion concentration (Range = 118.00) exceeding the NESREA standard of 0.05mg/l. . Iron ion concentration and chemical Oxygen demand ranged from 0.15 -5.80 (1.94 ± 0.23) mg/l and 1.40- 5.60 (3.03 ± 0.18) mg/l respectively. The value for iron ion concentration exceeded the NESREA standard of 0.30mg/l while COD values fell below the permissible NESREA standard of 30mg/l.

Biological parameter, Faecal coliform count range between 0.70 and 3.30 with a mean value of (2.60 ± 1.91 MPN/100ml). This value exceeded the WHO regulatory standard of 0.5 MPN/100ml.

Table 4.1: Descriptive statistics of the Physical, Chemical and Biological parameters of Onuiyieke River

	Minimum	Maximum	Range	Mean	SE	WHO (2011)	NESREA (2011)
pH	5.40	7.00	1.60	6.18	0.06	6.5	6.-9
Total hardness(mg/L)	4.20	200.00	195.80	73.08	9.85		300
Water Temperature(^{0}C)	26.00	29.00	3.00	27.6738	0.14	20-30	20-30
TSS(mg/l)	6.00	3012.00	3006.00	198.19	80.93	30	0.25
EC (μS/cm)	7.00	1368.00	1361.00	331.81	59.78	40	-
TDS(mg/l)	4.00	830.00	826.00	219.70	39.30	50	<1000
TS(mg/L)	56.00	3722.00	3666.00	417.72	105.33	259-500	500
Turbidity(NTU)	4.50	53.00	48.50	18.84	2.22	6	10
DO(mg/L)	3.00	8.30	5.30	6.58	0.22	7.5	6.00
BOD_5(mg/L)	0.70	3.30	2.60	1.77	0.10	6-9	-
Chloride(mg/L)	3.00	121.00	118.00	41.90	5.51		300
Calcium(mg/L)	3.00	39.00	36.00	15.15	1.87	50	
Magnesium(mg/L)	0.09	0.46	0.37	0.22	0.02		0.20
Phosphate(mg/L)	0.17	4.00	3.83	2.0843	0.18		3.50
Nitrate(mg/L)	4.50	28.10	23.60	14.7695	0.92	20	50
Ammonia(mg/L)	5.13	25.50	20.37	14.6179	0.89	<1.50	0.05
Iron(mg/l))	0.15	5.80	5.65	1.9352	0.23	-	0.30
COD(mg/l)	1.40	5.60	4.20	3.0340	0.18	45	30
Faecal/Coliform(MPN/100ml)	0.70	3.30	2.60	1.9114	0.10	0.5	

SE= standard error of mean, TSS=Total Suspended Solids, EC=Electrical Conductivity, TDS= Total Dissolved Solids, Do=Dissolved Oxygen, BOD= Biological Oxygen Demand, COD= Chemical Oxygen Demand. Sources: WHO (2011), NESREA (2011).

4.2 Principal Component Analysis (PCA)

PCA analysis was carried out to investigate the parameters that contributed to the highest variabilities in the water quality. The physical, chemical and biological parameters that were subjected to the PCA procedures produced high Initial and Extraction Communalities (Appendix 2a). This indicates that the extracted components represent the variables well. The first four Principal Components, (PCA) formed the Extraction solution, with a cumulative percentage Variability of about 77.67% in the original 19 variables (Appendix 2b, Table 4.2).

This reduces the complexity of the data set by using these components with only about 22.33% loss of information. The rotation maintained the cumulative percentage of variation explained by the extracted components (77.67%) (Table 4.3) The Scree plot represents the Eigenvalue of each component in the initial solution. The extracted components are on the steep slope, while the components on the shallow slope contributed little (22.33%) to the solution (Fig.4.1).

The last big drop occurred between the 4^{th} and 5^{th} components. With this rotation, the first component contributed almost 48.333% to the total variability, while second, third and fourth contributed 12.534%, 10.592% and 6.212% respectively to the total variability The first PC (PC1) was most highly related with Mg ions concentration (0.925) and also had high loading for electrical Conductivity (EC)(0.733), Total Dissolved Solids (TDS) (0.810), Chloride ions (0.787), Total Hardness (0.894), Calcium ions (0.917) and Fe ions concentration (0.646) (Appendix C). The first factor (PC1) seemed to be associated with the earth's crust and the geological formation of the area.

PC2 was most highly correlated with NH_3 (0.903) and also had high loadings for Turbidity (0.510). Biological Oxygen Demand (BOD) (0.739), Faecal Coliforms (0.659), Nitrate ions concentration (0.835) and Chemical Oxygen Demand (COD) (0.670). This factor can be attributed to the mining activities, agro products processing, and anthropogenic sources.

PC3 was most highly correlated with Total Suspended Solids (TSS) (0.903) and also had high loadings for Total Solids (TS) (0.867), Turbidity (0.531), and COD (0.517).

However, PC4 was most highly correlated with water temperature (0.840) and also had high loadings for PO_4^{3-} (0.623).

The Component plot in rotated space revealed that all of the parameters measured except TSS were closely related (Fig 4.2).

Table 4.2 Extraction Sums of Squared Loadings of physical, chemical and biological parameters of Onuiyieke River in Imo State, Nigeria

Components	Total	% of Variance	Cumulative %
1	9.183	48.333	48.333
2	2.381	12.534	60.867
3	2.012	10.592	71.458
4	1.180	6.212	77.670

Table 4.3 Rotation Sums of Squared Loadings of physical, chemical and biological parameters of Onuiyieke River in Imo State, Nigeria

Components	Total	% of Variance	Cumulative %
1	5.804	30.546	30.546
2	4.070	21.419	51.964
3	3.439	18.098	70.062
4	1.446	7.608	77.670

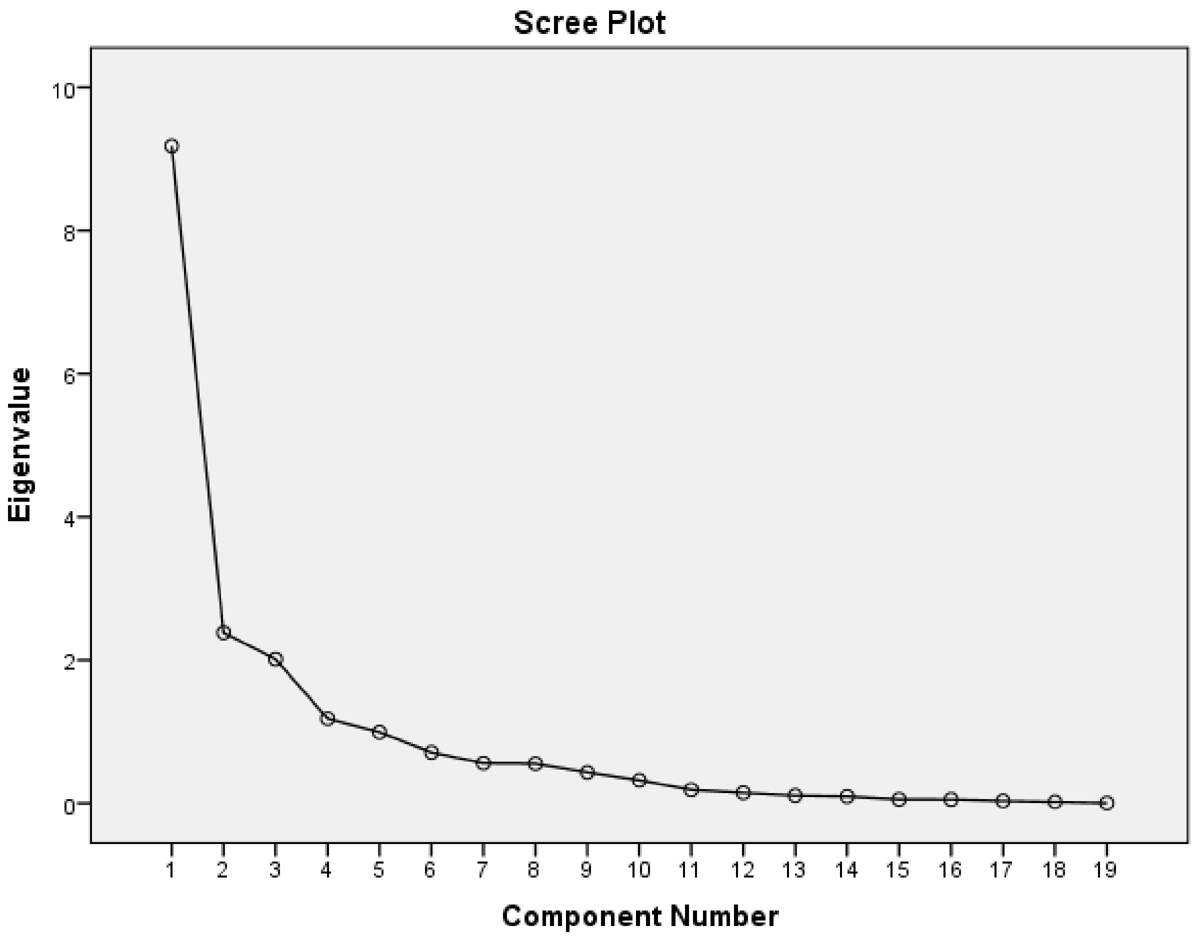

Fig. 4.1 Scree Plot of Eigenvalues by Component numbers of the Physical, chemical and biological parameters of Onuiyieke River

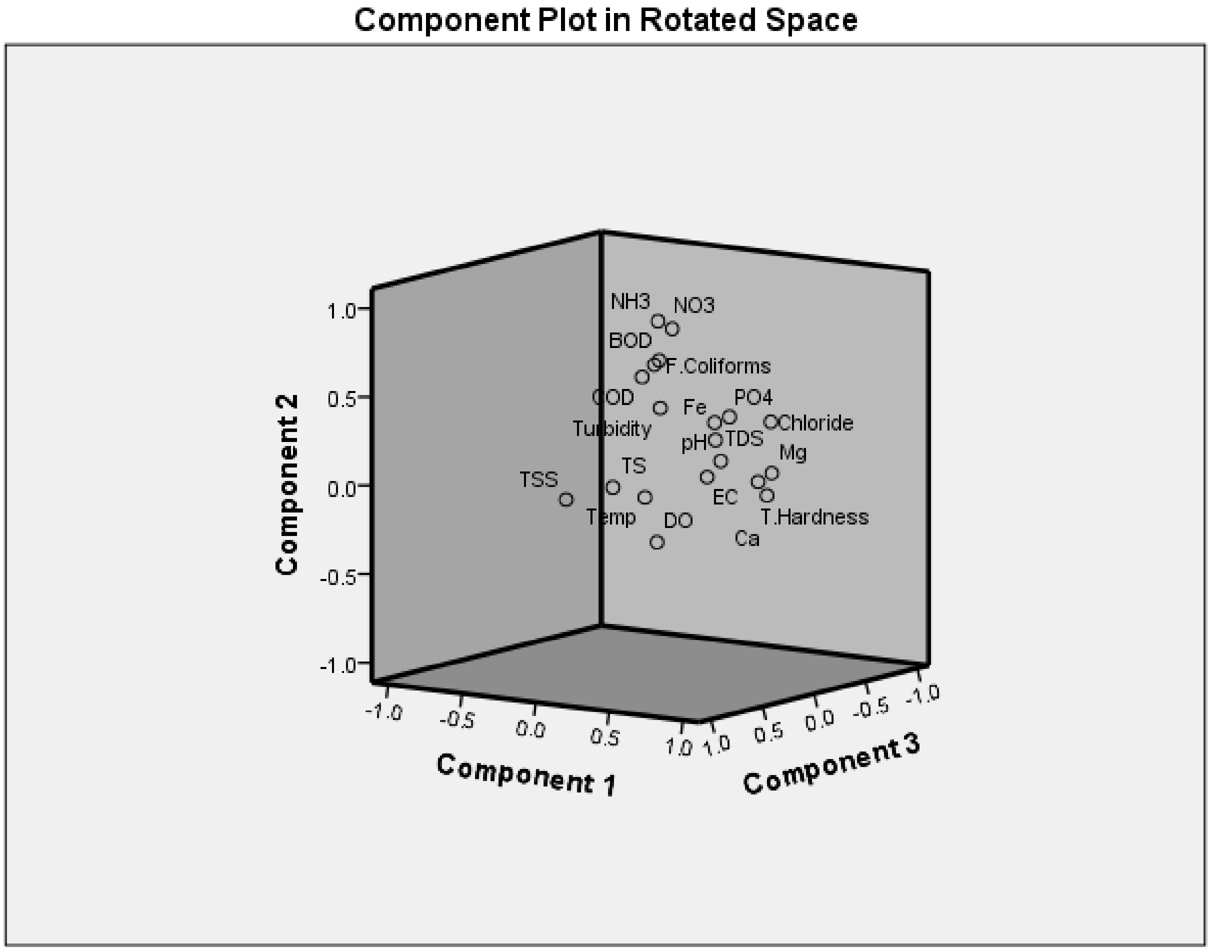

Fig 4.2 Component Plot in Rotated Space of the Physical, Chemical and Biological Parameters of the Onuiyieke River

4.3 Spatial variations in physical, chemical and biological parameters

The physical, chemical and biological parameters measured in the river varied across the seven sampling Locations studied (Appendix 3). Mean pH varied from 5.40 (±0.16) in SL 2 to 7.00 (± 0.13) in SL 3. Mean Total hardness varied from 11.83 (±1.29) mg/l in SL 1 to 182.67(± 7.51) mg/l in SL 3 . Temperature varied from 27.00 (±0.45) ^{0}C in SL 4 to 28.17 (± 0.25)^{0}C in SL 6. Mean TSS varied from, 63.96 (± 6.14) mg/l in SL1, to 894.17 (± 509.5) mg/l in SL 3.Mean EC varied from, 21.50 (± 6.00) µS/cm in SL1, to 1065.00 (± 192.30) µS/cm in SL 3. Mean TDS varied from, 12.53 (± 3.63) mg/l in SL1, to 778.167 (± 19.46) mg/l, in SL 3. Iron ion concentration varied from 0.61 (± 0.20) mg/l in SL 4 to 4.13 (±0.42) mg/l in SL 6. Mean TS varied from 76.55 (± 6.80) mg/l in SL1 to 1680.67 (± 492.96) mg/l in SL 3.Mean Turbidity varied from 6.73 (± 0.88) NTU in SL 1 to 43.20 (± 5.73) NTU in SL 3. However, mean DO varied from, 4.28 (± 0.48) mg/l in SL 3, to 8.07 (± 7.91) mg/l in SL 1. Mean BOD varied from 1.03(± 0.27) mg/l in SL 1 to 2.68 (± 0.17) in SL 3.

