PHYSIOCHEMICAL CHARACTERIZATION OF WATER SAMPLES FROM UDU RIVER, DELTA STATE

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FACULTY OF PHYSICAL SCIENCES

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CERTIFICATION

This is to certify that this project work was carried out by OSHEMUGHEN ESTHER EMUROBOHWO, Matriculation Number PG/PSC1817999 in the department of chemistry, faculty of physical sciences, University of Benin, Benin city, Nigeria under my supervisor.

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DEDICATION

This work is dedicated to my heavenly father God Almighty who has always been my source of joy and my highly esteem family for their care, prayers and support during the period of study.

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TABLE OF CONTENTS

LISTS OF TABLES

LIST OF PLATES

ABSTRACT

Water is one of the elements and the necessity that most major global to the daily life. The physico-chemical properties of the upstream, midstream and downstream of Udu River in Delta State, Nigeria were investigated in this work. The properties were compared to the World Health Organization (WHO). The physico-chemical properties considered and their average values are pH (7.06 ± 1.01), temperature (31.33 ± 0.58℃), turbidity (10.22±1.10 NTU), alkalinity (8.77±0.68 mg/L), electrical conductivity (140.03±62.50 μS/cm), dissolved oxygen (2.67±0.25 mg/L), biochemical oxygen demand (1.65±0.35 mg/L), total dissolved solids (79.82±35.61 mg/L), total suspended solids (0.87±0.56 mg/L), nitrate (5.19±0.51 mg/L), chloride (6.67±2.96mg/L), bicarbonate (2.51±0.27 mg/L), sulphate (1.13±0.32 mg/L), chemical oxygen demand (16.00±5.29 mg/L), phosphate (8.06±4.34 mg/L), total hardness (15.61±2.13 mg/L), iron (0.77±0.12 mg/L), zinc (0.01±0.01 mg/L), Chromium (0.18±0.07 mg/L), manganese (0.07±0.06 mg/L), copper (0.03±0.00), sodium (0.70±0.00 mg/L) and potassium (0.82±0.00 mg/L). The values of the physico-chemical properties in comparison with the WHO standards of portable water indicate that Udu River needs to be constantly monitored in order to preserve its quality for safe consumption.

CHAPTER ONE

INTRODUCTION AND LITERATURE REVIEW

INTRODUCTION

1.1.1 Background of study

Our survival on Earth depends on three basic resources – water, air and soil, nature's three valuable gifts to mankind. Among which water is the most important component as it forms the basic medium for origin of life. Water is one of the elements and the necessity that most major global to the daily life. Approximately 71% of the surface of the earth is covered by water. From that number, only 2.5% is the water surface such as the rivers and lakes. Almost every economic activity for example agriculture, fisheries, mining district, transport and tourism need water as their water resources (David *et al.*, 2016). Most important use of water to human is for drinking, washing, and bathing. Moreover, the water demand is not only for human beings but also for aquatic life that use water or river as their habitats and this aquatic life eventually become a source of protein for humans (Aweng, *et al.*,2011).

Serious degradation of the quality of surface water constantly arises from the increasing human population, uncontrolled urbanization and inadequate sanitation infrastructure (Mulu *et al*., 2013). As a result, many rivers and streams are heavily polluted as they flow through major cities and towns (Wassie, 2008). Pollutants can enter surface waters from point sources such as single source industrial discharges and waste water treatment plants. However, most pollutants result from non-point source pollution activities including runoff from agricultural lands, urban areas, construction and industrial sites, and failed septic tanks (Yohannes and Elias, 2017).

Urban rivers can be referred to as novel or hybrid ecosystems, and as such have experienced substantial biotic and abiotic changes that render them problematic to return to their historic system states (Robert, 2004). Cultural requirements and natural properties converge at riversides in urban areas. Knowledge of the interrelations between urban conditions and the state of waters in urban areas as well as instruments and techniques for their management is needed for the sustainable development of urban rivers. This is evidently true in highly industrial nations where much of the population live in cities and towns. Impacts on waters of sewage discharge, the high dynamics of storm water runoff, limited groundwater recharge, fragmentation, canalization, culverting and others cause serious effects on aquatic organisms and the whole water ecosystems. In return they lead to manifold influences on urban life e.g. decrease of water supply, risk to public health due to chemical and bacteriological water pollution, threats by flooding or loss of quality of urban open spaces by reduced aesthetic value, etc. (Schanze *et al.*, 2004).

The intensive exploitation of ecosystem services and urbanization severely impact rivers (Walsh *et al*., 2005) resulting in ecological degradations which leads to decrease of the socio-ecological functions of the rivers (Wantzen *et al*., 2016). In recent years, river restoration was recognized as essential to reestablish socio-ecological functions of the rivers (Jørgensen, 2015).

The management of water resources is an issue particularly sensitive to the question of *scale*. The mismatch between administrative limits and hydrological boundaries can lead to local actors (e.g. municipalities) placing their own interests ahead when designing and implementing water resources management policies and strategies, rather than integrating the needs of the river basin and aquifers (OECD, 2015).

The Udu River which spans 48 km^2 is a tributary of the Warri River in Warri South Local Government Area of Delta State, Nigeria. The river flows across a large uninhabited stretch of land. Companies involved in one form of marine activity or the other basically occupy the inhabited expanse of land. This rapid industrialization around Udu River environs has led to alterations in the water quality of the river thus causing great concern for the immediate users of the river water (Aluyi *et al*., 2006).

1.1.1 Statement of problem

All over the world, human pressures on rivers are increasing thereby threatening the water security and the aquatic ecosystem health. The problem is particularly acute in urbanized regions because the cities, due to their specific features, are a major factor influencing the water cycle, in general, and the river systems, in particular. Urbanization has caused important changes in watershed drainage system and hydrology: the rivers crossing city areas have been exploited for water supply and have been regulated, channelized, dammed, diverted, and buried (Ceola *et al*., 2015). As natural receptacles for urban wastewaters, the rivers undergo continuous qualitative alterations, which affect the related ecosystem's health or their ecological integrity (Oliveira and Cortes, 2006). In urbanized areas, the ecosystem, functions and services of rivers are affected by the modification of river flow regime, water chemistry and quality.

Worldwide waterborne diseases are the cause of death and suffering of millions of people, especially, children in developing countries (Schafera *et al*., 2009). River water is largely the major source of water for the people who live around the river environs. The river water is contaminated as a result of urbanization and industrialization thereby leading to poor quality of the water for those who depend on the river water for survival and also for aquatic lives. Effluents of large and small scale industries, agricultural runoff and city sewage have been marked as sources of pollution of river water during various researches (Dwivedi, 2017). These sources affect the physico-chemical and biological properties of water thereby degrading the quality of the river water making it unfit for consumption. The physical properties of water include colour, odour, taste, turbidity, etc. These properties can be measured with or without the use of specialized equipment as they can be rated by sight. The chemical properties include pH, electrical conductivity, trace and heavy metals, total suspended soils, chemical oxygen demand (COD), biochemical oxygen demand (BOD), dissolved oxygen (DO), etc. The chemical properties of water are very largely important as they determine the chemistry of water or quantify the amount of contamination experienced by river water.

