THE ASSESSMENT AND MODELING OF DEPLETION OF DISSOLVED OXYGEN IN WOJI/OKUJAGU STREAM

BY

OWOR, ALEXANDER ALEXANDER (B.Tech PGD)
REG. NO. 20154900588

A THESIS SUBMITTED TO SCHOOL OF POSTGRADUATE STUDIES, FEDERAL UNIVERSITY OF TECHNOLOGY OWERRI. IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE AWARD OF MASTER OF ENGINEERING (M.ENG.) DEGREE IN CIVIL ENGINEERING (WATER RESOURCES ENGINEERING)

MAY, 2021

©Federal University of Technology, Owerri

CERTIFICATION

This is to certify that this research work on "The assessment and modeling of the depletion of dissolved oxygen in Woji/Okujagu stream" by **Owor, Alexander Alexander** with registration No. 20154900588 is hereby approved for the award of a Master of Engineering (M.ENG) Degree in Civil Engineering, School of Engineering and Engineering Technology, Federal University of Technology, Owerri, Imo State.

Engr. Prof. (Mrs.) B. U. Dike (Supervisor)	28/06/21 Date
Engr. Prof. J. C. Osuagwu (Supervisor)	25/05/2021 Date
Rev. Engr. Dr. L. O. Ettu (Head of Department)	28/06/21 Date
Engr. Prof. J. C. Ezeh (Dean, SEET)	19/07/2021 Date
Prof. C. C. Eze (Dean School of PGS)	Date
Prof. Ify Nwaogazie (External Examiner)	25-05-2021 Date

DEDICATION

This research work is dedicated to the Omniscient Spirit, the Almighty God for His grace, good health, wisdom and knowledge to carry out this project successfully. And also to my lovely wife Mrs. Regina Alexander Owor and to my beloved God fearing mother Mrs. Ataisi Alexander Owor.

ACKNOWLEDGEMENT

My profound gratitude goes to God Almighty who has always been my source of inspiration and whose enduring grace made it possible for the accomplishment of this research work.

My appreciation goes to my project supervisors Engr. Prof. (Mrs.) B. U. Dike and Engr. Prof. J. C. Osuagwu, whose professional advice made the accomplishment of this research a success. I also want to thank my Head of Department Rev. Engr. Dr. L. O. Ettu, Dean School of Engineering and Engineering Technology Engr. Prof. J. C. Ezeh and other lecturers in Civil Engineering Department namely, Engr. Rev. Dr. N. L. Nwakwasi, Engr. Dr. H. U. Nwoke, Engr. Dr. L. Anyaogu, Engr. Dr. U. C. Anya, Engr. Prof. B. C. Okoro, Engr. Dr. O. M. Ibearugbulem, Engr. Dr. O. R. Onosakponome, Engr. Dr. (Mrs.) J. I. Arimanwa, Engr. Prof. D. O. Onwuka, Engr. A. N. Nwachukwu, Engr. F. C. Njoku, Engr. K. C. Nwachukwu, Engr. (Mrs.) C. T. G. Awodiji, Engr. K. Agbo, Engr. K. Njoku, Engr. C. I. Onyechere, Engr. T. Anyanwu, Mr. A. P. C. Amanze and Mr. O. Igbojiaku for their immeasurable support during my academic program.

My invaluable gratitude goes to my mother Prophetess (Mrs.) Ataisi Alexander Owor and my siblings Mrs. Glory M. Ezekiel, Ms. Martha Alexander Owor, Ms. Juliana Alexander Owor, Mr. Ebirien Alexander Owor, Ms. Virginia Alexander Owor, Ms. Rhoda Alexander Owor, Master Mojana Alexander Owor, Master Blessing Alexander Owor and my loving wife Mrs. Reginah Alexander Owor for their contributions towards the successful completion of my academic programme. I also want to thank my mentors Engr. I. Z. S. Akobo, Head of Civil Engineering Department RSU, Engr. Prof. S. B. Akpila and Engr. Dr. F. E. Ezeilo for their support, companionship and courage to carry out this project work and my friends Mr. I. Nwachukwu Civil Technologist Futo, Mr. Ukpong Aniefiok, Mr. M. Nnanna, Mr. A.I. Braide, Mr. E. Solomon, Mr. E. Cletus, Mr. N. Ukomi and Mr. O. Ginikanwa.