Mean Chloride ion concentration varied from 5.33 (± 1.28) mg/l in SL 1, to 82.00 (±2.14) mg/l in SL 6. Mean Calcium ion concentration varied from 3.67(± 3.12) mg/l in SL 1 to 34.00(± 1.70) mg/l in SL 3. Total Magnesium ion concentration varied from 0.11(± 0.01) mg/l in SL 1 to 0.38(± 0.03) mg/l in SL 3. Total Phosphate ion concentration varied from 1.04 (±0.27) mg/l in SL 1 to 2.72 (± 0.54) mg/l in SL 5. Nitrate ion concentration varied from 5.48(± 0.41) mg/l in SL1 to 22.57 (±0.64) mg/l in SL 5. Ammonium ion concentration varied from 6.21 (± 0.29) mg/l in SL1 to 23.52 (± 0.54) mg/l in S 5. Fe ion concentration varied from 0.43(± 0.08) mg/l in SL1 to 4.14(± 0.42) mg/l in SL 3. COD varied from 1.93(± 0.18) mg/l in SL 1 to 4.88(± 0.24) mg/l in SL 3. Faecal Coliforms varied from 1.15(± 0.179) MPN/100ml SL to 2.52 (± 0.27) MPN/100ml in SL 3.

The One-Way Analysis of Variance (ANOVA) revealed that all the parameters measured, except phosphate ion concentration (Sig F value 0.190) and water temperature (Sig F value = 0.095), differed significantly in their mean concentrations (Sig F values =0.000 to 0.039) across the sampling locations at $p<0.05$ (Appendix 3)

A post-hoc mean separation using Duncan Multiple Range Test revealed that the observed significant differences in pH were between SL 1, SL 2 and SL 3. For Total hardness, observed significant differences were between SLs 1, 3, 6 and 7. For Temperature, there was observed significant differences between SLs 4 and 6, also there was observed significant differences between SLs 5 and 6. For TSS, there are no observed significant differences between Sample locations (SLs) 1, 2,4,5,6, and 7 but the observed significant difference was in SL 3. For EC, there is observed significant differences between SLs 1, 3 and 5. There were also observed significant differences between SLs 2, 3 and 5.

For TDS there were observed significant differences between SLs 1, 2, 3, and 6. Also, there were observed significant differences between SLs 4, 5 and 7. For TS there were observed significant differences between SL 3 and all the other site locations. For turbidity, there were observed significant differences between SLs 1, 3 and 5. For DO, observed significant differences SLs 1, 2, 3 and 5. For BOD, observed significant differences between SL 1, 3, and 4.there were also observed significant differences between SL 5 and SL 6. For Cl^- observed significant differences between SLs 1, 3 and 5. There were also observed significant differences between SLs, 4, 6 and 7. There were also observed significant differences between SLs 2, 3, 6 and 7. For Ca, there were observed significant differences between SLs 1, 3 and 6. There were observed significant differences between SLs 2, 3 and 7. For Mg, there were observed significant differences between SLs 1, 3 and 5. For PO_4^{3-}, there were observed significant differences between SLs 1 and 3. For $NO_{3,}$ there were observed significant differences between SLs 1, 2, 4 and 5, as well as between SLs 4 and 7.

For $NH_{3,}$ there were observed significant differences between SLs 1, 2, 3 and 5, as were observed between SLs 5, 6 and 7. For Fe, there were observed significant differences SLs 1, 3 and 5, also there were observed significant differences between SLs 3, 4 and 5. For COD, there were observed significant differences between SLs 1, 2 and 3.

For faecal coliforms, there were observed significant differences between SLs 1 and 2, also between SLs 1 and 3, also between SLs 1 and 4, and between SLs 2 and 7

Table 4.4 Mean Separation in the physical, chemical and biological Parameters using Multiple Range test ($P<0.05$)

	Sampling locations						
Parameters	SL 1	SL 2	SL 3	SL 4	SL 5	SL 6	SL7
pH	5.7500^{a}	6.2867^{bc}	6.5550^{c}	5.990^{ab}	6.1633^{bc}	6.3633^{bc}	6.1067^{ab}
T-Hardness	11.8333^{a}	31.0000^{a}	182.6667^{d}	29.0333^{a}	31.2167^{a}	133.9500^{c}	91.8333^{b}
Temperature	27.8500^{ab}	27.1667^{ab}	27.6500^{ab}	27.0000^{a}	27.9167^{a}	28.1667^{b}	27.9667^{ab}
TSS	63.9633^{a}	81.6667^{a}	894.1667^{b}	71.8333^{a}	92.0000^{a}	109.3333^{a}	74.3333^{a}
EC	21.50000^{a}	37.3333^{a}	1065.0000^{c}	66.500^{ab}	302.000^{b}	428.667^{ab}	401.667^{ab}
TDS	12.53^{a}	28.00^{b}	778.17^{d}	38.67^{a}	177.83^{b}	285.00^{c}	222.67^{c}
TS	76.56^{a}	115.50^{a}	1680.67^{b}	110.50^{a}	269.83^{a}	401.00^{a}	270.00^{a}
Turbidity	6.733^{a}	11.283^{ab}	43.20^{c}	16.50^{ab}	22.17^{b}	17.25^{bc}	14.77^{ab}
DO	8.0667^{d}	7.0333^{c}	4.2833^{a}	7.4833^{cd}	5.2333^{b}	6.8500^{c}	7.1000^{c}
BOD	1.0333^{a}	1.4883^{ab}	2.6750^{c}	1.7250^{b}	2.4083^{c}	1.6833^{b}	1.3467^{ab}
Chloride	5.3333^{a}	11.7500^{a}	78.0000^{c}	16.6667^{a}	51.8333^{b}	82.0000^{c}	47.7500^{b}
Ca	3.6667^{a}	6.0000^{a}	34.0000^{c}	6.3333^{a}	6.6667^{a}	26.0000^{b}	23.3500^{b}
Mg	0.1133^{a}	0.1467^{ab}	0.3767^{c}	0.1400^{ab}	0.1883^{b}	0.3100^{c}	0.2633^{c}
PO_4^{3-}	1.0400^{a}	1.6733^{ab}	2.5233^{b}	1.7217^{ab}	2.7150^{b}	2.7033^{b}	2.2133^{ab}
NO_3	5.4800^{a}	11.7633^{b}	15.3083^{bc}	17.4583^{c}	22.5650^{d}	17.6450^{c}	13.1667^{b}
NH_3	6.2133^{a}	11.2067^{b}	18.0117^{c}	17.2000^{c}	23.5150^{d}	16.3783^{c}	9.8000^{b}
Fe	0.4250^{a}	1.4200^{ab}	4.1383^{c}	0.6133^{a}	2.3933^{b}	2.3733^{b}	2.1833^{b}
COD	1.9283^{a}	2.8217^{b}	4.8800^{c}	2.3750^{ab}	4.3000^{c}	2.5450^{ab}	2.3883^{ab}
Faecal Coliforms	1.1467^{a}	2.2833^{b}	2.5167^{b}	2.3667^{b}	2.0667^{b}	1.6000^{a}	1.4000^{a}

SE= standard error of mean, TSS=Total Suspended Solids, EC=Electrical Conductivity, TDS= Total Dissolved Solids, Do=Dissolved Oxygen, BOD= Biological Oxygen Demand, COD= Chemical Oxygen Demand. Source: Author's Fieldwork, (2018)

4.4 Temporal Variations in physical, chemical and biological parameters of Onuiyieke River

The physical, chemical and biological parameters of the river in the study area varied during the study period between September 2017 and February 2018 (Appendix 1a -1f,). Mean pH varied from 5.86 (± 0.11) in February 2018 to 6.44 (± 0.11) in September 2017, mean DO from 5.97 (± 0.62) mg/l in November and December 2017 to 7.06 (±0.47) mg/l in February 2018. BOD varied from 1.50 (± 0.25) mg/l in October 2017 to 2.41 (± 0.23) mg/l in January 2018 .Chemical Oxygen Demand varied from 2.61 (± 0.43) mg/l in February 2018 to 3.60 (0.38) mg/l in November 2017. (Fig.4.1)

Mean TSS varied from 66.57(± 12.26) mg/l in December 2017 to 488.14 (±420.74) mg/l in November 2017). Mean TDS varied from, 187.71 (± 93.63) mg/l in November 2017 to 251.71 (± 108.02) mg/l in September 2017. Turbidity varied from, 12.16 (±1.81) mg/l, in December 2017 to 30.29 (± 5.82) mg/l in January 2018. (Fig 4.2)

Mean Electrical Conductivity varied from, 243.14 (±87.74) mg/l in September 2017 to 405.00 mg/l (±179.56) mg/l in January 2018. TS varied from, 268.71 (±103.43) mg/l in December 2017, to, 523.47 (± 351.33) mg/l in October 2017. Chloride ion concentration varied from 28.14 (± 9.90) in December 2017 to 54.43 (± 16.43) mg/l in September 2017. (Fig.4.3)

Total Hardness varied from 61.51 (± 22.72) mg/l in January 2017 to 80.74 (±26.37) mg/l in November 2017. Calcium ion concentration varied from 13.00 (± 4.45) in January 2018 to 17.85 (± 5.58) mg/l in November 2017. Magnesium ion concentration varied from 0.20 (± 0.04) mg/l in October 2017 to 0.25 (± 0.05) mg/l in February 2018. Temperature varied from 27.60 (± 0.38) mg/l in October 2017 to 28.21 (± 0.26) mg/l in December 2017(Fig.4.4)

PO_4^{3-} varied from 0.26 (± 0.03) mg/l in November 2017 to 2.75 (± 0.35) mg/l in October 2017. NO_3 varied from 13.43 (± 2.14) mg/l in February 2018 to 16.44 (± 2.89) mg/l in September 2017. Also, Ammonium ion concentration varied from 14.18 (± 2.17) mg/l in January 2018 to 15.03 (± 2.31) mg/l in October 2017. Fe+ concentration varied from 1.22(± 0.40) mg/l, in November 2017 to 2.64 (± 0.65) mg/l, in February 2018 (Fig 4.5). Faecal Coliforms varied from 1.81 (± 0.27) mg/l in January 2018 to 2.00 (± 0.28) in September 2017 (Fig 4.5)

The ANOVA test revealed that all of the parameters measured, except $PO43^-$ did not differ significantly during the study period (Sept 2017-Feb.2018) (Sig. F Values =0.078 to 1000) (Appendix 4a). PO_4^{3-} differed significantly (Sig. F Value = 0.000) between November 2017 and the rest of the months at $p<0.05$ (Appendix 4b).