1.1.2 Aim and objectives

The aim of the study is to investigate the physico-chemical properties of Udu River water. The specific objectives include;

i. To obtain river water from 3 main streams (upstream, middle stream and downstream) of Udu River.
ii. To characterize and compare the physico-chemical properties of the water obtained from the different streams.

1.1.3 Scope of study

The study is limited to obtaining water from Udu River in Delta State. The study area lies within 5.51524 N 5^{O}30’54.87” and 5.78648 E 5^{O} 47 ‘ 11.328”. It is situated in the southern part of the Niger delta. Its geomorphologic features consist mainly of fresh water swamps, mangrove swamps, beaches and estuaries. The water will be characterized in terms of physico-chemical properties using standar procedures. The physicochemical properties of the water will be compared to the world health organization standard (WHO) of the portable water to ascertain the quality of the river water for consumption.

1.1.4 Relevance of study

Continual improvement in the quality of water for purposes of drinking, domestic consumption, personal hygiene and certain medical situations is among the top challenges of the world (Asadullah and Seema, 2013).The provision of high quality drinking water is one the most important connote for improving human health of a community by preventing the spread of water born disease (Benjamin and Brown, 2003). Drinking water plays an important role in taking essential minerals and elevated level of nonessential elements can cause morphological abnormalities, reduce growth, increase mortality and mutagenic effects (Asaolu, 2002; Adeyeye, 2000; Asadullah and Seema, 2013).

This study will provide information and data on:

i. The physico-chemical properties of properties of Udu River water.

ii. The comparison of Udu River water with some standards of portable water.

LITERATURE REVIEW

1.2.1 Water

Although often perceived to be pretty ordinary, water is the most remarkable substance. We wash in it, fish in it, swim in it, drink it and cook with it, although probably not all at the same time. We are about two-thirds water and require water to live. Life as we know it could not have evolved without water and dies without it. Droughts cause famines and floods cause death and disease. Because of its clear importance, water is the most studied material on Earth. It comes as a surprise, therefore, to find that it is so poorly understood, not only by peoples in general, but also by scientists working with it every day (Chaplin, 2001).

Water is an excellent solvent due to its polarity, high dielectric constant and small size, particularly for polar and ionic compounds and salts. Indeed, its solvation properties are so impressive that it is difficult to obtain really pure water. Water ionizes and allows easy proton exchange between molecules, so contributing to the richness of the ionic interactions in biology. The structuring of water around molecules allows them to sense and be sensed at a distance. The unique hydration properties of water towards biological macromolecules (particularly proteins and nucleic acids) to a large extent determine their three-dimensional structures, and hence their functions, in solution (Chaplin, 2001).

1.2.1.1 Properties of water

Water quality parameters which determine the suitability of water for a particular use are measured/monitored on a regular basis. These properties include measurement of physical (e.g., turbidity), chemical (cations and anions, organic pollutants), and biological (microbial).

1.2.1.1.1 Physical properties of water

The physical characteristics of water (colour, odour, temperature, taste, etc.) are determined by senses of touch, sight, smell and taste. For example, temperature by touch, colour, floating debris, turbidity and suspended solids by sight, and taste and odor by smell.

Color: Color in water is primarily a concern of water quality for aesthetic reason. Colored water give the appearance of being unfit to drink, even though the water may be perfectly safe for public use. Color of the water body can indicate the presence of organic substances, such as algae or humic compounds. In recent times, color has been used as a quantitative assessment of the presence of potentially hazardous or toxic organic materials in water. Color is vital as most water users, be it domestic or industrial, usually prefer colorless water. Determination of color can help in estimating the costs related to discoloration of the water. Color is reduced or removed from water through the use of coagulation, settling and filtration techniques.

Taste and Odor: Taste and odor are human perceptions of water quality. Human perception of taste includes sour (hydrochloric acid), salty (sodium chloride), sweet (sucrose) and bitter (caffeine). Relatively simple compounds produce sour and salty tastes. However, sweet and bitter tastes are produced by more complex organic compounds. Odor is produced by gas production due to the decomposition of organic matter or by substances added to the wastewater. Odor is measured by special instruments such as the Portable H_2S meter which is used for measuring the concentration of hydrogen sulfide. Some examples of odor producing substances are shown in Table 1.1.

Table 1.1: Odor producing substances.

Compound	**Chemical Formula**	**Odor Quality**
Amines	CH_3NH_2, $(CH_3)\ _3H$	Fishy
Diamines	$NH_2(CH_2)_4NH_2$, $(CH_2)_5NH_2H_{25}$	Rotten eggs
Mercaptans (E. g, methy1 and ethy1)	CH_3SH, $CH_3(CH_2)$ SH	Decayed cabbage
Organic sulfides	Rotten cabbage	
Skatole	C_9H_9N	Faeces

Temperature: Temperature is a measure of the average energy (kinetic) of water molecules. It is measured on a linear scale of degrees Celsius or degrees Fahrenheit. Temperature is a basic water quality variable. It determines the suitability of water for various forms of aquatic life. Depending on the geographic location the mean annual temperature varies in the range of 10 to 21℃ with an average of 16℃. Temperature affects a number of water quality parameters such as dissolved oxygen which is a chemical characteristic. Oxygen solubility is less in warm water than cold water. Temperature also affects the aquatic life, for example, trout and salmon require cool temperature for survival and reproduction whereas bass and sunfish do better at warmer temperatures. Temperature in water bodies generally follows mean daily air temperature. It influences: amount of oxygen that can be dissolved in water, rate of photosynthesis by algae and other aquatic plants, metabolic rates of organisms, sensitivity of organisms to toxic wastes, parasites and diseases, and timing of reproduction, migration, and aestivation of aquatic organisms.

Turbidity: Turbidity is a measure of the light-transmitting properties of water and is comprised of suspended and colloidal material. It is important for health and aesthetic reasons. Transparency of natural water bodies is affected by human activity, decaying plant matter, algal blooms, suspended sediments, and plant nutrients. Turbidity provides an inexpensive estimate of total suspended solids (TSS) concentration. It has little meaning except in relatively clear waters but is useful in defining drinking-water quality in water treatment.

Solids: Total dissolved solids (TDS) is the term used to describe the inorganic salts and small amounts of organic matter present in solution in water. The principal constituents are usually calcium, magnesium, sodium, and potassium cations and carbonate, hydrogen carbonate, chloride, sulfate, and nitrate anions. The total solids content of water is defined as the residue remaining after evaporation of the water and drying the residue to a constant weight at 103°C to 105°C.