TABLE OF CONTENTS

CHAPTER 3: METHODOLOGY

CHAPTER 4: RESULTS AND DISCUSSION

CHAPTER 5: CONCLUSION AND RECOMMENDATION

LIST OF TABLES

LIST OF APPENDIX

LIST OF FIGURES

LIST OF PLATES

ABSTRACT

This research work presents the study of the depletion of dissolved oxygen in Woji/Okujagu River in Port Harcourt Local Government Area of STREAM State, Nigeria. The study was carried out between February, 2017 (dry season) and August, 2017 (wet season). The sampling exercise was done on six (6) selected stations (stations A, B, C, D, E and F) along the river located at progressive distances 200m upstream and downstream from the point of influent discharge. Sampling was done three times during the dry season (February) and during wet season (August) 2017. The physical and chemical properties of the river samples such as Temperature, Total Suspended Solids (TSS), Electrical Conductivity (EC), pH, Nitrates, Biochemical Oxygen Demand (BOD_5), and Dissolved Oxygen (DO) were analysed using standard methods. The parameters were then compared to ascertain their conformity with national and international standards set by the Nigerian Environmental Standard and Regulation Enforcement Agency (NESREA) and the World Health Organisation (WHO). Further analysis was carried out by the application of extended version of Thomas slope and O′Connor re-aeration and Streeter-Phelps models to determine the depletion of dissolved oxygen in the River by the decomposition characteristics of the discharged effluents. The results of the analysis showed that the temperature ranged from 25.4 - 29.5^{0}C, TSS ranged from 145.6 – 484.4mg/L, EC ranged from 422.7 - 982.2 µS/cm, pH ranged from 6.0 - 7.3, Nitrates ranged from 12.5 - 97.3mg/L, BOD ranged from 22.5 – 75.2mg/L and DO ranged from 2.2 – 6.5mg/L. Only pH values were within the recommended NESREA and WHO standards. The pollution index for all the stations was 2.7081. The critical time t_c was 6250 sec (0.0353 day). De-oxygenation constant K_d and ultimate BOD L_o were 0.744 and 79.2mg/l, respectively. The re-aeration constant K_r was 0.0282. The values of DO obtained from laboratory analysis were plotted against time. The DO curve generated showed that the minimum DO level of the River is 2.7mg/l. From the curve, the measured and simulated DO showed that the DO reduction rate tends to be greater than self-purification rate which can contribute greatly to the degradation of the quality of the river ecosystem and human/aquatic life. It is therefore recommended that relevant authorities should embark on regular monitoring activities of receiving STREAM in STREAM State to ensure the safety of human and aquatic population and the environment.

Keywords: Influent discharge, river pollution, physicochemical parameters, dissolved oxygen, models.

CHAPTER ONE

INTRODUCTION

1.1 BACKGROUND OF INFORMATION

Water bodies such as rivers and streams are the primary means for discharge of waste, especially effluents, from municipal, agricultural and industrial waste around them. These effluents from industries have a great deal of influence on the pollution of the water body and can alter the physical, chemical and biological nature of the receiving water body. The alteration of the physical, chemical and biological properties of any water due to discharge of any liquid, gaseous or solid substances that is likely to create detrimental or injurious effect to aquatic life and consequently public health, could be termed water pollution (Pandey and Shukla, 2005).

The initial effect of waste is to degrade the physical quality of the water. Later biological degradation becomes evident in terms of number, variety and organization of the living organisms in the water. Often the water bodies readily assimilate the waste materials they receive without significant deterioration of some quality criteria; the extent of this is referred to as its assimilative capacity. The input of waste into water bodies therefore does not always impact negatively on aquatic environment because of the self-purification property of lotic systems (Ifabiyi, 2008).

However, the availability of quality water needed for maintenance of normal biological function is on the decline (Odigie and Fajemirokun, 2005). Surface water and ground water degradation are major problems arising from pollution due to introduction of industrial influent. Industrial influent is unwanted water generated from industrial activities and are inappropriately discharged into the environment or receiving stream. Its characteristics provide basic information about the integrity of the rivers and streams into which they are discharged (Kanu et al., 2006). The discharge of industrial effluents has led inevitably, to alteration in the quality and ecology of receiving water bodies (Ogbeibu and Edutie, 2002).

Industrial waste is increasing yearly due to the fact that industries are increasing because most countries are getting industrialized. The extent of discharge of domestic and industrial waste is such that stream receiving untreated influent cannot give dilution necessary for their survival as good quality water sources. The transfer of unfavorable releases from industries is detrimental to human and animal health and safety. There is thus a challenge of providing water in adequate quantity and of the required quality to minimize hazards to human health and conserve the water bodies and the environment. Wastewater discharge from sewage and industries are major component of water pollution, contributing to oxygen demand and nutrient loading of the water bodies, promoting toxic algal blooms and leading to a destabilized aquatic ecosystem (Morrison et al, 2001).

Port Harcourt City is becoming fairly industrialized, with some of these industries situated some distance away from stream; their effluents are channeled into such stream as Woji/Okujagu Stream. One of these industries is a soft drink industry and agricultural activities at the slaughter market near the river. The wastewater effluents from the activities of these industries are conveyed over a distance through channels and discharged into the stream. Also waste food products from activities of the slaughter market are discharged directly into the river without treatment. These effluents which are rich in organic and inorganic substances are capable of producing adverse effects on the physical, chemical and biotic components of the environment and impact either directly or indirectly on human health (Ogbeibu and Ezeunara, 2002).