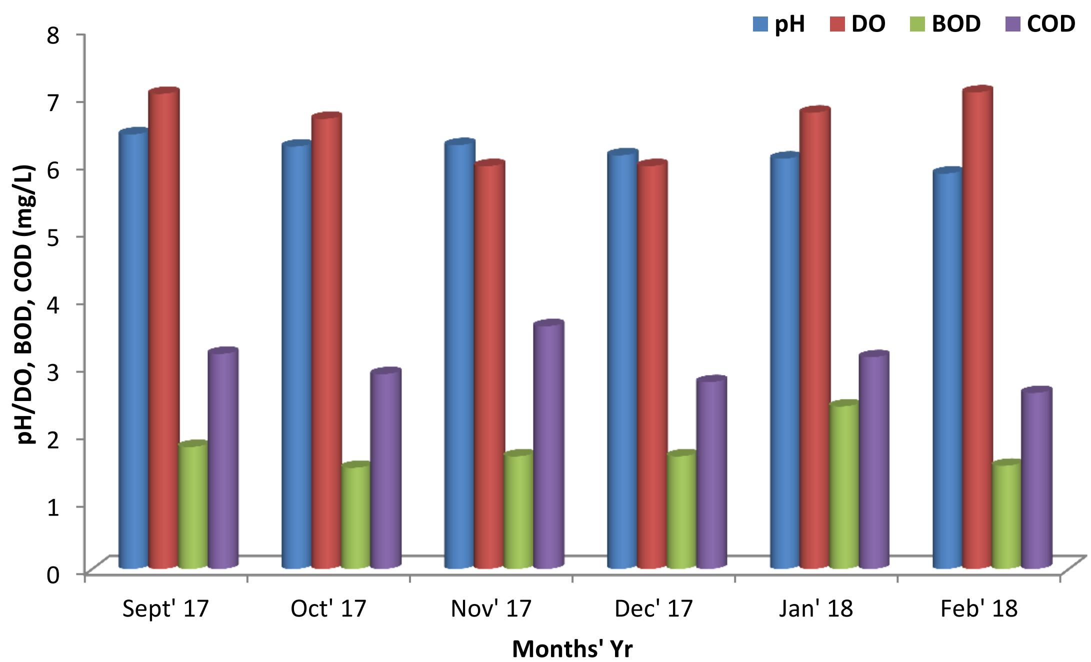

Fig. 4.5. Mean temporal variations in pH, Dissolved oxygen, Biological and Chemical Oxygen Demands of the Onuiyieke River in Imo State

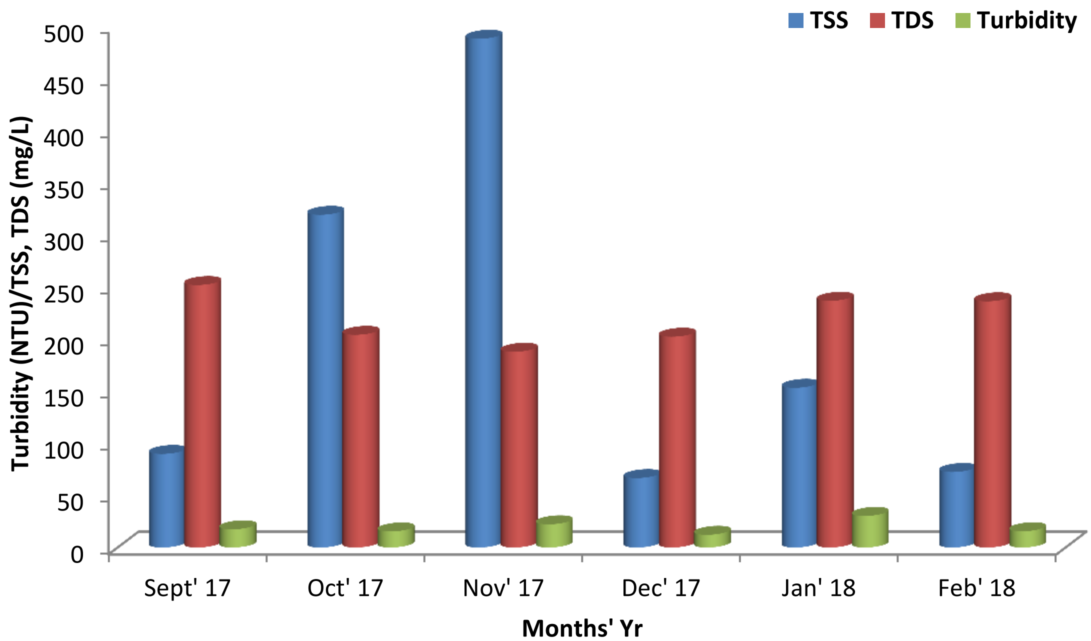

Fig. 4.6. Mean temporal variations in Total Suspended and Dissolved Solids, and Turbidity of the Onuiyieke River in Imo State

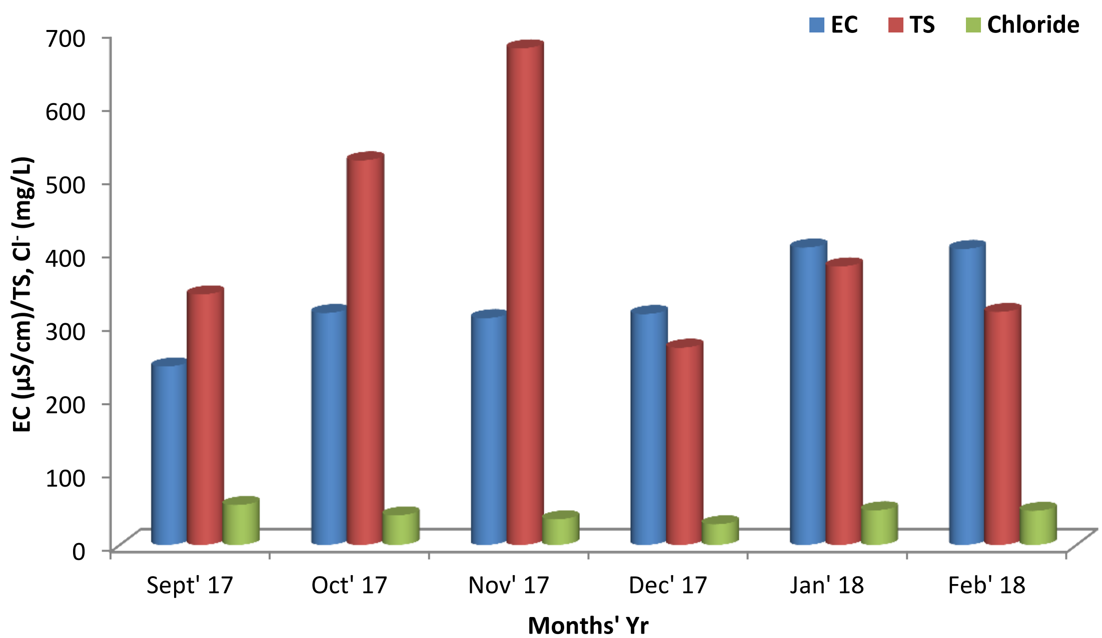

Fig. 4.7. Mean temporal variations in Electrical conductivity, Total solids and Chloride ion concentrations of the Onuiyieke River in Imo State

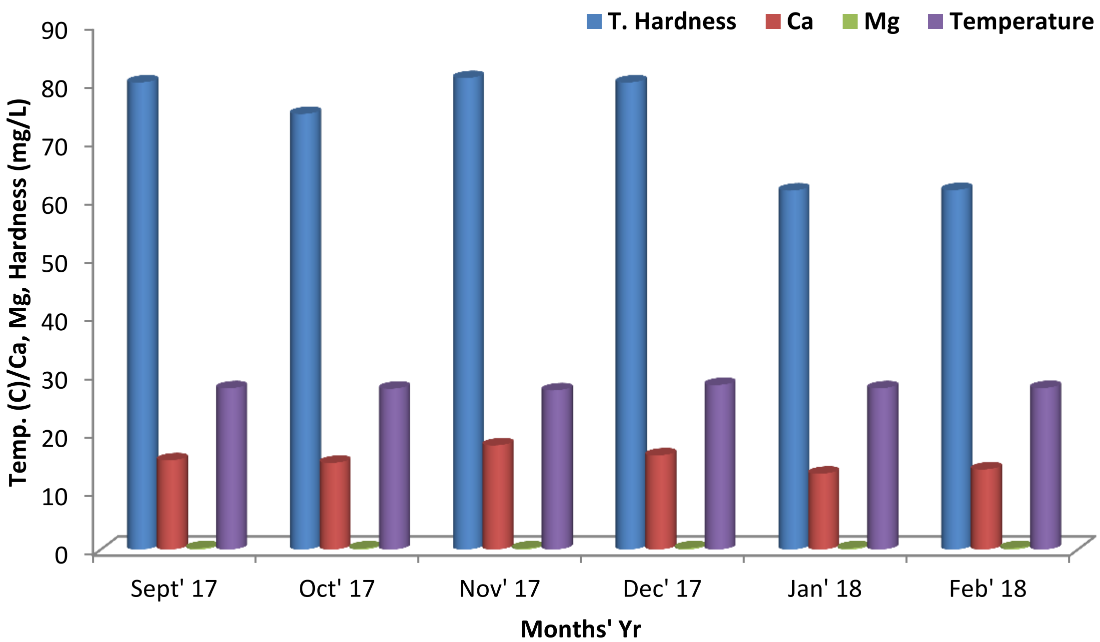

Fig. 4.8. Mean temporal variations in Total hardness, Ca, Mg and Temperature of the Onuiyieke River in Imo State

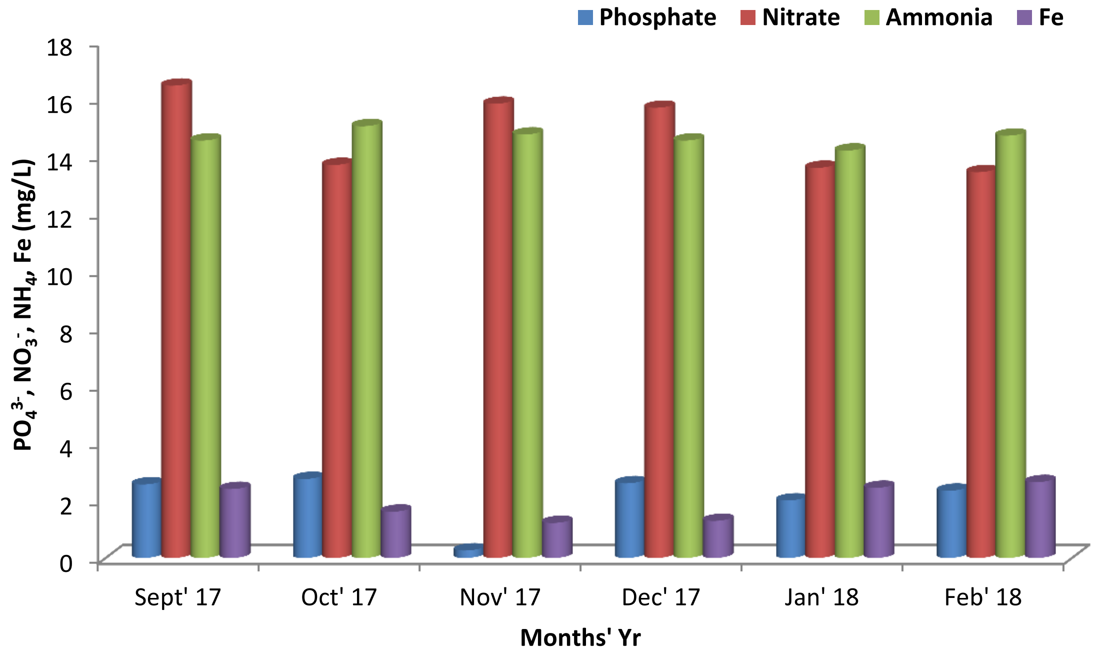

Fig. 4.9. Mean temporal variations in Phosphate, Nitrate, Ammonia and Fe ion concentrations of the Onuiyieke River in Imo State

4.5 Relationships between physical, chemical and biological Parameters

The Pearson correlations between the parameters are shown in Table 4.5. At $p<0.05$, pH correlated positively with EC (r = 0.315), TS (r =0.329), Turbidity (r =0.376), BOD(r = 0.364), Mg(r = 0.389), Faecal Coliforms (r =0.367), Fe (r = 0.351), NO_3 (r = 0.332), NH_3 (r = 0.320) and correlated negatively with DO(r = -0.389). TSS correlated positively with Total Hardness (r = 0.316) showing the impact of TSS on Total hardness of the water sample. EC correlated positively with PO_4^{3-} (r = 0.341), NH_3 (r = 0.317) TDS correlated positively with PO_4^{3-} (r = 0.350). TS correlated positively with Chloride ion concentration (r = 0.312) Turbidity correlated positively with NO_3 (r = 0. (r = 355).

DO correlated negatively with Chloride(r = -0.384), Faecal Coliforms (r = -0.349).BOD correlated positively with Total Hardness (r = 0.372) and Ca (r = 0.320).Ca correlated positively with BOD (r =0 .309) Phosphates correlated positively with NH_3 (r = 0.363) and Temperature (r = 0.331). NH_3 correlated positively with Fe (r = 0.341). At $P<0.01$, pH correlated positively with TDS (r = 0.459), Chloride (r = 0.393), Total Hardness (r = 0.543), Ca (r = 0.502) and COD (r = 0.472).

TSS correlated positively and strongly with EC (r = 0.462) indicating that increase in one affects the other , TDS (r = 0.469), TS (r = 0.943), COD (r = 0.442) but had negative correlation with Turbidity (r = -0.510). EC correlated positively with TDS (r = 0.889), TS (r = 0.687), Turbidity (r = 0.632), DO (r = 0.716), BOD (r = 0.582), Total Hardness (r = 0.742), Cl (r =0.584), Ca (r = 0.773), Mg (r = 0.773), Fe (r = 0.666) and COD (r = 0.59). TDS correlated positively with TS(r = 0.735), Turbidity (r =0.726), BOD (r = 0.615), Cl (r = 0.695), Total Hardness (0.852), Ca (0.803), Mg

(0.855), Fe (r = 0.788), COD (r =0.665) but correlated negatively with DO (r =-0.726).

TS correlated positively with Turbidity (r =0.650), BOD (r =0. 429), Cl (r =0.312), Total Hardness (r =0. 562) but correlated negatively with DO (r =0. -667) Turbidity Correlated negatively with DO (r = -0.590) but correlated positively with BOD (r =0.839), Cl (r =0.585), Total Hardness (r =0.518), Ca (r =0.464), and Mg (r =0.547). DO correlated positively with BOD (r =0.647) but correlated negatively with Total Hardness (r = -0.529), Ca(r = -0.474), Mg (r = -0.523), NO3 (r = -0.574), Temp (r = -0.574), Fe (r = -0.527) and COD (r -0.800).