Solids are classified as settle-able solids, suspended solids and filterable solids. Settle-able solids (silt and heavy organic solids) are the one that settle under the influence of gravity. Suspended solids and filterable solids are classified based on particle size and the retention of suspended solids on standard glass-fibre filters. The significance of suspended solids in water is great, on a number of grounds. The solids may in fact consist of algal growths leading to severe eutrophic conditions in any water body. They will reduce light penetration in surface waters and interfere with aquatic plant life. Deposition of these on the bed of rivers and lakes may give rise to septic and offensive conditions; and they may indicate the presence of unsatisfactory sewage effluent discharges.

1.2.1.1.2 Chemical properties of water

The health concerns associated with chemical constituents of drinking-water arise mainly from the ability of chemical constituents to cause adverse health effects after extended exposure time. There are few chemical constituents of water that can lead to health problems resulting from even a single exposure. An appreciable number of serious health concerns may occur as a result of the chemical contamination of drinking-water. The major chemical properties of the water are discussed below.

Electrical Conductivity: The conductivity of water is an expression of its ability to conduct an electric current as a result of breakdown of dissolved solids into positively and negatively charged ions. The major positively charged ions are sodium (Na^{+}), calcium (Ca^{2+}), potassium (K^{+}) and magnesium (Mg^{2+}). The major negatively charged ions in water include chloride (Cl^{-}), sulfate (SO_4^{2-}), carbonate (CO_3^{2-}), and bicarbonate (HCO_3^{-}). Nitrates (NO_3^{2-}) and phosphates (PO_4^{3-}) are minor contributors to conductivity, although they are very important biologically. Conductivity in itself is a property of little interest but it is an invaluable indicator of the range of hardness, alkalinity and the dissolved solids content of the water. Conductivity will vary with water source: ground water, water drained from agricultural fields, municipal waste water, rainfall. Therefore, conductivity can indicate groundwater seepage or a sewage leak.

Salinity: Salinity is a measure of the amount of salts in the water. Because dissolved ions increase salinity as well as conductivity, the two measures are related. The salts in sea water are primarily sodium chloride (NaCl). However, other saline waters owe their high salinity to a combination of dissolved ions including sodium, chloride, carbonate and sulfate. Salts and other substances affect the quality of water used for irrigation or drinking. They also have a critical influence on aquatic biota, and every kind of organism has a typical salinity range that it can tolerate. The presence of a high salt content may make water unsuitable for domestic, agricultural or industrial use. Moreover, the ionic composition of the water can be critical. For example, Cladocerans (water fleas) are far more sensitive to potassium chloride than sodium chloride at the same concentration.

Alkalinity: The alkalinity of natural water is generally due to the presence of bicarbonates formed in reactions in the soils through which the water percolates. It is a measure of the capacity of the water to neutralize acids and it reflects its *buffer capacity*. It may also be attributed to the presence of carbonates and hydroxides. Alkalinity is important for fish and aquatic life because it protects or buffers against rapid pH changes. Living organisms, especially aquatic life, function best in a pH range of 6.0 to 9.0. Higher alkalinity levels in surface waters can buffer the acid rain and other acid wastes. This inhibits harmful pH changes for the protection of aquatic life. Alkalinity in streams is influenced by rocks and soils, salts, certain plant activities, and certain industrial wastewater discharges. Low nutrient (oligotrophic) lakes tend to have lower alkalinity while high nutrient (eutrophic) lakes have a tendency of higher alkalinity.

pH: pH is a measure of how acidic or basic (alkaline) the water is. It is defined as the negative log of the hydrogen ion concentration. The pH scale is logarithmic and ranges from 0 (very acidic) to 14 (very alkaline). For each whole number increase (i.e. 1 to 2) the hydrogen ion concentration decreases tenfold and the water becomes less acidic. The range of natural pH in fresh waters extends from around 4.5, for acid, peaty upland waters, to over 10.0 in waters where there is intense photosynthetic activity by algae. However, the most frequently encountered range is 6.5-8.0. The range of pH apt for fisheries is considered to be 5.0-9.0, though 6.5-8.5 is preferable. At the extreme ends of the pH scale, (2 or 13) physical damage to gills, exoskeleton and fins occurs. Changes in pH may alter the concentrations of other substances in water to a more toxic form. Ammonia toxicity, chlorine disinfection efficiency, and metal solubility are all subjective to changes in pH value.

Hardness: Hardness is a natural characteristic of water which can enhance its palatability and consumer acceptability for drinking purposes. The hardness of water is due to the presence of calcium and magnesium minerals that are naturally present in the water. The common signs of a hard water supply are poor lathering of soaps and scum. The hardness is made up of two parts: temporary (carbonate) and permanent (non-carbonate) hardness. The temporary hardness of water can easily be removed by boiling the water. The following is a measure of hardness (expressed in mg/l as $CaCO_3$):

Soft: 0 - 100 mg/l as $CaCO_3$

Moderate: 100 - 200 mg/l as $CaCO_3$

Hard: 200 - 300 mg/l as $CaCO_3$

Very hard: 300 - 500 mg/l as $CaCO_3$

Extremely hard: 500 - 1,000 mg/l as $CaCO_3$

Major ions in Water: There are various kinds of trace ions in water supply that influence chemical nature and account for the bulk of natural water mineral content. Most of the dissolved, inorganic chemicals in freshwater occur as ions. The main ionic species of natural water are given in Table 1.2. These ions come in water body from atmospheric deposition, rock weathering, runoff etc.

Table 1.2: Major ions in water

Major Cations	**Major Anions**
Sodium (Na^+)	Chloride (Cl^-)
Potassium (K^+)	Sulphate (SO_4^{2-})
Calcium (Ca^{2+})	Carbonates/Bicrabonates (CO_3^{2-}/HCO_3^-)
Magnesium (Mg^{2+})	Nitrates (NO_3^-)

Nitrates: Nitrates even at low concentrations can cause health problem to infants of six months of age or less and pregnant women by affecting the oxygen carrying capacity of the blood.

Heavy Metals: Heavy metal refers to any metallic chemical element that has a relatively high density and is toxic or poisonous at low concentration. The some major examples of heavy metals are mercury (Hg), cadmium (Cd), arsenic (As), chromium (Cr), nickel (Ni), copper (Cu), cobalt (Co) and lead (Pb) etc. These are the natural components of geological environment. They enter the human body via food, drinking water and air to small extent. Some heavy metals (e.g. copper, selenium, zinc) are necessary to keep up the metabolism of the human body as trace elements. However, they can be poisonous at higher concentrations leading to various serious diseases.

Dissolved Oxygen: Dissolved oxygen is the amount of gaseous oxygen (O_2) dissolved in an aqueous solution. It gets into water by diffusion from the surrounding air, by aeration (rapid movement), and as a waste product of photosynthesis. The oxygen in dissolved form is needed by most aquatic organisms to survive and grow. Organisms such as trout and stoneflies require high amount of DO while some others like catfish, worms and dragonflies can survive in somewhat lower amount. The absence of enough amount of oxygen in water can lead to death of adults and juveniles, reduction in growth, failure of eggs/larvae to survive, change of species present in a given water body. The hypoxic condition in water body (DO< 3mg/L) causes reduced cell functioning and disrupts circulatory fluid balance in aquatic system, eventually leading to death.