1.2 PROBLEM STATEMENT

Most industries channel the wastewater component into water bodies without adequate treatment prior to the discharge. This practice of direct discharge of industrial wastewater into receiving water bodies is of major concern as it could result amongst other things in a substantial increase in organic load and consequently in depletion of the dissolved oxygen content of the receiving water body (Flores-Laureano and Navar, 2002; McAvoy, et al., 2003).

Uncontrolled domestic wastewater discharge into stream without any form of treatment has resulted in eutrophication of the water bodies as evidence by substantial algal bloom; dissolve oxygen depletion in the subsurface water leads to large fish kill and other oxygen requiring organisms. Sewage discharge into the environment which enhanced concentration of nutrients, sediments and toxic substances which may have a serious negative impact on the quality and life forms of the receiving water body when discharged untreated or partially treated (Schulz and Howe, 2000).

The ingestion of aquatic foods from contaminated water with human or animal faeces are the major source of faecal microorganisms, including pathogens and microbial intestinal infections such as cholera, typhoid fever and bacillary dysentery (Cabral, 2010). These diseases caused by bacteria, viruses and protozoa are the most common health risks associated with contaminated water sources (WHO, 2008). Therefore, understanding the problem associated with the indiscriminate discharge of effluents from municipal, agricultural and industrial waste which results in the depletion of oxygen in receiving stream and streams is essential for remediation.

1.3 OBJECTIVES OF STUDY

The aim of this thesis is to evaluate the depletion of dissolved oxygen in Woji/Okujagu Stream in Port Harcourt Local Government Area of Rivers State. This will be achieved through the following specific objectives:

i. To identify sources of pollution along Woji/Okujagu River.
ii. Determination of the geometric and hydraulic parameters of the stream.
iii. To test the physical and chemical parameters of the stream along the pollution source.
iv. To compare the parameters obtained with drinking water standards and determine the water pollution index of the receiving stream.
v. To determine the depletion of Dissolved Oxygen (DO) in the receiving stream using Thomas slope, O′Connor re-aeration and Streeter-Phelps models.

1.4 SIGNIFICANCE OF STUDY

In general the findings of this research will provide environmental baseline information for the Urban and Regional Planners, Civil Engineers, Environmental Managers/Auditors, industrialist and other governmental authorities. Such information will help them in planning and finding alternative methods of disposing effluents into receiving streams. Furthermore, the study will suggest and put forward an accurate/adequate eco-harmonious method of managing the industrial and agricultural wastes in order to reduce the problem of water pollution in the study area.

1.5 SCOPE OF THE STUDY

The study consists of a field survey, sampling exercise, laboratory analysis of water samples obtained and interpretation of laboratory data using statistical, graphical and established modeling tools. The field survey was carried out on a receiving river near the abattoir in Woji/Okujagu Town in Port Harcourt Local Government Area of Rivers State. The study will focus on the impact of abattoir waste effluents at the slaughter market on depletion of water quality parameters such as Temperature, Total Suspended Solids (TSS), Electrical Conductivity (EC), pH, Nitrates, Biochemical Oxygen Demand (BOD_5), and Dissolved Oxygen (DO) and to ascertain their conformity with national and international standards set by the Nigerian Environmental Standard and Regulation Enforcement Agency (NESREA) and the World Health Organisation (WHO).

1.6 LIMITATION OF STUDY

The pioneering study in this topic exposed me to all the necessary information regarding the assessment and modeling of dissolved oxygen in the stream. I had to put up the courage on various occasions, particularly issues that dealt with finance, insecurity, movement of boats transporting crude and equipments, inter-communal crises, restriction of taking datas from host community, obstruction caused by Construction of Bridge along the study area etc. Nevertheless, these limitations I consciously accepted from the inception to the completion of the study.

One of the challenges faced in the field study was the insecurity in the Niger Delta region. At present, the region has been experiencing insecurity arising from the cult, rivalry, kidnapping, and intra/inters communal clashes. Consequently, the escalating level of insecurity in the region limited the collection of data which are relevant to the study. For instance, not all the questionnaires distributed were retrieved. This, to the extent, limited data for the study.

Funding the project was a major challenge. Financial constraints adversely affected the number of visits to the study area. Again, transportation, particularly, to the stream line communities and hiring of speedboat and equipments to the study area. These research assistants were supportive in actualizing the aim of the study. Also, this project was personally funded.