BOD correlated positively with Cl (r = 0.532), Mg (r = 0.454), Faecal Coliforms (r =0.429). NO_3 (r = 0.521), NH_3 (r = 683), Fe (r = 600), and COD (r = 0.784). Chloride ion concentration correlated positively with Total Hardness (r = 0.690), Ca (r = 0.685), Mg (r =0.832), PO_4^{3-} (r =0.481), NO_3 (r = 0.443), NH_3 (r = 0.442), Fe (r = 0.677) and COD(r = 0.477). Total Hardness correlated positively with Ca(r = 0.959), Mg (r = 0.821), Fe (r = 0.561) and COD (r =0.428). Ca correlated with Mg (r = 0.823) and Fe (r =0.530). Mg correlated positively with PO_4^{3-} (r = 0.422), Fe (r = 0.725) and COD (r = 0.411). PO_4^{3-} correlated positively with Fe (r = 0.504). Faecal Coliforms correlated positively with NO_3 (r = 0.440), NH_3 (r = 0.486) and COD (r = 0.486). NO_3 correlated positively with NH_3 (r =0.84) and COD (r = 0.467). NH_3 correlated positively with COD (r = 0.623). Fe correlated positively with COD (r = 0.596) thus high correlations show that the parameters are derived from the same source. Therefore the correlation matrix of the Onuiyieke River can be checked very effectively by controlling the PH, EC,TS, DO and the ionic concentrations.

Table 4.5 Correlation (r) Matrix between the physical, chemical and biological Parameters of Onuiyieke River

	pH	TSS	EC	TDS	TS	Turbidity	DO	BOD	Cl-	T-Hardness	Ca	Mg	PO_4^{3-}	Faecal coli	NO_3	NH_4	Temp	Fe	COD
pH																			
TSS	0.192																		
EC	0.315*	0.462**																	
TDS	0.459**	0.469**	0.889**																
TS	0.329*	0.943**	0.687**	0.735**															
Turbidity	0.376*	0.499**	0.632**	0.726**	0.650**														
DO	-0.389*	- 0.510**	- 0.716**	- 0.705**	- 0.657**	-0.590**													
BOD	0.364*	0.263	0.582**	0.615**	0.429**	0.839**	- 0.647**												
Cl-	0.393**	0.066	0.584**	0.695**	0.312*	0.586**	- 0.384*	0.532**											
T-Hardness	0.543**	0.316*	0.742**	0.852**	0562**	0.518**	- 0.529**	0.372*	0.690**										
Ca	0.502**	0.262	0.737**	0.803**	0.503**	0.464**	- 0.474**	0.309*	0.685**	0.477**									
Mg	0.389*	0.212	0.737**	0.855***	0.486**	0.547**	- 0.523**	0.454**	0.832**	0.821**	0.828**								
PO_4^{3-}	0.258	-.0132	0.341*	0.350*	0.030	0.172	-0.198	0.320*	0.481**	0.263	0.240	0.422**							
Faecal coliforms	0.367*	.0170	0.112	0.285	0.246	0.406**	- 0.349*	0.429**	0.228	0.208	0.102	0.163	0.106						
NO_3	0.332*	0.040	0.142	0.216	0.115	0.355*	- 0.400**	0.521**	0.443**	0.249	0.208	0.206	0.301	0.440**					
NH_3	0.320*	0.130	0.317*	0.350*	0.236	0.490**	- 0.574**	0.683**	0.442**	0.259	0.177	0.261	0.363*	0.486**	0.840**				
Temperature	0.055	0.097	0.104	0.121	0.105	0.004	-0.078	0.037	0.144	0.185	0.155	0.080	0.331*	-0.217	0.081	-0.028			
Fe	0.351*	0.288	0.666**	0.788**	0.509**	0.649**	- 0.527**	0.600**	0.677**	0.561**	0.530**	0.725**	0.504**	0.203	0.211	0.341*	.*		
COD	0.472**	0.442**	0.539**	0.665**	0.590**	0.718**	- 0.800**	0.784**	0.477**	0.428**	0.366*	0.411**	0.142	0.486**	0.467**	0.623**	596*		

*. Correlation is significant at the 0.05 level (2-tailed).
**. Correlation is significant at the 0.01 level (2-tailed).

4.6 Results of Water Quality Index (WQI) of Onuiyieke River

Water Quality Index of the present waterbody is established from important various physical, chemical and biological parameters in different site locations. Table 4.6 shows the result of the Water Quality Index across the sampling locations of the Onuiyieke River. The Water Quality for SL 1 gave WQI of 16.24 showing that the control had excellent water quality while SL 2 gave WQI of 36.46 indicating good water quality. However, SL3 gave WQI of 123.04 indicating that the water from that location was unsuitable for drinking. SL 4 had WQI of 58. 05 classified as medium, while SL 5 graded very poor water having WQI of 87.70 showing that the water from the location is of medium quality. SL 7 had a WQI of 58.05, indicating the self-cleansing characteristic of the river, thus it is graded medium water quality according to the Weighted Arithmetic Water Quality Index Method (WAWQI).

The water quality report showing the quality index for the nine parameters for each of the sampling locations can be seen in Tables 4.61. In SL 1, Dissolved Oxygen and BOD gave the quality rating of (2.66) and (20.6) while pH and EC gave the quality rating of (57.77) and (7.17) Nitrate and Chloride gave quality ratings of (12.18) and (2.13) TSS, Total Hardness and Total Dissolved Solids gave the quality ratings of (12.79), (3.94) and (2.51) respectively.

In SL 2, Dissolved Oxygen and BOD gave the quality rating of (78.85) and (29.80) while pH and EC gave the quality rating of (47.33) and (7.17) Nitrate and Chloride gave quality ratings of (26.16) and (4.7) TSS, Total Hardness and Total Dissolved Solids gave the quality ratings of (16.33), (10.33) and (5.60) respectively.

In SL 3, Dissolved Oxygen and BOD gave the quality rating of (107.50) and (53.60) while pH and EC gave the quality rating of (29.00) and (355.00) Nitrate and Chloride gave quality ratings of (40.02) and (173.33) TSS, Total Hardness and Total Dissolved Solids gave the quality ratings of (178.83), (60.89) and (155.634) respectively.

Table 4.6.1 Water Quality Indices for the seven sample locations

Water Quality Report for SL1

Parameters	Unit Weight	Quality rating
pH	0.2190	59.33
EC	0.3710	7.17
DO	0.3727	0.68
Chloride	0.0074	2.13
Nitrate	0.412	12.18
BOD	0.3723	20.60
TSS	0.0037	12.79
T-Hardness	11.83	3.94
TDS	12.53	2.51

Water Quality Report for SL 2

Parameters	Unit Weight	Quality rating
pH	0.2190	47.33
EC	0.3710	7.17
DO	0.3727	78.85
Chloride	0.0074	4.70
Nitrate	0.412	26.16
BOD	0.3723	29.8
TSS	0.0037	16.33
T-Hardness	11.83	10.33
TDS	12.53	5.60

Water Quality Report for SL 3

Parameters	Unit Weight	Quality rating
pH	0.2190	29.00
EC	0.3710	355.00
DO	0.3727	107.50
Chloride	0.0074	173.33
Nitrate	0.412	40.02
BOD	0.3723	53.60
TSS	0.0037	178.83
T-Hardness	11.83	60.89
TDS	12.53	155.634

Water Quality Report for SL 4

Parameters	Unit Weight	Quality rating
pH	0.2190	67.33
EC	0.3710	22.16
DO	0.3727	74.17
Chloride	0.0074	6.67

Nitrate	0.412	38.80
BOD	0.3723	35.00
TSS	0.0037	14.37
T-Hardness	11.83	9.68
TDS	12.53	7.73

Water Quality Report for SL 5

Parameters	**Unit Weight**	**Quality rating**
pH	0.2190	56.00
EC	0.3710	100.72
DO	0.3727	97.60
Chloride	0.0074	20.73
Nitrate	0.412	50.16
BOD	0.3723	48.20
TSS	0.0037	18.40
T-Hardness	11.83	10.41
TDS	12.53	35.57

Water Quality Report for SL 6

Parameters	**Unit Weight**	**Quality rating**
pH	0.2190	42.67
EC	0.3710	142.89
DO	0.3727	80.83
Chloride	0.0074	32.80
Nitrate	0.412	39.22
BOD	0.3723	33.60
TSS	0.0037	21.87
T-Hardness	11.83	44.67
TDS	12.53	57.00

Water Quality Report for SL 7

Parameters	**Unit Weight**	**Quality rating**
pH	0.2190	59.33
EC	0.3710	133.89
DO	0.3727	19.10
Chloride	0.0074	29.27
Nitrate	0.412	27.00
BOD	0.3723	1.22
TSS	0.0037	30.61
T-Hardness	11.83	44.53
TDS	12.53	46.59

In SL 4, Dissolved Oxygen and BOD gave the quality rating of (74.167) and (35.00) while pH and EC gave the quality rating of (67.33) and (22.16) Nitrate and Chloride gave quality ratings of (38.80) and (6.67) TSS, Total Hardness and Total Dissolved Solids gave the quality ratings of (14.37), (9.68) and (7.73) respectively. In SL 5, Dissolved Oxygen and BOD gave the quality rating of (97.60) and (48.20) while pH and EC gave the quality rating of (56.00) and (100.72) Nitrate and Chloride gave quality ratings of (50.16) and (20.73) TSS, Total Hardness and Total Dissolved Solids gave the quality ratings of (18.40), (10.41) and (35.57) respectively.

In SL 6, Dissolved Oxygen and BOD gave the quality rating of (80.83) and (33.6) while pH and EC gave the quality rating of (42.67) and (142.89) Nitrate and Chloride gave quality ratings of (39.22) and (32.80) TSS, Total Hardness and Total Dissolved Solids gave the quality ratings of (21.87), (44.65) and (57.00) respectively. In SL 7, Dissolved Oxygen and BOD gave the quality rating of (46.59) and (27.00) while pH and EC gave the quality rating of (59.33) and (133.89) Nitrate and Chloride gave quality ratings of (29.27) and (19.10) TSS, Total Hardness and Total Dissolved Solids gave the quality ratings of (1.22), (30.61) and (44.53) respectively. These values fall within the classification of water quality based on the weighted arithmetic WQI method as given in Table 2.2. SL3 had significant bad water quality this may be as a result of industrial and agro effluent, refuse dump disposal, runoff into the river at those locations. It follows that untreated water from site locations having water quality status of 51 and above is must, therefore, be treated before use to avoid water-related diseases. The water quality index of Onuiyieke River varies from excellent to unsuitable for drinking status suggesting impact of anthropogenic activities in the water body like the inflow of direct sewerage from residential and commercial establishments, lack of proper sanitation system, agricultural run-off, direct disposal of untreated effluents and unabated dumping of solid wastes by the communities residing in the area, etc.

Table 4.6.2 Spatial parameters used in the calculation of the Water Quality Index of Onuiyieke River.

s/no	Parameters	SL1	SL2	SL3	SL4	SL5	SL6	SL7
1	pH	5.99	6.29	6.56	5.99	6.16	6.36	6.11
2	EC	21.50	37.33	1065.00	66.50	302.17	428.67	401.67
3	DO	8.07	7.03	4.28	7.48	5.23	6.85	47.75
4	Chloride	5.33	11.75	78.00	16.67	51.83	82.00	13.17
5	Nitrate	5.48	11.77	18.01	17.46	22.57	17.65	1.35
6	BOD	1.03	1.49	2.68	1.75	2.41	1.68	6.11
7	TSS	63.96	81.67	894.17	71.83	92.00	109.33	91.83
8	Total hardness	11.83	31.00	182.67	29.03	31.22	133.95	222.67
9	Total dissolved solids	12.53	28.00	778.17	38.67	177.83	285.00	7.10
Water Quality Index		**16.24**	**34.46**	**123.05**	**45.14**	**87.70**	**68.98**	**58.05**

Source: Author's Fieldwork, (2018)

Table 4.7 Summary of water quality index (WQI) by site location along the course of Onuiyieke River.

S/N	Site locations	0-25 Excellent	25 -50 Good	50 -70 Medium	70 -90 Very poor	90-100 Unsuitable
1	SL 1	16.24				
2	SL 2		34.46			
3	SL 3					123.05
4	SL 4		45.14			
5	SL 5				87.70	
6	SL 6			68.98		
7	SL 7			58.05		

Source: Author's Fieldwork, (2018)

4.7 Discussion

From the analysis of available data, the major findings of this research are as follows: Variations in the parameters of the Onuiyieke River are shown in Table 4.1. The physical, chemical and biological characteristics of a water body are important in the determination of its productive capacity and effect on the biota.