Biochemical Oxygen Demand (BOD): Biochemical oxygen demand the amount of dissolved oxygen required by aerobic biological organisms to degrade the organic material present in a water body at certain temperature over a specific time period. It widely used as an indication of the organic quality of water and thus representing the pollution load. It is most commonly expressed in milligrams of oxygen consumed per liter of sample during 5 days (BOD_5) of incubation at 20°C. When organic matter decomposes, microorganisms (such as bacteria and fungi) feed upon this decaying material and eventually the matter becomes oxidized. The harder the microorganisms work, the more oxygen will be used up giving a high measure of BOD, leaving less oxygen for other life in the water.

Chemical Oxygen Demand: Chemical Oxygen Demand (COD) determines the quantity of oxygen required to oxidize the organic matter present in water body under specific conditions of oxidizing agent, temperature and time. COD is an important water quality parameter as it provides an index to assess the effect discharged wastewater will have on the receiving environment. Higher COD levels represent the presence of greater amount of oxidizable organic material in the sample, the degradation of which will again lead to hypoxic conditions in the water body. The ratio of BOD to COD indicates the percent of organic material in water that can be degraded by natural microorganism in the environment.

1.2.2.1 Sources of water (types)

There are three types of water source: i) surface water ii) rainwater and iii) groundwater.

1.2.2.1.1 Surface water

When rain falls to the ground it becomes surface water, where it may move across the ground in the form of streams or rivers, or remain in one place in the form of ponds or lakes. Surface water is easily polluted and can be affected by wide seasonal variations in turbidity ('muddiness') and flow. Variations in turbidity present a challenge for the effective operation of treatment processes, while variations in flow affect the location and design of abstraction structures. Surface water, however, is often the easiest to access.

1.2.2.1.2 Rainwater

Collecting rainwater from either an existing roof structure or a ground catchment area can provide a useful supplementary source of water even if it is not used as the main supply. Storage tanks are usually required to make the best use of rainwater.

1.2.2.1.3 Groundwater

Groundwater is usually used to describe subsurface water that occurs beneath the water-table in soils and geologic formations that are fully saturated. Groundwater accounts for about 88% safe drinking water in rural areas where there is widely dispersed population and water treatment infrastructure and transportation does not exist (Alexander, 2008). Ground waters have unique features which make them suitable for public water supply. They are usually free from pathogens, have acceptable colour and turbidity and can be consumed directly without treatment (Alexander, 2008; Aina and Oshunrinade, 2016). Groundwater may be obtained in several ways: water from mountain springs, Shallow wells, and Shallow or deep boreholes. Water from mountain springs can often be transmitted to areas of demand by gravity, limiting the operation and maintenance requirements of a supply system.

1.2.2.2 Rivers

Rivers are the most important freshwater resource for man. Social, economic and political development has, in the past, been largely related to the availability and distribution of fresh waters contained in riverine systems. Major river water uses can be summarized as follows:

- sources of drinking water supply,
- irrigation of agricultural lands,

• industrial and municipal water supplies,

• industrial and municipal waste disposal,

• navigation,

• fishing, boating and body-contact recreation,

• Aesthetic value.

A simple evaluation of surface waters available for regional, national or trans-boundary use can be based on the total river water discharge (Chapman, 1992, 1996). Upstream use of water must only be undertaken in such a way that it does not affect water quantity, or water quality, for downstream users. Use of river water is, therefore, the subject of major political negotiations at all levels. Consequently, river water managers require high quality scientific information on the quantity and quality of the waters under their control. Provision of this information requires a network of river monitoring stations in order: to

• establish short- and long-term fluctuations in water quantity in relation to basin

characteristics and climate,

• determine the water quality criteria required to optimise and maintain water uses, and

• determine seasonal, short- and long-term trends in water quantity and quality in relation to demographic changes, water use changes and management interventions for the purpose of water quality protection. As with all freshwater systems, river quality data must be interpreted within the context of a basic understanding of the fluvial and river basin processes which control the underlying characteristics of the river system. Similarly, the design of the monitoring network, selection of sampling methods and variables to be measured must be based on an understanding of fluvial processes as well as the requirements for water use (Chapman, 1992, 1996).

1.2.2.2.1 Contamination of river water

Contaminants are substances that are dissolved in water and make it unfit for use. Some contaminants can be easily identified only by assessing the taste, odour and turbidity of the water because pure water remains tasteless, colourless and odourless. However, most cannot be easily detected and require testing to reveal whether or not water is contaminated. Physicochemical parameters of water are important to determine the quality of drinking water as according to WHO (1996) the physical parameters that are likely to give rise to complaint from consumers are colour, taste, odour and turbidity while low pH causes corrosion and high pH results in taste complaints (Chan *et al*., 2007). Generally, the pollutants come from three prominent sources- (i) sewage discharged into the river, (ii) industrial effluents discharged into the river without any pretreatment and (iii) surface run off from agricultural land, where chemical fertilizers, pesticides, insecticides and manures are used. This makes the river water unsafe for drinking and bathing. About 1500 substances have been listed as pollutants in freshwater ecosystems and a generalised list of pollutants includes acids and alkalies, anions (e.g. sulphide, sulphite, cyanide), detergents, domestic sewage and farm manure, food processing water, gases chlorine, ammonia), heat, metals (cadmium, zinc, lead), nutrients (phosphates, nitrates), oil and oil dispersants, organic toxic wastes (formaldehydes, phenols) pathogens, pesticides, polychlorinated biphenyls and radionuclides, in addition to oxidizable materials, domestic sewage contains detergents, nutrients, metals, pathogens and a variety of other compounds (Tripathi *et al*., 1990). Now a day a large number of factors are being used for the study of pollution. A modification in biology of polluted water was explained by Chen and Twillery (1999). Silicon and nitrate in fresh water was studied by House *et al*. (2001). Biological character with respect to physico-chemical properties in ponds was studied by Dwivedi (2000).

1.2.2.2.3 Impacts of River Pollution

The odour of sewage is common in most road side drains of the cities and towns, and most rivers along the main industry zones are excessively polluted. This generates waterborne diseases, decreases the quality of life, and undermines the attractiveness of cities to foreign investors, and the competitiveness of tourism (FDRE, 2015). The main impacts of river pollution are environmental, social and economical.

1.2.2.2.4 Environmental impact

Pathogens, organic compounds, synthetic chemicals, microplastics, nutrients and heavy metals are some elements that pollute fresh water. Unregulated discharge of wastewater undermines biological diversity, natural resilience and the capacity of the planet to provide fundamental ecosystem services (Teshager, 2014). Rivers highly affected by pollution has significant impact on macroinvertebrates composition since water quality deteriorates (Beyene *et al*., 2009). The contamination of surface water by heavy metals is a serious ecological problem as many heavy metals such as Hg, As, Pb, Sb, Ni, Sr and Cd are toxic even at low concentrations. They are non-degradable and can accumulate in the human body and causing damage to nervous system and internal organs (Lee *et al.,* 2007; Lohani *et al*., 2008). Though some metals such as Cu, Fe, Mn and Zn are essential as micronutrients for living organisms, they can be detrimental to their physiology at higher concentrations (Kar *et al*., 2008; Nair *et al*., 2010). Heavy metal affects highly the water biota (Aschale *et al*., 2015). Anthropogenic sources of heavy metal are associated mainly with industrial and domestic effluents, surface runoff, landfill leachate, mining of coal and ore, atmospheric sources and inputs from agricultural activities (Zarazua *et al.*, 2006). As surface and groundwater are intimately linked to each other, there might be leakage from the highly polluted River. In the area, where large-scale industries have been expanding, pollution due to disposal of untreated industrial waste seems to be forthcoming (Alemayehu, 2001; Shaqa, 2010). Different studies point out that quality of surface water is affected by waste disposal and these would have also potential impact on the quality of groundwater.

Another environmental effect of the pollution of the water sources is eutrophication. Caused by excessive use of phosphorous and nitrogen in agriculture, and effluents from sewerage and pit latrines and municipal wastes, eutrophication causes growth of algae and weeds, which deplete the oxygen level of the water bodies, and in turn affect aquatic fauna and flora.

1.2.2.2.5 Social impact

Industries are contributing to the loss of the well-being of society and are one of the causes for society's health problems. In principle, development activities of a country are meant to make the lives of citizens better off. But if the benefits people get out of development activities such as the development of industries is overwhelmed by the problems they face, it is considered as undesirable to society. The harmful industrial waste liquids when mixed with rivers and streams endanger public health through different uses (Mohammed, 2002). Heavy metals have a capacity to accumulate in the food web especially in fishes and vegetables and threat living organisms (Schwarzenbach *et al*., 2010). For a long time, it has been known that intake of food that contains high levels of heavy metals, poses risks to human health**.** Report says that high accumulation of heavy metal (beyond maximum limit) in most vegetables from sample taken; high arsenic in carrot, cadmium and chromium in lettuce, iron and zinc in Swiss chard, mercury in kale and high concentration of lead in cabbage. These vegetables directly consumed by the people, which could affect the health of the consumers. Itanna (2002) reported that Cabbage was in general the least accumulator of metals/metalloids. Lettuce and Swiss in a few cases, As, Cr, Fe and Pb in these vegetables have surpassed maximum permitted concentrations. The intake of most of the metals constitutes less than 10% of the theoretical maximum daily intake (TMDI) at present, and hence health risk is minimal. But with increase in vegetable consumption by the community the situation could worsen in the future (Yohannes and Elias, 2017).

1.2.2.2.6 Economic impact

Polluted water bears two kinds of economic costs: Firstly, pollution reduces the total amount of adequate water available for household consumption or agricultural and industrial usage. Thus, there are economic costs of water held back from supply. Secondly, there are costs related to the use of pollute d water for consumption and production. The costs of using contaminated water for production refer to the decrease in both quality and quantity of products. In Africa, due to water pollution and lack of sanitation, the overall economic loss is estimated to be 5% of the gross domestic product (UNESCO, 2009).

1.2.3 Udu River water

The Udu River which is a tributary of the Warri River is located in Warri South Local Government Area of Delta State and spans over 48 km^2. The river has its source from Aboh in Delta North, lying between longitude 6.20^0N and Latitude 5.45^0E. The river flows southwest to Warri where it is joined by a large number of creeks from where it empties into the very brackish Forcados River and finally into the Atlantic Ocean (Aluyi *et al*., 2006).

The river flows across a large uninhabited stretch of land. Companies involved in one form of marine activity or the other basically occupy the inhabited expanse of land. This rapid industrialization has led to alterations in the water quality of the river thus causing great concern for the immediate users of the river water and the larger society. The location of a jetty where people take boat straight from Ovwian to Igbudu (a central position of Warri main town) thereby avoiding the numerous traffic in the town has resulted in increased human activities along the course of the river. This is evident in higher faecal contamination of the river, urban run offs, abattoir effluent discharges and organic and inorganic dumps around or directly into the river. The continued dumping of chemicals by companies like Nissco and Globester involved in the fabrication of oilrig platforms, has further led to great alterations of the bacteriological and physico-chemical quality of the river (Aluyi *et al*., 2006).

The Udu river serves communities like Ujevwu, Egini, Ekete, Owhase, Aladja, and Ovwian where fishing serves as major source of occupation for most inhabitants of those communities. Other activities like swimming, bathing, dumping of sawdust and wasing of clothes in the river are also common feature of water pollution observed here (Aluyi et al., 2006).

CHAPTER TWO

MATERIALS AND METHODS

MATERIALS

2.1.1 Chemicals/reagents

Analytical grade chemicals were bought from local chemical vendors in Benin City, Edo State, Nigeria. The chemicals were used for solution preparation, standardization and washing of apparatus. The chemicals were used without further purification. Some of the chemicals used are: buffer 4 and 7, distilled water, H_2SO_4, HCL, Na_2CO_3, NaCl, sodium thiosulphate, NaOH, sodium azide, $AgNO_3$, k_2CrO_4, brucine sulphate, KCL, acetic acid, bromocresol green, manganese sulphate and phenolthalein.

Equipment/apparatus

The equipment/apparatus used in this study are given in Table 2.1.

Table 2.1: Equipment/apparatus of study

Equipment/apparatus	**Uses**
pH meter	was used to determine the pH of the water samples and other solutions
Conductivity meter	Was used to determine the electrical conductivity of the water samples
Turbidity meter	Was used to determine the turbidity of the samples
Thermometer	Was used to determine the temperature of the water samples
Atomic absorption spectrophotometer (AAS)	Was used to determine the concentration of heavy metals in water samples

2.1.2 Chemicals/reagents

Water samples were obtained randomly from the upstream, middle stream and downstream of Udu River, Warri, Delta State. On the spot analysis was carried out on the water samples to determine some physico-chemical properties of the water samples. The samples were stored in bottles for further analysis.

The water samples were taken using sampling bottles, previously rinsed with station water and transferred to labeled plastic containers. They were then stored at 4ºC in cold ice during transport to the laboratory and analyzed within 24 hours as recommended by standards (Elshemy and Mea, 2011; APHA, 2014).

2.2 METHODS

2.2.1 Measurement of physico-chemical parameters

The experiment took place in two phases, which was the *in-situ* (on field) and *ex-situ* (outside field).

2.2.1.1 *In-situ* experiment

In-situ phase of the experiment includes unstable parameter which can alter within a short period or are influenced easily or can only be determined on the field, such parameters include pH and water temperature which were determined using Hanna multimeter (APHA, 2014).