Consumption of low pH (Table 4.1) water could lead to acidosis, which results in peptic ulcer. The low pH observed in all sampling points except SL 2 could be a result of human activities. These activities may have caused the death of some aquatic life forms. These aquatic life forms release proteins including ammonia upon death and decay. Comparing the mean pH of the water samples showed that their pH level was between 6.12- 7.00, within the range of standard limits for safe drinking water by WHO. The mean pH indicates slightly acidic water according to (NESREA, 2011) standards. Also, many biological processes such as reproduction cannot function in acidic or alkaline waters. Amadi, Olaselinde, Okosun, & Yis., (2010) also recorded similar pH values in the Otamiri and Urammiriukwa rivers and attributed it to discharge from industries, urban runoffs, hair salons, waste dumps at the banks of the river. He reported that excessively high and low pH of water increases the solubility of metals which may be toxic to fish and render the water unsuitable for other uses especially when the pH falls below 4.5. The released ammonia dissolved in water hence causing a drastic change that manifests as low pH.

The temperature of water is important in terms of its intended use. For instance, drinking water should have a temperature range of 20-30^{o}C. Temperature range (26.00- 29.00^{o}C) of Onuiyieke River falls within the WHO standard for drinking water. The mean temperature values of the water samples are not statistically different from each other ($p < 0.05$) and also fall within the normal temperature range supportive of good surface water quality which is 0 °C to 30 °C Hence, the temperature of the water from Onuiyieke River could not be implicated as influencing the observed variations in the bacterial population as well as in other physical, chemical parameters. However, the observed range of the temperature allows for optimum proliferation of most of the bacteria isolated from the water samples. Temperature is a measure of the average energy (Kinetic) of water molecules, (Andem, Udofia, Okoroafor, Okete, & Ugwumba, 2012). Most aquatic organisms are sensitive to changes in temperature. The temperature of any given water determines the rates of metabolism of aquatic organisms and the concentration of dissolved gases (Akankli & Oronsaye, 2012). The high temperature recorded in SL 5 and 6 when compared to the control location SL 1 might be as a result of agricultural inputs from downstream nearby. PC 4 was most highly correlated with water temperature which according to (Boulton, 2012) might be a result of industrial and agricultural discharges, including runoffs into the river.

Water hardness was originally described as the soap-destroying power of water, caused by the presence of calcium and magnesium salts. The consumption of hard water could set up a problem in the system. (Boulton, 2012) noted that the degree of water hardness (dH) is determined by the concentration of calcium carbonate. The Total hardness range (4.20 – 200.00 mg/l) of the studied river falls within the degree of water hardness indicated. Though Total Hardness was within permissible limits with SL3 being the highest at 200.00mg/l in December 2017, The water is hard and is thus largely unsuitable for direct use by communities that use it for laundry work and bathing. Calcium and Magnesium hardness range from 3.00mg/l to 39.00mg/l and from 0.09 to 0.46 mg/l respectively. However, the mean concentration of calcium and magnesium are 15.15 and 0.22 mg L^{-1} which are below the recommended permissible limit of 200.00 mg L^{-1} for both calcium and magnesium (WHO, 2011b).

Solids found in a water body exist as total, suspended, or dissolved (WHO, 2011a). Total solid (TS), an estimate of whole solids in a water body as observed in Onuiyieke River ranged between 56.00-2722.00 mg/l. Some of these observed solids existed as un-dissolved suspended solids (6.00- 3012.00 mg/l) as observed in the present study and most dissolved to form dissolved solids (4.00- 830.00mg/l) as the case with Onuiyieke River. Water containing high solids may cause laxative or constipation effects. The variations in the total solids, total suspended solids and total dissolved solids as well as the dissolved oxygen content are shown in Table 4.1 The significantly high levels of total dissolved solids (TDS) of the water ($p < 0.05$) are implicative of a high level of pollution of the Onuiyieke River when compared to the WHO standard limit for good water quality which is 500 mg/L for TSS and 50 mg/L for TDS. The high TSS and TDS content values of the water show significant direct relationships to the high bacterial population obtained from the water samples. Consumption of water with high solid could lead to gastrointestinal upset, which may pave way for other gastrointestinal diseases (Nkwocha & Egejuru, 2010).

TSS, according to Andem *et al.* (2012), can be defined as the portion of total solids in a water sample retained by a filter. Mean TSS (198.19 mg/l) in the present study when compared to the Control Location (SL 1) showed very high pollution in the Onuiyike River according to NESREA permissible limits of 0.25mg/L. PC 3 had the highest loading of TSS which can be attributed to discharges from agro-industries, dumping of solid wastes at the banks of the river, agricultural runoff and domestic sewage. Olajumoke, Oluwatoshin, Olumujiwa, & Abimbola, (2010) who also observed a high level of TSS in Majawe river attributed it to the brewing industry located nearby which according to them, may contain organic materials like spent grains, waste yeast, spent hops and grit.

Andem *et al.*, (2012) reports that the continuous discharge of these wastes/effluents around the river could lead to the reduction of the volume of the water and free flow of the river. They further reported that the long term deposition of materials in the river could also result in flooding, particularly during rainfall thereby increasing the TSS value of the river. Also, (Awomeso *et al.*, 2012) reported that high TSS and TS tend reducing light penetration into the river thereby leading to reduced photosynthesis with subsequent effects on both phytoplankton and zooplankton.

According to Kumar & Prabhabar (2012), conductivity is the measure of the capacity of a substance to conduct electric current. Electrical conductivity estimates the amount of TDS or dissolved ions in water therefore; Conductivity is related with total dissolved solids in a water body. Aremu, Odaofe, Ikokoh, & Yakubu, (2011) noted that for estimates of conductivity of water, total dissolved solids are divided by a factor range of 0.55-0.90. The high conductivity values observed in SL 3, 5 and 6 could be attributed to high dissolved solids observed at the points. The progression of water conductivity level that increased from 7.00microhms/cm, in October 2017, at control point SL1, to 1368.00 microhms/cm at SL3 in February 2018 (an increase of about 52 percent) reflects the status of inorganic pollution and is a measure of TDS in water thus far exceeding the WHO maximum permissible limit (Appendix 1). Comparing these values with 40 micros /cm, which is the drinking water standard by (WHO, 2011a), this concentration level poses a great threat to the health of the local population that uses the river water as a source of water supply. However, Freshwater streams ideally should have conductivity 150 to 500 µS/cm to support diverse aquatic life (Chatterjee, 2011).

The high value of the mean EC observed in the present study may be due to an increase in concentrations of salts, organic and inorganic materials as a result of discharges from industries, runoff from domestic and other human activities into the river. TDS in the present study also showed a similar trend with EC with the highest values being observed at SL 3 (Table 4.1). High values of EC and TDS recorded in SL 3 can be attributed to the nature of effluents discharged nearby. These discharges can contain high amounts of ions that exceed the recommended standard of (NESREA, 2011). This differs from the Control Location (SL 1) where the value is very low due to the absence of industries around that area. The wide range observed in the EC of the Onuiyike River indicates varying levels of conducting ions being discharged into the river. This may also be the reason for the positive correlations between the EC and the trace metals at $P<0.01$ in this study. Also, the high positive correlations between EC and TDS in this study indicate that as TDS increases, the EC of the river also increases.

Dissolved oxygen (DO), is the oxygen present in a dissolved form in a water body. It is labile and can be easily reduced by carbon compounds to form carbon (IV) oxide (CO_2). It is generally related to the ability of a water body to hold aquatic life forms (Murhekar, 2011). Dissolved oxygen levels of Onuiyieke River were lower than that of the WHO standard. SL 3 recorded the least value of DO which according to (NESREA, 2011) can pose a threat to fish and other higher forms of aquatic organisms. This low DO can be attributed to increased industrial effluents that may carry a high concentration of oxygen demanding materials from nearby farmlands. Similar results were obtained by Umunnakwe, Akagha, & Aharanwa (2012) on Aba River and Akubugwo & Duru (2011) on Otamiri River but this result was different from the result of (Nibedita, 2015). Bacterial decomposition consumes a great deal of oxygen and dissolved oxygen is depleted by the decaying process.

The lower level of DO noted at site SL 3 may be attributed to increased growth of aerobic bacteria in the presence of large organic matter, due to anaerobiosis. SL1 (upstream) had DO mean values within the acceptable (8.01mg/l). This indicates less organic waste input which provides enabling environment for aquatic life. The midstream, SL 3 and SL 5, however, had relatively lower DO values. This could be attributed to the impact of municipal wastes dumped in the river directly or through runoff. Iwuoha, Osuji, & Horsfall, (2012) maintain that microbial breakdown of the organic material leads to higher DO utilization and reduction.

The mean BOD and COD indicate that the Onuiyieke River was relatively poor for aquatic growth according to NESREA Standards (NESREA, 2011). BOD is a standard water-treatment test for the presence of organic pollutants and directly shows the amount of biodegradable organic matter by microbial metabolism while COD is the oxygen required for the chemical oxidation of organic matter with the help of strong chemical oxidant (Water Research Center, 2015). The values of COD recorded in the present study according to (Amadi *et al.*, 2010) who also recorded similar values of BOD and COD can be caused by inflow of domestic, agricultural and growth of iron bacteria that hasten the rusting process of ferrous metals that come in contact with the water. In their study (Desai & Tank, 2010) corroborates that high levels of pollutants in river water systems causes an increase in biological oxygen demand (BOD), chemical oxygen demand (COD), total dissolved solids (TDS), total suspended solids (TSS), and faecal coliform and hence make such water unsuitable for drinking, irrigation, and aquatic life .

The mean value of turbidity from the present study exceeded the desired limit of 10NTU according to NESREA standards, thereby making the river unfit for aquatic life. Also, the mean value of turbidity (18.84 NTU) exceeded that of SL 1 (NESREA, 2011). The greater the amount of suspended solids in water, the murkier it appears and the higher the measured turbidity also, higher turbidity increases water temperatures and in turn reduces the concentration of Dissolved Oxygen (DO) (Bu, Tan, Li, & Zhang, 2010). This can be the reason for the inverse correlations between turbidity and DO in the present study. The high level of turbidity observed in this study can be attributed to runoff and anthropogenic activities. Turbidity of the water increased greatly from 4.5 NTU at SL1 to 48.70 NTU at SL 3 all in November 2017 showing an increase in the concentration of suspended matters in the water sample and soil particles transported by runoff to the river but highest at the point SL 3 after input of wastes from effluents (Table 4.1, Appendix a-f). Reduction at the point of leaving in SL 7 is indicative of self-purification by the river. Turbidity may also indicate the presence of disease-causing organisms.

The mean total hardness in the present study showed a similar trend with EC at SL 3 recording highest values (73.08mg/l). Total Hardness according to Cosmas & Samuel (2011), is the sum of the Calcium and Magnesium concentration both expressed as calcium carbonate in milligrams per litre. This may be the reason for the positive correlations between calcium and magnesium as against Total Hardness in the present study. Umunnakwe *et al.,* (2012) observed similar values of total hardness in Aba River and reported that exceeding the standard limits of hardness could cause poor lathering of soap and scaling of boilers and industrial equipment. It can also lead to heart diseases and kidney stones formation.

Chloride is one of the important indicators of water pollution. The mean Chloride ions in this study suggest that the river is suitable for the growth of organic organisms (41.9mg/l) when compared to the NESREA standards of 300mg/l. The existence of considerable amount of Cl^- ions in river water may be attributed to the discharge of agro and industrial effluents into the river as seen at SL 3 which is relatively high compared to the values of the control (SL1) The high correlations between Cl^- and conductivity shows that when Chlorine is introduced into the water, the quantity of electrolytes of total dissolved solids in the water rises which in turn raise the conductivity of water. This agrees with the work of Umunnakwe *et al* (2012) who also recorded a positive correlations between Cl^- ions, and conductivity in Aba River.

The high mean ammonium and mean nitrate ions concentration recorded in SL 3 might be attributed to nitrogenous input indicating their heavy impact on the river. Nitrates find their way into water bodies through agricultural fertilizers, industrial wastewaters, landfills and garbage dumps (Soraya, Lakhdar, & Larbi, 2017). Mean Nitrate levels across the sampling locations were progressively high, the highest located at SL 5 (22.57mg/l). This may explain the rich growth of water weeds and plankton around the site location. Farming and dumping of animal waste along the river course might be responsible for these high readings. Leachates from fertilizer and waste disposal can lead to high nitrate concentration which causes eutrophication (WHO, 2011a).

Mean phosphate levels varied along the sampling locations, the highest recorded at SL5 (2.72 mg/l). Larger streams may react to phosphate only at levels approaching 0.1 mg/L, while small streams may react to levels of PO_4^{-3} at levels of 0.01 mg/L or less (Huang, Wang, Lou, Zhou, & Wu, 2010). Ideriah, Amachree, & Stanley, (2010) opines that increased nutrients especially nitrate and phosphates simply increasing plant bloom, a situation which may lead to eutrophication in the future. Most domestic wastes contain chlorides and phosphates. Phosphate is one of the most important nutrients responsible for the eutrophication of rivers and lakes which increases algal growth, lowers light penetration and reduces dissolved oxygen levels. It also causes aesthetic degradation of surface water bodies (Anhwange, Agbaji, & Gimba, 2012) The mean phosphate from the present study according to (NESREA, 2011) indicates that the river is relatively good for aquatic life but higher than the value of the Control Location SL1. The results obtained were similar to the results of (Amadi *et al.*, 2010) on the Aba River. He attributed the source of trace metals in the river to anthropogenic activities such as discharge of industrial effluents and laundry waste that take place along the river course.

Calcium and Magnesium are essential elements needed in good quantity by the human body and they also contribute to water hardness. Calcium functions in teeth and bone formation and neuromuscular tissues (Egereonu, Ukiwe, Edet, & Ogukwe, 2012). PC1 was most highly correlated with Mg^+ ion concentration which may find their way into the river from fertilizer application in nearby farmlands and poultry. According to (Ekubo & Abowei, 2011), these heavy metals have no nutritional value rather they are carcinogenic and bioaccumulate into the toxic level to damage essential human organs. Sulphate, nitrate, and chloride in water are indicators of agrochemical usage on lands surrounding the river. These may have entered the river as runoff during rainfall.

Akubugwo & Duru, (2011) noted that microorganisms are commonly present in surface water. (Nkwocha & Egejuru, 2010) further noted that a wide range of indigenous species of microorganisms is usually present in water. This is in line with the present study. Organisms such as *Escherichia coli*, *Klebsiella sp.*, *Vibrocholerae*, *Proteus sp.*, *Shigella sp.*, *Salmonella sp.*, *Staphylococcus epidermidis*, *Bacillus sp.*, *Pseudomonas aeruginosa*, and *Citrobacter sp.*, were among the wide range of organisms isolated from Onuiyieke River water. The presence of these microorganisms has practical significance in terms of human activities (Barnerjee & Morella, 2011) For instance, *Escherichia coli* signifies faecal coliform contamination of a water body (WHO, 2011b). *Escherichia coli*, *Klebsiella sp.*, *Proteus sp.*, *Shigella sp., and Salmonella sp.*, belong to the family known as *Enterobacteriaceae* (AIRBDA, 2014). Their presence in water indicates faecal waste contamination. The presence of microorganisms in water becomes important when their health impact is considered. Aside *Escherichia coli* and some *Bacillus sp.*, most microorganisms have been implicated as a causative agent of one waterborne disease or the other. For instance, *Salmonella sp.*, *Shigella sp.*, and *Proteus sp.* are the causative agents of typhoid fever, dysentery. and urinary tract infection respectively (Amadi *et al.*, 2010). *Staphylococcus epidermises* cause wound infection and endocarditis (Desai & Tank, 2010). The presence of total coliform in water is an indication of faecal contamination and is responsible for most water-borne diseases such as meningitis, cholera, and diarrhoea as well as morbidity and mortality among children.

On average about 70% of the total coliforms are of faecal origin. The total bacterial count ranged from 3.0×10^4 to 7.5×10^4 CFU/ml. Faecal indicators are microbes whose presence indicates that the water may be contaminated with human or animal wastes. Results of bacteriological analyses including total heterotrophic count, total coliform and thermotolerant coliform counts revealed a high level of faecal pollution of the river. This range is higher than WHO standards. Some genera could be of soil origin while others are of intestinal and hence faecal origin. Bacteria and other pathogens are the greatest threat to the quality of water for domestic consumption. Bacteria originating from human faeces are a leading cause of child mortality, and water is a common transmission route. The presence of the organism shows that the river cannot be used directly as a source of drinking water; it ranks among water that requires auxiliary treatment. Also, some of the organisms encountered in the water are potential pathogens contrary to the recommendation that drinking water should be free of pathogens. All these observations pose serious public health hazards, as they constitute potential sources of food-borne gastroenteritis, diarrhoea, salmonellosis, dysentery, etc. Increases in nutrient levels, river flow, and aeration enhance aerobic decomposition of organic matter and therefore bacterial counts, leading to deterioration of the aesthetic value of the river

Galadima *et al*., (2011) noted that the presence of a number of microorganisms in water depends on the contamination and the ability of the organisms to survive or multiply. *Vibrocholerae*, *Pseudomonas aeruginosa*, and *Citrobacter sp.,* identified in the present study further indicate the presence of more pathogens in Onuiyieke River. The differences observed in concentrations of these organisms could be as a result of human activities. The presence of these organisms in Onuiyieke River may be an indication of possible water-borne diseases such as typhoid fever, cholera, dysentery, etc. on the consumption of water from the river by humans.

CHAPTER FIVE

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

The water quality of the water body is an important and significant technique for a complete assessment of the water body. The physical, chemical and biological parameters such as pH, turbidity, Electrical Conductivity, Ammonia, Iron, BOD, Magnesium and faecal coliforms exceeded the maximum permissible limits of NESREA and WHO. Also, the result of the water quality index across the sampling locations indicates bad water quality in some locations while for others, it is average, it can, therefore, be concluded that water from Onuiyieke River is not potable but may be used for other purposes.

5.2 Recommendations

Arising from the research findings, the following recommendations were made**:**

i. The quality of the river water can be raised to the regulatory standards for safe drinking water by applying the necessary treatment procedures. For instance; using sodium bicarbonate (soda ash), boiling and subjection to treatment using chlorine before consumption.

ii. Human activities along the course of the river should be monitored for the sustainability of the ecosystem. Onuiyieke river demands appropriate monitoring procedures for pollution control and mitigation for a sustainable development of the resource.

iii. The water from the river should be tested from time to see whether the physical, chemical and biological parameters are changing. The Federal and State Environmental Agencies should ensure the enforcement of prescribed standards and regulations for agro-processors that discharge their effluents into river bodies.

iv. The creation of public awareness on the causes and hazards of water pollution can have a desirable effect at curtailing the problem. Basic environmental hygiene should be made known to the residents along the Onuiyieke River which includes proper waste disposal in order not to further deteriorate the quality of the river. Educating farmers properly could help to make the shift from the use of chemical fertilizers to traditional manure that is less injurious pollutants than agro-chemicals.

v. Measures should also be put in place to control soil erosion that usually transfers chemicals and other solid matter into the water body to pollute it.

5.3 Contribution to Knowledge

This research confers better knowledge of surface water quality of Onuiyieke River in Imo State. The knowledge and awareness sensitize community members and inhabitants living near the river to contribute to solving water pollution challenges, adopt pollution reduction behaviours and practice better water conservation approach to water use. This research add to add to scientific knowledge data collection and distribution for improved forecasting and war resources operations.

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APPENDICES

Appendix 1a: Descriptive Statistics Of physical, chemical and biological Parameters of Samples From Site Locations (September, 2017)

PARAMETERS	SL 1	SL 2	SL 3	SL 4	SL 5	SL 6	SL 7
pH	6.30	6.50	7.00	6.42	6.20	6.55	6.12
TSS(mg/l)	40.00	45.00	123.00	52.00	80.00	220.00	68.00
EC (µs/cm)	27.00	48.00	1350	87.00	297.00	498.00	610.00
TDS(mg/l)	16.00	28.00	810.00	52.00	162.00	405.00	289.00
TS(mg/L)	56.00	73.00	933.00	104.00	242.00	625.00	357.00
Turbidity(NTU)	9.00	12.00	45.00	10.00	18.00	16.00	12.20
DO(mg/L)	8.10	7.80	6.00	8.10	5.70	6.90	6.70
BOD_5(mg/L)	1.00	1.80	2.50	1.80	2.70	1.70	1.20
Chloride(mg/L)	7.00	16.00	120.00	16.00	55.00	80.00	87.00
Total hardness(mg/L)	17.00	30.00	200.00	29.00	32.00	160.00	92.00
Calcium(mg/L)	4.00	6.00	35.00	5.00	8.00	23.00	26.00
Magnesium(mg/L)	0.12	0.15	0.37	0.13	0.18	0.29	0.37
Phosphate(mg/L)	1.70	2.40	2.54	2.78	2.69	3.00	2.78
Faecal Coliform(MPN/100ml)	1.70	2.50	3.30	2.10	1.90	1.50	1.00
Nitrate(mg/L)	5.50	13.20	19..10	15.00	23.20	28.10	11.00
Ammonia(mg/L)	7.00	10.00	17.80	15.90	22.50	18.10	10.40
Water Temperature(^{0}C)	28.00	28.50	27.50	26.00	28.00	28.50	27.00
Iron(mg/l))	0.78	1.10	5.80	1.30	2.70	3.00	2.10
COD(mg/l)	1.50	2.60	5.60	3.00	5.00	2.50	2.10

All parameters in mg/l except pH, DO= dissolved oxygen, PO_4^{-3} = phosphates, BOD= biochemical oxygen demand, COD= chemical oxygen demand, EC= electrical conductivity.

Appendix 1b: Descriptive Statistics Of physical, chemical and biological Parameters of Samples From Site Locations (October, 2017)

PARAMETERS	SL 1	SL 2	SL 3	SL 4	SL 5	SL 6	SL 7
pH	5.40	6.30	6.70	5.70	6.20	6.55	7.00
TSS(mg/l)	64.78	86.00	1858.00	58.00	46.00	63.00	58.00
EC (µs/cm)	7.00	23.00	1172.00	60.00	330.00	370.00	250.00
TDS(mg/l)	4.5	15.00	764.00	37.00	220.00	230.00	157.00
TS(mg/L)	72.28	101.00	2622.00	95.00	266.00	293.00	215.00
Turbidity(NTU)	4.80	8.20	48.50	13.00	14.00	12.00	7.00
DO(mg/L)	7.90	7.30	4.10	7.80	4.70	7.50	7.40
BOD_5(mg/L)	0.70	1.20	2.60	1.60	2.10	1.30	0.98
Chloride(mg/L)	4.00	8.50	102.00	18.00	55.00	80.00	15.00
Total hardness(mg/L)	4.30	33.00	160.00	32.00	31.00	165.00	97.00
Calcium(mg/L)	3.00	7.00	29.00	5.00	8.00	30.00	22.00
Magnesium(mg/L)	0.10	0.13	0.40	0.12	0.18	0.30	0.15
Phosphate(mg/L)	1.00	2.50	3.00	2.67	4.00	3.40	2.70
Faecal Coliform(MPN/100ml)	0.9	2.60	3.20	2.50	2.00	1.50	1.10
Nitrate(mg/L)	4.50	8.40	16.00	17.80	21.05	18.00	10.00
Ammonia(mg/L)	6.00	9.60	18.10	20.10	22.20	18.20	11.00
Water Temperature(^{0}C)	26.00	27.00	27.50	27.00	28.00	28.50	29.00
Iron(mg/l))	0.47	2.07	3.90	0.30	2.09	1.17	1.30
COD(mg/l)	1.94	2.03	5.08	2.20	4.80	2.10	2.08

All parameters in mg/l except pH, DO= dissolved oxygen, PO_4^{-3} = phosphates, BOD= biochemical oxygen demand, COD= chemical oxygen demand, EC= electrical conductivity.

Appendix 1c: Descriptive Statistics Of physical, chemical and biological Parameters of Samples From Site Locations (November, 2017)

PARAMETERS	SL 1	SL 2	SL 3	SL 4	SL 5	SL 6	SL 7
pH	6.00	6.30	6.35	6.42	6.20	6.55	6.12
TSS(mg/l)	73.00	110.00	3012.00	72.00	70.00	50.00	30.00
EC (µs/cm)	7.00	19.00	1057.00	60.00	350.00	370.00	300.00
TDS(mg/l)	4.00	13.00	710.00	27.00	200.00	230.00	130.00
TS(mg/L)	77.00	123.00	3722.00	99.00	270.00	280.00	160.00
Turbidity(NTU)	4.50	10.50	48.70	35.00	29.00	16.00	12.00
DO(mg/L)	8.10	5.80	3.00	6.70	5.00	6.10	7.10
BOD_5(mg/L)	1.00	1.20	2.30	2.00	2.40	1.60	1.20
Chloride(mg/L)	3.00	10.00	15.00	20.00	60.00	86.00	50.00
Total hardness(mg/L)	4.20	30.00	160.00	37.00	34.00	170.00	130.00
Calcium(mg/L)	4.00	5.00	29.00	10.00	6.00	35.00	36.00
Magnesium(mg/L)	0.09	0.15	0.25	0.17	0.22	0.30	0.19
Phosphate(mg/L)	0.38	0.30	0.27	0.17	0.24	0.25	0.22
Faecal Coliform(MPN/100ml)	0.70	2.20	1.90	2.10	2.40	2.00	1.90
Nitrate(mg/L)	5.20	8.20	15.10	20.00	25.20	18.00	19.00
Ammonia(mg/L)	6.10	8.20	17.30	20.40	25.50	15.20	10.50
Water Temperature(^{0}C)	28.10	26.50	28.40	26.00	26.50	28.50	27.00
Iron(mg/l))	0.27	1.30	3.34	0.15	1.50	1.10	0.90
COD(mg/l)	2.60	3.90	5.30	2.80	4.50	3.00	3.10

All parameters in mg/l except pH, DO= dissolved oxygen, PO_4^{-3} = phosphates, BOD= biochemical oxygen demand, COD= chemical oxygen demand, EC= electrical conductivity.