2.2.1.1.1 pH determination

The pH of the water samples was analyzed using method by USDA (2021). Hand pH metre was calibrated with the buffers 4 and 7 solutions, and the electrode(s) and glassware were rinsed with distilled or deionized water. 100 ml each of the water samples were carefully measured in a 150 ml beaker for the pH measurement at room temperature. The rinsed electrode was placed in the test samples. The pH was analyzed within 5 minutes of uncapping the sample bottle. The sample was stirred very gently, preferably with a magnetic stirrer and took up to 3 minutes for the reading to become stable. When stable, not in excess of 5 minutes, the sample pH was recorded to the nearest 0.01 pH unit.

2.2.1.1.2 Temperature determination

The temperatures of the water samples were taken using a portable Celsius thermometer. This was done by immersing the probe of the thermometer below the water surface (the sample) to a depth of about four inches for one minute. The value displayed on the meter was then recorded.

2.2.1.2 *Ex-situ* experiment

The following parameters were determined ex-situ in the laboratory: Nitrate, Alkalinity, Biochemical oxygen demand, chlorine, conductivity, total dissolved solids and dissolved oxygen.

2.2.1.2.1 Nitrate/nitrite determination

NO_3 solution was prepared by dissolving 2.5g of brucine in 100ml flak using acetic acid top up to the mark.

10ml of the sample was measured into 50ml flask then 2ml of brucine was added then rapidly 10ml conc. H_2SO_4, mix well and let it stand for 10 minutes. The standard were similarly treated, samples and standards were then made to mark, and read spectrophotometrically at 470nm. The reading for all the various concentrations were taken and plotted against absorbance. The absorbance was measured and the corresponding nitrate concentration was determined from the calibration curve.

NO_3(mg/l)= concentration

$$\frac{concentration\ of\ nitrate\ ion \times volume\ of\ colour}{volume\ of\ sample}$$

Where:

IR= instrumental reading

SR= slope reciprocal

2.2.1.2.2 **Alkalinity determination**

50ml burette was rinsed with 0.02M H_2SO_4, the burette was filled with H_2SO_4 solution and 50ml of the water sample measured and poured into a 250ml Erlenmeyer flask, two drops of bromocresol green indicator was added. It was the titrated until a change in color (blue to yellow) was observed. Triplicate titrations were done.

Calculation:

Alkalinity = vp x M x 100000/ml of sample

Where: vp = ml titrant of H_2SO_4

M= molarity of H_2SO

2.2.1.2.3 Total hardness determination

The total hardness of the water samples was determined from the concentration of calcium ions and magnesium ions obtained from the atomic absorption spectrophotometer (AAS).

2.2.1.2.3 Biochemical oxygen demand (BOD) determination

The water sample was thoroughly aerated. The sample was then seed with a little diluted domestic palm oil (1-2 m1 per litre). Then a DO determination was carried out on a suitable portion for day 1. A screw-topped incubation bottled was filled to the brim with the remainder of the diluted palm oil. The bottled was then sealed and incubated in the dark for 5 days at 20℃. A DO determination was carried out on a suitable portion of the incubated sample. The difference between the two determined DO level (DO_1 and DO_5) give the BOD, DO_1-DO_5 (BOD) (Ademoroti, 1996).

2.2.1.2.4 Determination of chlorides

10ml of the water sample was pipetted into a 250ml conical flask, 3 drops of potassium chromate (k_2CrO_4) indicator, this was then titrated with 0.05M silver nitrate solution until a brick red ppt end point was obtained. The burette reading was noted i.e. volume of silver nitrate solution used.

$$\text{chloride}\left(\frac{mg}{1}\right) = \frac{molarity \times titre \times mol.wt \times 1000}{aliquot\ taken}$$

2.2.1.2.5 Conductivity and total dissolved solid (TDS) determination

This was done in accordance with the method described by Ademoroti (1996). The conductivity meter was switched on by pressing the power button; it was then allowed to stabilize for 10 minutes. It was calibrated by pressing CND and immersing the probe in 0.1 M KCL solution. The probe was then rinsed and immersed into the sample. The conductivity was read by pressing CND.

TDS = EC X conversion factor

Where,

EC= electrical conductivity

TDS = total dissolved solid

2.2.1.2.5 Total suspended solid (TSS)

A whatmann filter paper was weighed in an oven at 104°C for 1 hour, it was cooled in dessicator and weighed. The filtration apparatus was assembled with the dried and weighed filter paper. The filter paper with a small amount of distilled water to seat it. 100ml of the sample was filtered into the conical flask, the filter paper was dried in an ovum and weighed.

Calculation:

$$\text{mg total suspended}\frac{solids}{L} = \frac{(A-B)\times 1000}{ml\ sample}$$

where:

A = weight of filter + dried residue, mg,

B = weight of filter, m

2.2.1.2.7 Determination of chemical oxygen demand (COD)

This was achieved following the method of Ademoroti (1996). 50 m1 of produced was pipetted into a conical flask after which l0 ml of 0.00833 $K_2Cr_2O_7$ solution was added followed by the addition of 1 g $HgSO_4$, 80 ml of Ag_2SO_4 solution and a few beads. A reflux greaseless condenser was fixed and the conical flask heated gently to boiling for exactly l0 mins after which the flask was allowed to cool. The condenser was then rinsed with distilled water and the flask cooled under running tap water. Two drops of ferrous indicator was added to the solution and titrated with 0.025M $Fe(NH_2)_2(S0_4)_2$. $6H_2O$ until the colour changed from blue-green to red-brown. A blank determination was also done following the above procedure before replacing with 50ml produced water. The COD in mg/l was then calculated using the relationship,

$$COD = \frac{(A-B)\times M\times 8000}{volume\ of\ sample} \quad (2.1)$$

Where A = volume of Fe $(HN_2)_2$ $(SO_4)_2$. $6H_2O$ used for blank

B = volume of Fe $(NH_2)_2$ $(SO_4)_2$. $6H_20$ used for sample

M = molarity of Fe $(NH_2)_2$ $(SO_4)_2$. $6H_20$

2.2.1.2.8 Dissolved oxygen (DO) determination

The sample was transferred into a BOD bottle, with care being taken to minimized exposure to air; the water was introduced to the bottom of the bottle with the help of a tube, which was removed slowly while the tube was overflowing. Then 2ml of $MnSO_4$ reagent was added with a dropper; well below the surface such that some of the sample overflowed, similarly 2 ml of sodium KI/NaOH solution. In each case the tip of the pipette was 2 cm below the neck of the bottle such that 2 m1 quantity was discharged directly into the bulk of the content. Then a stopper was placed on the table, to ensure that no air was capped. Afterward, the bottle was inverted to distribute the precipitate uniformly. When the precipitate had settled at about 3cm below the stopper, lml of concentrated (1M) H_2SO_4 was introduced well below the surface and the stopper. With a graduated cylinder, 200m1 of the acidified sample was measured into a 500m1 conical flask and titrated with 0.025N $Na_2S_2O_3.5H_2O$ until iodine colour becomes faint. Thereafter, lml of starch indicator was introduced before the titration was completed. The dissolved oxygen was then calculated from the relationship T x $lmgO_2$ where the volume of sodium thiosulphate used

2.2.1.2.9 Determination of Turbidity

5ml each of hydrazine sulphate and hexaneethylene tetraammine were mixed in a 100ml flask and allowed to stand for 24 hours at room temperature. The solution was diluted in 100ml flask and mixed well. This mixed solution was 400NTU. 0,10,20,30, 40, and 50NTU respectively were measured as working standards in 50ml flasks.