Appendix 1d: Descriptive Statistics Of physical, chemical and biological Parameters of Samples From Site Locations (December, 2017)

PARAMETERS	SL 1	SL 2	SL 3	SL 4	SL 5	SL 6	SL 7
pH	6.00	6.20	6.50	6.00	6.10	6.00	6.10
TSS(mg/l)	53.00	73.00	110.00	40.00	110.00	30.00	50.00
EC (µs/cm)	27.00	45.00	1300.00	50.00	300.00	260.00	220.00
TDS(mg/l)	10.00	25.00	740.00	30.00	170.00	240.00	200.00
TS(mg/L)	63.00	98.00	850.00	70.00	280.00	270.00	250.00
Turbidity(NTU)	5.10	6.00	15.00	17.00	14.00	16.00	12.00
DO(mg/L)	8.10	5.80	3.00	6.70	5.00	6.10	7.10
BOD_5(mg/L)	1.00	1.20	2.30	2.00	2.40	1.60	1.20
Chloride(mg/L)	3.00	9.00	10.00	18.00	50.00	75.00	32.00
Total hardness(mg/L)	17.00	30.00	200.00	29.00	32.00	160.00	92.00
Calcium(mg/L)	3.00	5.00	39.00	9.00	6.00	25.00	26.00
Magnesium(mg/L)	0.12	0.15	0.37	0.13	0.18	0.29	0.27
Phosphate(mg/L)	2.00	2.40	2.54	2.78	2.69	3.00	2.78
Faecal Coliform(MPN/100ml)	1.70	2.20	1.70	2.10	2.100	2.00	1.90
Nitrate(mg/L)	7.20	13.20	11..10	22.00	21.20	15.00	20.00
Ammonia(mg/L)	7.00	10.00	17.80	15.90	22.50	18.10	10.40
Water Temperature(^{0}C)	29.00	28.00	27.00	29.00	28.00	28.50	28.00
Iron(mg/l))	0.37	1.50	3.58	0.20	1.60	1.10	0.70
COD(mg/l)	2.10	2.30	4.00	2.20	4.00	2.50	2.30

All parameters in mg/l except pH, DO= dissolved oxygen, PO_4^{-3} = phosphates, BOD= biochemical oxygen demand, COD= chemical oxygen demand, EC= electrical conductivity.

Appendix 1e: Descriptive Statistics Of physical, chemical and biological Parameters of Samples From Site Locations (January, 2018)

PARAMETERS	SL 1	SL 2	SL 3	SL 4	SL 5	SL 6	SL 7
pH	5.40	6.30	6.70	5.70	6.20	6.55	5.70
TSS(mg/l)	72.00	170.00	130.00	120.00	150.00	290.00	180.00
EC (µs/cm)	43.00	47.00	1370.00	60.00	250.00	530.00	400.00
TDS(mg/l)	28.00	30.00	830.00	37.00	152.00	279.00	300.00
TS(mg/L)	100.00	200.00	1010.00	157.00	302.00	569.00	318.00
Turbidity(NTU)	9.00	11.00	49.00	15.00	45.00	35.00	38.00
DO(mg/L)	7.70	7.50	4.50	6.70	5.80	6.00	6.10
BOD_5(mg/L)	1.50	2.10	3.30	2.00	2.85	2.65	2.60
Chloride(mg/L)	10.00	11.00	98.00	17.00	54.00	90.00	80.00
Total hardness(mg/L)	15.60	28.00	182.00	18.00	28.00	73.40	70.00
Calcium(mg/L)	3.50	5.00	34.50	3.00	6.00	22.00	18.00
Magnesium(mg/L)	0.12	0.16	0.42	0.16	0.20	0.32	0.23
Phosphate(mg/L)	0.50	0.60	2.80	0.70	3.80	3.20	2.50
Faecal Coliform(MPN/100ml)	0.96	2.20	2.50	2.70	2.00	1.30	1.00
Nitrate(mg/L)	5.97	13.00	14.00	16.50	23.00	14.00	11.00
Ammonia(mg/L)	6.05	13.90	14.70	15.80	25.50	15.50	10.50
Water Temperature(^{0}C)	28.00	27.00	27.50	27.00	28.00	27.00	29.00
Iron(mg/l))	0.25	1.19	3.20	0.64	3.50	4.00	4.30
COD(mg/l)	2.03	3.50	4.50	2.00	4.10	3.07	2.80

All parameters in mg/l except pH, DO= dissolved oxygen, PO_4^{-3} = phosphates, BOD= biochemical oxygen demand, COD= chemical oxygen demand, EC= electrical conductivity.

Appendix 1f: Descriptive Statistics Of physical, chemical and biological Parameters of Samples From Site Locations (February, 2018)

PARAMETERS	SL 1	SL 2	SL 3	SL 4	SL 5	SL 6	SL 7
pH	5.30	6.20	6.10	5.60	6.90	7.00	5.80
TSS(mg/l)	82.00	50.00	128.00	80.00	92.00	50.00	57.00
EC (µs/cm)	17.00	42.00	1368.00	70.00	280.00	537.00	520.00
TDS(mg/l)	13.00	30.00	810.00	50.00	160.00	330.00	250.00
TS(mg/L)	99.00	90.00	938.00	130.00	252.00	382.00	307.00
Turbidity(NTU)	9.00	11.00	49.00	15.00	45.00	35.00	38.00
DO(mg/L)	7.70	7.50	4.50	6.70	5.80	6.00	6.10
BOD_5(mg/L)	1.50	2.10	3.30	2.00	2.85	2.65	2.60
Chloride(mg/L)	10.00	11.00	98.00	17.00	54.00	90.00	80.00
Total hardness(mg/L)	15.60	28.00	182.00	18.00	28.00	73.40	70.00
Calcium(mg/L)	3.50	5.00	34.50	3.00	6.00	22.00	18.00
Magnesium(mg/L)	0.12	0.16	0.42	0.16	0.20	0.32	0.23
Phosphate(mg/L)	0.50	0.60	2.80	0.70	3.80	3.20	2.50
Faecal Coliform(MPN/100ml)	0.92	2.00	2.50	2.70	2.00	1.30	1.50
Nitrate(mg/L)	5.97	13.00	14.00	16.50	23.00	14.00	11.00
Ammonia(mg/L)	6.05	13.90	14.70	15.80	25.50	15.50	10.50
Water Temperature(^{0}C)	27.00	26.00	27.50	27.00	28.00	28.00	29.00
Iron(mg/l))	0.25	1.19	3.20	0.64	3.50	4.00	4.30
COD(mg/l)	2.03	3.50	4.50	2.00	4.10	3.07	2.80

All parameters in mg/l except pH, DO= dissolved oxygen, PO_4^{-3} = phosphates, BOD= biochemical oxygen demand, COD= chemical oxygen demand, EC= electrical conductivity.

Appendix 2a: Principal Components Analysis (PCA) Communalities of the physical, chemical and biological parameters of Onuiyieke River in Imo State, Nigeria

	Initial	Extraction
pH	1.000	.400
TSS	1.000	.872
EC	1.000	.824
TDS	1.000	.944
TS	1.000	.934
Turbidity	1.000	.735
DO	1.000	.736
BOD	1.000	.777
Chloride	1.000	.803
T.Hardness	1.000	.863
Ca	1.000	.871
Mg	1.000	.906
PO4	1.000	.701
F.Coliforms	1.000	.598
NO3	1.000	.728
NH3	1.000	.845
Temp	1.000	.731
Fe	1.000	.669
COD	1.000	.819

Appendix 2b: Extraction Method: Principal Component Analysis.

Total Variance Explained

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumul
1	9.183	48.333	48.333	9.183	48.333	48.333
2	2.381	12.534	60.867	2.381	12.534	60.867
3	2.012	10.592	71.458	2.012	10.592	71.458
4	1.180	6.212	77.670	1.180	6.212	77.670
5	.992	5.220	82.890			
6	.707	3.723	86.614			
7	.559	2.942	89.556			
8	.551	2.900	92.456			
9	.430	2.262	94.718			
10	.319	1.678	96.396			
11	.187	.982	97.379			
12	.144	.759	98.137			
13	.106	.559	98.696			
14	.094	.497	99.192			
15	.053	.277	99.469			
16	.051	.271	99.740			
17	.031	.164	99.904			
18	.018	.093	99.997			
19	.001	.003	100.000			

Extraction Method: Principal Component Analysis.

APPENDIX 2c: Rotated Component Matrix[a]

	Component			
	1	2	3	4
pH	.491	.368	.078	-.135
TSS	.080	.015	.930	-.018
EC	.733	.145	.495	.148
TDS	.810	.240	.474	.079
TS	.368	.106	.887	.001
Turbidity	.440	.510	.531	-.018
DO	-.371	-.491	-.595	-.058
BOD	.307	.739	.352	.111
Chloride	.787	.384	-.043	.185
T.Hardness	.894	.097	.233	.015
Ca	.916	.014	.177	.006
Mg	.925	.136	.145	.100
PO4	.378	.344	-.228	.623
F.Coliforms	.099	.659	.104	-.379
NO3	.097	.835	-.074	.125
NH3	.113	.903	.086	.100
Temp	.045	-.094	.117	.840
Fe	.646	.315	.293	.257
COD	.307	.670	.517	-.090

Extraction Method: Principal Component Analysis.
Rotation Method: Varimax with Kaiser Normalization.
a. Rotation converged in 6 iterations.

Appendix 3 Descriptive Spatial variations in physical, chemical and biological parameters

		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
						Lower Bound	Upper Bound		
pH	1.00	6	5.7500	.39875	.16279	5.3315	6.1685	5.40	6.30
	2.00	6	6.2867	.12754	.05207	6.1528	6.4205	6.12	6.50
	3.00	6	6.5550	.31961	.13048	6.2196	6.8904	6.08	7.00
	4.00	6	5.9950	.34801	.14207	5.6298	6.3602	5.70	6.42
	5.00	6	6.1633	.05715	.02333	6.1034	6.2233	6.08	6.20
	6.00	6	6.3633	.28925	.11809	6.0598	6.6669	5.98	6.55
	7.00	6	6.1067	.49407	.20170	5.5882	6.6252	5.60	7.00
	Total	42	6.1743	.38600	.05956	6.0540	6.2946	5.40	7.00
TSS	1.00	6	63.9633	15.04394	6.14166	48.1757	79.7510	40.00	81.00
	2.00	6	81.6667	56.15930	22.92694	22.7311	140.6022	6.00	170.00
	3.00	6	894.1667	1248.09109	509.53105	-415.6246	2203.9579	110.00	3012.00
	4.00	6	71.8333	29.02700	11.85022	41.3714	102.2953	40.00	120.00
	5.00	6	92.0000	35.91100	14.66060	54.3137	129.6863	46.00	150.00
	6.00	6	109.3333	98.38225	40.16438	6.0875	212.5792	30.00	250.00
	7.00	6	74.3333	53.35791	21.78328	18.3376	130.3290	30.00	180.00
	Total	42	198.1852	524.46458	80.92664	34.7506	361.6199	6.00	3012.00
EC	1.00	6	21.5000	14.58424	5.95399	6.1948	36.8052	7.00	45.00
	2.00	6	37.3333	12.81666	5.23238	23.8831	50.7836	19.00	48.00
	3.00	6	1065.0000	471.01932	192.29283	570.6955	1559.3045	135.00	1368.00
	4.00	6	66.5000	14.55679	5.94278	51.2236	81.7764	50.00	87.00
	5.00	6	302.0000	33.23251	13.56712	267.1246	336.8754	264.00	350.00
	6.00	6	428.6667	112.83735	46.06565	310.2511	547.0822	260.00	542.00
	7.00	6	401.6667	164.61065	67.20202	228.9184	574.4150	220.00	610.00
	Total	42	331.8095	387.41169	59.77892	211.0835	452.5355	7.00	1368.00
TDS	1.00	6	12.5283	8.88847	3.62870	3.2005	21.8562	4.00	28.00
	2.00	6	23.0000	7.18331	2.93258	15.4616	30.5384	13.00	30.00
	3.00	6	778.1667	47.66725	19.46007	728.1430	828.1904	710.00	830.00
	4.00	6	38.6667	10.01332	4.08792	28.1583	49.1750	27.00	52.00
	5.00	6	177.8333	26.33945	10.75304	150.1918	205.4749	152.00	220.00
	6.00	6	285.0000	69.55861	28.39718	212.0027	357.9973	230.00	405.00
	7.00	6	222.6667	70.97511	28.97547	148.1829	297.1505	130.00	300.00
	Total	42	219.6945	254.67014	39.29646	140.3337	299.0553	4.00	830.00
TS	1.00	6	76.5467	16.63157	6.78981	59.0929	94.0004	56.00	100.00
	2.00	6	115.5000	44.32945	18.09742	68.9791	162.0209	73.00	200.00
	3.00	6	1680.6667	1207.49520	492.95785	413.4782	2947.8552	850.00	3722.00
	4.00	6	110.5000	31.53886	12.87569	77.4020	143.5980	70.00	157.00
	5.00	6	269.8333	20.22292	8.25597	248.6107	291.0560	242.00	302.00
	6.00	6	401.0000	156.77372	64.00260	236.4761	565.5239	270.00	625.00
	7.00	6	270.0000	74.69672	30.49481	191.6106	348.3894	160.00	357.00
	Total	42	417.7210	682.64180	105.33392	204.9948	630.4471	56.00	3722.00
Turbidity	1.00	6	6.7333	2.15747	.88078	4.4692	8.9975	4.50	9.00
	2.00	6	11.2833	5.18861	2.11824	5.8382	16.7284	6.00	21.00
	3.00	6	43.2000	14.04635	5.73440	28.4593	57.9407	15.00	53.00
	4.00	6	16.5000	9.54463	3.89658	6.4835	26.5165	9.00	35.00
	5.00	6	22.1667	12.67149	5.17311	8.8688	35.4646	13.00	45.00
	6.00	6	17.2500	9.20733	3.75888	7.5875	26.9125	8.50	35.00
	7.00	6	14.7667	11.62990	4.74789	2.5618	26.9715	7.00	38.00
	Total	42	18.8429	14.39795	2.22165	14.3561	23.3296	4.50	53.00
DO	1.00	6	8.0667	.15055	.06146	7.9087	8.2247	7.90	8.30
	2.00	6	7.0333	.97707	.39889	6.0080	8.0587	5.80	7.90
	3.00	6	4.2833	1.18223	.48264	3.0427	5.5240	3.00	6.00
	4.00	6	7.4833	.63061	.25744	6.8216	8.1451	6.70	8.10
	5.00	6	5.2333	.39328	.16055	4.8206	5.6461	4.70	5.70
	6.00	6	6.8500	.61887	.25265	6.2005	7.4995	6.10	7.50
	7.00	6	7.1000	.22804	.09309	6.8607	7.3393	6.70	7.40
	Total	42	6.5786	1.40375	.21660	6.1411	7.0160	3.00	8.30
BOD	1.00	6	1.0333	.26613	.10865	.7540	1.3126	.70	1.52
	2.00	6	1.4883	.43176	.17627	1.0352	1.9414	1.20	2.23