25ml of distilled water was read with UV spectrometer at 450nm. 25ml of he sample was poured into the curvette and read. The working standards were done similarly.

Calculation

Turbidity (NTU) = Instrument reading x slope reciprocal

2.2.1.2.10 Heavy metal determination

The concentration of K^+, Na^+, Mg^{2+}, Ca^{2+}, fe^{2+}, Zn^{2+}, Cr^{2+}, Cd^{2+}, Ni^{2+}, Mn^{2+}, Pb^{2+} and Cu^{2+} were determined using atomic absorption spectrophotometer (buck scientific VGP 210 model) and the various absorbances were recorded for the working curve without digestion.

2.2.1.2.11 Determination of phosphate

1ml of aliquot of water sample was pipetted into a test tube, 1ml of color solution was added and shaken then 0.5 ml of ascorbic acid solution was added, shaken and allowed to stand for 15 minutes. 1ml of each of 0, 0.2, 0.5, 1.0, 2.0, 4.0 and 8.0 ppm standard p working solutions respectively were pipetted into 7 test tubes, 8ml of distilled water was added and then 1ml of color solution and 0.5ml of ascorbic acid solution were added, shaken and allowed to stand for 15 minutes. The color intensity was measured in spectrophotometer with 710nm wavelength.

2.2.1.2.12 Determination of sulphate

10ml of the sample was measured into a beaker, 1ml of starch solution, 1ml of 6N HCL and 0.5ml of $BACL_2$ were added shaken and allowed to stand for 2 minutes. 0,0.5, 2.0, 2.0, 4.0, and 8.0ml of 100ml volumetric flasks and made up to respectively were pipetted into seven 100ml volumetric flasks and were made up to mark with distilled water. The samples and standards were read with UV spectrometer at 420nm.

2.2.2 Data Analysis

Data obtained from physical and chemical measurements were statistically analyzed for variance using the Microsoft excel 16.00 (Microsoft inc., USA) software package. The mean values were compared with the water quality criteria of the world health organization (WHO) and Nigeria industrial standard (NIS). Microsoft excel was used for graphical presentation.

CHAPTER THREE

RESULTS AND DISCUSSION

3.1 Physico-chemical properties of udu river water

The values of the physicochemical parameters and heavy metals in the upstream, middle stream and downstream of the udu river are given in table 3.1.

Table 3.1: physico-chemical properties of udu river

Parameters	upstream	middle stream	downstream	mean± SD	WHO(2004
PH	7.07	7.07	7.05	7.06±1.01	6.5-8.5
PH	7.07	7.07	7.05	7.06±1.01	6.5-8.5
Temperature	31.00	31.00	32.00	31.33±0.58	-
Turbidity (NTU)	9.67	9.50	11.50	10.22±1.10	25
Alkalinity (mg/L)	9.30	8.00	9.00	8.77±0.68	20
EC (µS/cm)	99.80	212.00	108.30	140.03±62.50	500-1000
DO	3.00	2.80	2.50	2.77±0.25	5
BOD (mg/L)	1.90	1.60	1.40	1.65±0.35	30
TDS (mg/L)	56.89	120.84	61.73	79.82±35.61	500
TSS (mg/L)	0.7	1.3	0.6	0.87±0.56	500
Nitrate (mg/L)	5.06	4.76	5.76	5.19±0.51	45
Chloride (mg/L)	4.33	5.67	10.00	6.67±2.96	600
Bicarbonate	2.35	2.35	2.82	2.51±0.27	350
COD (mg/L)	10.00	20.00	18.00	16.00±5.29	160

Sulphate (mg/L)	1.04	0.86	1.49	1.13±0.32	250
phosphate (mg/L)	12.67	4.05	7.47	8.06±4.34	250
total hardness (mg/L)	15.18	17.92	13.73	15.61±2.13	500
carbonate (mg/L)	ND	ND	ND	ND	-
Metals					
Fe (mg/L)	0.07	0.70	0.90	0.77±0.12	0.3
Zn (mg/L)	0.01	0.02	0.01	0.01±0.01	0.01-3
Cr (mg/L)	0.11	0.18	0.25	0.18±0.07	0.05-2
Cd (mg/L)	ND	ND	ND	0.00±0.00	0.01
Ni (mg/L)	ND	ND	ND	0.00±0.00	1
Mn (mg/L)	0.00	0.10	0.10	0.07±0.06	0.1-0.5
Pb (mg/L)	ND	ND	ND	0.00±0.00	1
Cu (mg/L)	ND	0.03	ND	0.03±0.00	2
Na (mg/L)	0.70	0.70	0.7	0.70±0.00	50
K (mg/L)	0.82	0.82	0.82	0.82±0.00	20

3.1.1 pH

Ph is an extremely important parameter in water and determines to a large extent the concentration of other parameters. It is defined as the acidity or alkalinity of a water body. The Ph of udu river water was found to be at 7.07 at the upstream, 7.07 at the middle stream and 7.05 at the downstream. The average value of Ph across the streams was 7.06±1.01. the ph recorded in the three stations was within the recommended ph of 6.6 to 8.5 by WHO (2004). These values correspond to those obtained by Andem et al. (2012) for ona river and oseji et al., (2019) for river niger at ilushi.

3.1.2 Water temperature

Water temperature is an important factor for aquatic organisms to thrive, as it affects the rate of photosynthesis which aquatic organism needs to florish. The water temperature was 31.0^{o}C at the mid stream and 32^{o}C at the downstream with average value of 31.33±0.58^{o}C. the high-water temperature recorded in these stations could be due to low vegetation cover and degree of exposure to solar heat (WHO, 2004). Oboh and Agbala (2017) recorded water temperature range of 29.5^{o}C to 32.670C in river siluko while oseji et al. (2019) recorded temperature range of 24-30^{o}C from the river Niger at Ilushi.

3.1.3 Turbidity

Turbidity is the determination of the muddiness or opaqueness of water and it is usually influenced by the total number of materias that are present in the water (Oboh and Agbala, 2017). Turbidity was found to be 9.67NTU in the upstream, 9.5NTU in the middle stream and 11.50NTU in the downstream. Average turbidity value across the stations of 10.22±1.10NTU was below WHO's standard of 25NTU which implies the water is abit cloudy. High turbidity may be influenced by the presence of phytoplankton which can impede aeration of the water body and subsequent decrease in dissolved oxygen for aquatic life (chinedu et al., 2011).

3.1.4 Alkalinity

Alkalinity varied across the streams as alkalinity value of the upstream, mid stream and downstream was found to be 9.30, 8.00 and 9.00mg\L, respectively. High alkalinity values can be as a result of runoffs which carry allochthonous organic materials from farmlands at the bank of this station into the river. The mean value of alkalinity of 8.77±0.68mg\L recorded in this present study was higher than 3.75mg\l recorded by francis (2011) in new calabar river freshwater section but lower than the value recorded in woji creek (davies et al., 2008)

3.1.5 Electrical conductivity (EC)

EC values in the upstream, middle stream and in downstream were found to be 99.80, 212.00 and 108.30µS/cm. The high conductivity recorded in the upstream is as a result of a nutrient load of surface runoffs from farms as well as washing of nutrient rich groundwater and solution of salts from inundated agricultural land at the bank of this station. Conductivity in this study is however below the recommended limit of 500µS/cm by WHO (2004). The mean conductivity value recorded in this present study is lower than 3752.74µS/cm recorded in new calabar river (Agbugui and Deekae, 2014).

3.1.6 Dissolved oxygen (DO)

The DO values were found to be 3.00, 2.80 and 2.50mg/L in the upstream, midstream and downstream respectively. The DO values in this study are low which could be as a result of regular dredging of the river. Dissolved oxygen is an unstable parameter that could change with prevailing climatic conditions. As such the variation could be due to the time of sampling (Agedah et al., 2015). Dissolved oxygen values can be reduced when enormous amounts of organic loads are discharged into water bodies which require a high level of oxygen to break down. The mean DO in the stations were lower than the permissible limit. The DO range recorded in this study is lower than the 0.58-10.00mg/L recorded by Ikongbeh et al. (2014) in lake Akata. The dissolved oxygen observed from this study suggest that he aquatic organisms such as fish and plants are getting the required oxygen needed for survival (Agedah et al., 2015).

3.1.7 Biochemical Oxygen demand (BOD)

BOD is a measure of the amount of oxygen required by microorganism to break down organic matter in 1 liter of water (clair et al., 2003). It is used to determine the pollution strength of waste water. The BOD of the upstream, middle stream and downstream of udu river water was found to be 1.90, 1.60 and 1.40mg\L respectively. The mean BOD values recorded in this present study of 1.65±0.35mg\L is lower than the WHO standard value of 405.57mg\l recorded in ona River by Andem et al. (2012).

3.1.8 Total dissolved solids (TDS)

TDS in this study were 56.89, 120.84 and 61.73mg\L in the upstream, middle stream and downstream of udu river water respectively. The relatively high TDS may be due to anthropogenic activities such as washing of motorcycles, washing of clothes, bathing and runoffs which may have brought in particles from the surrounding land. The average TDS of 79.82±35.61mg\/l in this study was however lower than the permissible limit of 2000mg/l by WHO (2004). Solids in water are undesireable, for they degrade the quantity of water, inhibit the photosynthetic process and reduce the utility of water (Ogbeibu and Anagbaso 2004).

3.1.9 Total suspended solids (TSS)

Total suspended solids was 0.70mg/l in upstream, 1.3mg/l in midstream and 0.60mg/l in downstream. Waste disposal and surface runoffs are he sources of TSS. The result obtained from this present study is contrary to the study conducted by Ofonmbuk et al., (2014) in Ediene stream. The total suspended solids in this study was low compared to other studies.

3.1.10 Nitrate

Nitrate values in this study was 5.06mg/l in upstream, 4.76mg/l in midstream and 5.76mg/l in downstream. The sources of nitrate are municipal waste, refuse dump, decaying plant and animal materials. The mean nitrate in the 3 stations was lower than the permissible limit (WHO, 2004). This present study is contrary to the study conducted by Iyiola (2014).

3.1.11 Chloride

Chloride values in this study was 4.33mg/l in upstream, 56.7mg/l in midstream and 10.00mg/l in downstream. Chlorides occur naturally in rocks, other sources include fertilizers, sewage and livestock wastes. The mean chloride recorded in all the stations was lower than WHO (2004) limit. A similar range was reported elsewhere in Edo state, Nigeria (Imoobe and Koye, 2011; Anyanwu, 2012).

3.1.12 Bicarbonate/carbonate

Bicarbonate values in this study was 2.35mg/l In upstream, 2.35mg/l in midstream and 2.82mg/l in downstream.

3.1.13 Chemical oxygen demand (COD)

COD is an important water quality parameter as it provides an index to assess the effect of discharged wastewater will have on the recieveing environment. Hiher

COD levels represent the presence of greater amount of oxidizable organic material in the sample, the degradation of which will again lead to hypoxic conditions in the water body. The average COD of the streams of Udu River was 16.00±5.29mg/l this indicates that the water is low in oxidizable organic matter.

3.1.14 Sulphate

Sulphate values in this sudy was 1.04mg/l in upstream, 0.86mg/l in midstream and 1.49mg/l in downstream. High sulphate can be attributed to agricultural activities such as the application of fertilizers which are transported by runoffs into the river (Essien-Ibok et al,. 2010). The mean sulphate in the 3 stations was lower than the permissible limit (WHO, 2004). 0.01-26.60mg/l was recorded by Okorafor et al., (2013).

3.1.15 Phosphate

Phosphate values in this study were 12.67mg/l in upstream, 4.05mg/l in midstream and 7.47mg/l in downstream. The significantly higher phosphate recorded in the upstream may be as a result of the leaching of fertilizers residues from the farm at the bank of this station into the river by runoffs. Phosphate occurs naturally in rocks and is introduced into rivers as the water flows through the rocks. Excessive phosphate leads to a reduction in dissolved oxygen and an increase in eutrophication. The mean phosphate in the 3 stations was lower than the permissible limit (WHO, 2004). The result from this study is similar to the study conducted by Imaobong et al., (2012), but contrary to the study carried out by Osimen et al., (2015).

3.1.16 Total hardness

Total hardness in this study was 15.18mg/l in upstream, 17.92mg/l in midstream dn 13.73mg/l in downstream. The hardness of water is the measure of the concentration of the multivalent cations, primarily it is equivalent to the calcium and magnesium concentrations of the water (Ababio, 2007)

3.1.17 Metals

Heavy metals are known to be detrimental to water bodies and may end up in humans directly or indirectly through the consumptions of aquatic animals. Consumption of heavy metals in high concentration may lead to severe diseases and even deat. The average values of fe, Zn, Cr, Mn, Cu, Na and K across the various streams of udu river water were found to be 0.77±0.12, 0.01±0.01, 0.18±0.07, 0.07±0.06, 0.03±0.00, 0.70±0.00 and 0.82±0.00mg/l respectively. Cadmium, nickel and lead were found to be below detectable limits in all the streams. The low concentrations of metals/heavy metals in the river water shows the relative absence of metal based and automobile companies in the neighborhood of udu river.

CONCLUSION

The results from this study showed that the physicochemical parameters of the river were below and above the limits set by the world health organization (WHO). The water is not fit for human consumption.

RECOMMENDATION

1. Further studies should be done on the microbial activities of the water.
2. The water should undergo further treatment before being used for any activity.

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