	3.00	6	2.6750	.41201	.16820	2.2426	3.1074	2.30	3.30
	4.00	6	1.7250	.31898	.13022	1.3902	2.0598	1.15	2.00
	5.00	6	2.4083	.32927	.13442	2.0628	2.7539	2.00	2.85
	6.00	6	1.6833	.53448	.21820	1.1224	2.2442	1.20	2.70
	7.00	6	1.3467	.57434	.23447	.7439	1.9494	.98	2.50
	Total	42	1.7657	.67148	.10361	1.5565	1.9750	.70	3.30
Chloride	1.00	6	5.3333	3.14113	1.28236	2.0369	8.6297	3.00	11.00
	2.00	6	11.7500	3.15832	1.28938	8.4355	15.0645	8.50	16.00
	3.00	6	78.0000	51.50922	21.02855	23.9444	132.0556	10.00	121.00
	4.00	6	16.6667	2.50333	1.02198	14.0396	19.2938	13.00	20.00
	5.00	6	51.8333	6.79461	2.77389	44.7028	58.9638	40.00	60.00
	6.00	6	82.0000	5.25357	2.14476	76.4867	87.5133	75.00	90.00
	7.00	6	47.7500	24.04527	9.81644	22.5160	72.9840	15.00	87.00
	Total	42	41.9048	35.68771	5.50673	30.7837	53.0258	3.00	121.00
T.Hardness	1.00	6	11.8333	6.16787	2.51802	5.3605	18.3061	4.20	17.00
	2.00	6	31.0000	1.54919	.63246	29.3742	32.6258	30.00	33.00
	3.00	6	182.6667	18.40290	7.51295	163.3540	201.9793	160.00	200.00
	4.00	6	29.0333	5.38207	2.19722	23.3852	34.6815	21.00	37.00
	5.00	6	31.2167	2.20945	.90200	28.8980	33.5353	27.30	34.00
	6.00	6	133.9500	46.31552	18.90823	85.3448	182.5552	73.90	170.00
	7.00	6	91.8333	22.30172	9.10464	68.4291	115.2376	65.00	130.00
	Total	42	73.0762	63.81393	9.84670	53.1904	92.9620	4.20	200.00
Ca	1.00	6	3.6667	.51640	.21082	3.1247	4.2086	3.00	4.00
	2.00	6	6.0000	.89443	.36515	5.0614	6.9386	5.00	7.00
	3.00	6	34.0000	4.14729	1.69312	29.6477	38.3523	29.00	39.00
	4.00	6	6.3333	2.50333	1.02198	3.7062	8.9604	4.00	10.00
	5.00	6	6.6667	1.21106	.49441	5.3957	7.9376	5.00	8.00
	6.00	6	26.0000	5.44059	2.22111	20.2905	31.7095	21.00	35.00
	7.00	6	23.3500	7.94324	3.24281	15.0141	31.6859	14.10	36.00
	Total	42	15.1452	12.12428	1.87082	11.3670	18.9234	3.00	39.00
Mg	1.00	6	.1133	.01506	.00615	.0975	.1291	.09	.13
	2.00	6	.1467	.00816	.00333	.1381	.1552	.13	.15
	3.00	6	.3767	.07033	.02871	.3029	.4505	.25	.46
	4.00	6	.1400	.01789	.00730	.1212	.1588	.12	.17
	5.00	6	.1883	.01602	.00654	.1715	.2051	.18	.22
	6.00	6	.3100	.02449	.01000	.2843	.3357	.29	.35
	7.00	6	.2633	.09501	.03879	.1636	.3630	.15	.38
	Total	42	.2198	.10233	.01579	.1879	.2516	.09	.46
PO4	1.00	6	1.0400	.67103	.27395	.3358	1.7442	.38	2.00
	2.00	6	1.6733	.96579	.39428	.6598	2.6869	.30	2.50
	3.00	6	2.5233	1.20028	.49001	1.2637	3.7829	.27	3.83
	4.00	6	1.7217	1.17087	.47801	.4929	2.9504	.17	2.78
	5.00	6	2.7150	1.32766	.54201	1.3217	4.1083	.24	4.00
	6.00	6	2.7033	1.21600	.49643	1.4272	3.9795	.25	3.42
	7.00	6	2.2133	.99218	.40506	1.1721	3.2546	.22	2.78
	Total	42	2.0843	1.17276	.18096	1.7188	2.4497	.17	4.00
F.Coliforms	1.00	6	1.1467	.43793	.17879	.6871	1.6063	.70	1.70
	2.00	6	2.2833	.22286	.09098	2.0495	2.5172	2.00	2.60
	3.00	6	2.5167	.65243	.26635	1.8320	3.2014	1.70	3.30
	4.00	6	2.3667	.30111	.12293	2.0507	2.6827	2.10	2.70
	5.00	6	2.0667	.17512	.07149	1.8829	2.2504	1.90	2.40
	6.00	6	1.6000	.32249	.13166	1.2616	1.9384	1.30	2.00
	7.00	6	1.4000	.42895	.17512	.9498	1.8502	1.00	1.90
	Total	42	1.9114	.61403	.09475	1.7201	2.1028	.70	3.30
NO3	1.00	6	5.4800	1.01485	.41431	4.4150	6.5450	4.50	7.20
	2.00	6	11.7633	2.76114	1.12723	8.8657	14.6610	8.20	14.73
	3.00	6	15.3083	2.83194	1.15613	12.3364	18.2803	11.10	19.10
	4.00	6	17.4583	3.01950	1.23271	14.2896	20.6271	14.92	22.00
	5.00	6	22.5650	1.57161	.64161	20.9157	24.2143	21.05	25.20
	6.00	6	17.6450	5.56689	2.27268	11.8029	23.4871	12.36	28.10
	7.00	6	13.1667	4.98665	2.03579	7.9335	18.3998	8.50	20.00
	Total	42	14.7695	5.98239	.92310	12.9053	16.6338	4.50	28.10
NH3	1.00	6	6.2133	.70659	.28846	5.4718	6.9549	5.13	7.00
	2.00	6	11.2067	2.81925	1.15095	8.2480	14.1653	8.20	15.23
	3.00	6	18.0117	2.52215	1.02966	15.3648	20.6585	14.62	22.45
	4.00	6	17.2000	2.37339	.96893	14.7093	19.6907	15.38	20.40
	5.00	6	23.5150	1.32972	.54286	22.1195	24.9105	22.20	25.50
	6.00	6	16.3783	1.98463	.81022	14.2956	18.4611	13.74	18.20

	7.00	6	9.8000	1.42127	.58023	8.3085	11.2915	7.10	11.00
	Total	42	14.6179	5.79405	.89404	12.8123	16.4234	5.13	25.50
Temp	1.00	6	27.8500	.98742	.40311	26.8138	28.8862	26.00	29.00
	2.00	6	27.1667	.93095	.38006	26.1897	28.1436	26.00	28.50
	3.00	6	27.6500	.48477	.19791	27.1413	28.1587	27.00	28.40
	4.00	6	27.0000	1.09545	.44721	25.8504	28.1496	26.00	29.00
	5.00	6	27.9167	.80104	.32702	27.0760	28.7573	26.50	29.00
	6.00	6	28.1667	.60553	.24721	27.5312	28.8021	27.00	28.50
	7.00	6	27.9667	.89815	.36667	27.0241	28.9092	27.00	29.00
	Total	42	27.6738	.88678	.13683	27.3975	27.9501	26.00	29.00
Fe	1.00	6	.4250	.19285	.07873	.2226	.6274	.25	.78
	2.00	6	1.4200	.34704	.14168	1.0558	1.7842	1.10	2.07
	3.00	6	4.1383	1.03993	.42455	3.0470	5.2297	3.20	5.80
	4.00	6	.6133	.48644	.19859	.1028	1.1238	.15	1.30
	5.00	6	2.3933	.79633	.32510	1.5576	3.2290	1.50	3.50
	6.00	6	2.3733	1.41206	.57647	.8915	3.8552	1.10	4.00
	7.00	6	2.1833	1.53156	.62526	.5761	3.7906	.70	4.30
	Total	42	1.9352	1.48086	.22850	1.4738	2.3967	.15	5.80
COD	1.00	6	1.9283	.43673	.17830	1.4700	2.3867	1.40	2.60
	2.00	6	2.8217	.72389	.29553	2.0620	3.5813	2.03	3.90
	3.00	6	4.8800	.57619	.23523	4.2753	5.4847	4.00	5.60
	4.00	6	2.3750	.41923	.17115	1.9350	2.8150	2.00	3.00
	5.00	6	4.3000	.58652	.23944	3.6845	4.9155	3.40	5.00
	6.00	6	2.5450	.42018	.17154	2.1040	2.9860	2.10	3.07
	7.00	6	2.3883	.45915	.18745	1.9065	2.8702	1.95	3.10
	Total	42	3.0340	1.14742	.17705	2.6765	3.3916	1.40	5.60

Appendix 4a: Test of Homogeneity in Mean Variance of the physical, chemical and biological Parameters (P< 0.05) across the sampling Locations

		Sum of Squares	Df	Mean Square	F	Sig.
pH	Between Groups	2.461	6	.410	3.935	.004
	Within Groups	3.648	35	.104		
	Total	6.109	41			
TSS	Between Groups	3398737.860	6	566456.310	2.516	.039
	Within Groups	7878849.267	35	225109.979		
	Total	11277587.127	41			
EC	Between Groups	4836693.476	6	806115.579	21.424	.000
	Within Groups	1316907.000	35	37625.914		
	Total	6153600.476	41			
TDS	Between Groups	2593768.702	6	432294.784	231.480	.000
	Within Groups	65363.357	35	1867.524		
	Total	2659132.060	41			
TS	Between Groups	11646754.836	6	1941125.806	9.108	.000
	Within Groups	7459238.212	35	213121.092		
	Total	19105993.048	41			
Turbidity	Between Groups	4996.480	6	832.747	8.321	.000
	Within Groups	3502.863	35	100.082		
	Total	8499.343	41			
DO	Between Groups	63.979	6	10.663	22.200	.000
	Within Groups	16.812	35	.480		
	Total	80.791	41			
BOD	Between Groups	12.223	6	2.037	11.383	.000
	Within Groups	6.263	35	.179		
	Total	18.486	41			
Chloride	Between Groups	35561.869	6	5926.978	12.454	.000
	Within Groups	16656.250	35	475.893		
	Total	52218.119	41			
T.Hardness	Between Groups	151683.660	6	25280.610	57.918	.000
	Within Groups	15277.257	35	436.493		
	Total	166960.916	41			
Ca	Between Groups	5433.449	6	905.575	53.406	.000
	Within Groups	593.475	35	16.956		
	Total	6026.924	41			
Mg	Between Groups	.352	6	.059	26.598	.000
	Within Groups	.077	35	.002		
	Total	.429	41			
PO4	Between Groups	14.288	6	2.381	1.980	.095
	Within Groups	42.102	35	1.203		
	Total	56.390	41			
F.Coliforms	Between Groups	10.076	6	1.679	10.921	.000
	Within Groups	5.382	35	.154		
	Total	15.459	41			
NO3	Between Groups	1046.756	6	174.459	14.518	.000
	Within Groups	420.590	35	12.017		
	Total	1467.346	41			
NH3	Between Groups	1235.567	6	205.928	51.174	.000
	Within Groups	140.842	35	4.024		
	Total	1376.409	41			
Temp	Between Groups	6.783	6	1.130	1.554	.190
	Within Groups	25.458	35	.727		
	Total	32.241	41			
Fe	Between Groups	57.664	6	9.611	10.431	.000
	Within Groups	32.247	35	.921		
	Total	89.911	41			
COD	Between Groups	44.210	6	7.368	26.398	.000
	Within Groups	9.769	35	.279		
	Total	53.979	41			

Appendix 4b: Mean Separation in the Physical Chemical and Biological Parameters using Duncan[a] Multiple Range Test ($P < 0.05$)

		Subset for alpha = 0.05	
Location	N	1	2
1.00	6	1.0400	
2.00	6	1.6733	1.6733
4.00	6	1.7217	1.7217
7.00	6	2.2133	2.2133
3.00	6		2.5233
6.00	6		2.7033
5.00	6		2.7150
Sig.		.098	.158

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 6.000.