CHAPTER TWO

LITERATURE REVIEW

2.1 SURFACE WATER QUALITY

Surface water quality, also called ambient water quality, relates to water bodies such as streams, lakes, streams, and oceans. Water quality standards for surface waters vary significantly due to different environmental conditions, ecosystems and intended human uses (Kanu et al., 2006). Toxic substances and high populations of certain microorganisms can present a health hazard for non-drinking purposes such as irrigation, swimming, fishing, rafting, boating, and industrial uses. These conditions may also affect wildlife, which use the water for drinking or as a habitat. Modern water quality laws generally specify protection of fisheries and recreational use and require, as a minimum, retention of current quality standards (Kanu et al., 2006).

There is desire among the public to return water bodies to pristine or pre-industrial conditions. Most current environmental laws focus on the designation of particular uses of a water body. In some countries these designations allow for some water contamination as long as the particular type of contamination is not harmful to the designated uses. Given the landscape changes (e.g., land development, urbanization, clear cutting in forested areas) in the watersheds of many freshwater bodies, returning to pristine conditions would be a significant challenge. In these cases, environmental scientists focus on achieving goals for maintaining healthy ecosystems and may concentrate on the protection of populations of endangered species and protecting human health.

Therefore, in order to protect the sustainability of the aquatic environment and by extension, future users of this freely occurring and highly essential element of nature, it is necessary that minimum water quality standards should be adhered to. The World Health Organisation (WHO) has also outlined guidelines for health and aesthetic situations, which shows the minimum requirements for an array of physical, chemical, biological and radiological aspects to ensure that drinking water is safe for consumption. These guidelines serve as guidance as to what can be considered as safe drinking water and directions to assist nations develop their own drinking water guidelines (WHO, 2006).

2.2 WATER QUALITY CHARACTERISTICS

It is very essential and important to test the water before it is used for drinking, domestic, agricultural or industrial purpose. The quality of water is accessed by characteristics used to ascertain its quality for its intended use. These can be classified into physical, chemical and biological parameters. Water contaminants from each of these parameters go a long way to affect the portability of water and make it unhealthy for consumption.

There are many natural and anthropogenic physical and chemical sources which can adversely affect water quality. Out of the many physicochemical properties that can adversely affect the quality of water, a few of them have actually caused large scale health issues from water exposure. These include but not limited to temperature, taste, odour, colour, turbidity, pH, electrical conductivity, hardness, suspended and dissolved solids, Dissolved Oxygen (DO), Biochemical Oxygen Demand (BOD_5), Chemical Oxygen Demand (COD), fluoride, arsenic, nitrates/nitrites, and lead (WHO, 2006).

Solids form the most common matter to be carried along by a flowing river. These solids could be from organic or inorganic sources. Examples include refuse, tree barks, tree trunks, silt, and boulders. When evaluating water quality, suspended solids (SS) is measured in mgl^{-1} (Shaw, 1994).

Temperature is measured in °C and is a good measure for assessing the effects of temperature changes on living organisms (Shaw, 1994). Color, taste and odor are properties that are subjectively determined. They are caused by dissolved impurities either from natural sources or from the discharge of noxious substances like excreta, oil, bathwater into the water course by man (Shaw, 1994).

Electrical conductivity (EC) is a physical property of water which is dependent on the level of dissolved salts. It is measured in microsiemens per centimeter (µS cm-1) and it gives a good estimate of the dissolved salt content of a river. Turbidity refers to the cloudiness of water due to fine suspended colloidal particles of clay or silt, waste effluents or micro-organisms is measured in turbidity units (NTU). Water pH measures the concentration of hydrogen ions (H^+) and it is an indicator of the degree of acidity or alkalinity of water. On the scale, the pH of water ranges from 0 to 14 and a pH of 7 indicate a neutral solution. When pH is less than 7, the water is said to be acidic and if pH is greater than 7, the water is alkaline (Payment et al, 2003).

Dissolved Oxygen (DO) plays a key role in the assessment of water quality. Fish and other forms of aquatic life require dissolved oxygen for their sustenance. Dissolved oxygen affects the taste of water and high concentrations of dissolved oxygen in domestic supplies are encouraged by aeration. Dissolved Oxygen (O_2) is measured in $mg1^{-1}$ (Payment et al, 2003).

Biochemical Oxygen Demand (BOD_5) is the amount of Dissolved Oxygen used up from the water sample by microorganisms as they break down organic material at 20^0C over a 5-day period. It takes about 5 days to complete the test and is usually measured in mg/l (Kiely, 1998).

Chemical Oxygen Demand (COD) test determines the amount of Oxygen needed to chemically oxidize the organic materials in the water or wastewater body. The test is usually reported in mg/l and it takes about two hours to complete the test (Kiely, 1998).

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 (N) give an indication of the state of pollution by organic wastes. It is measured in $mg1^{-1}$ (Payment et al, 2003).

Biological parameters of water quality include some harmful diseases which can be transmitted by water-borne organisms. An example is Bilharzia caused by schistosoma. The common organism found in all human excreta is Escherichia coli (E.Coli) and this gives an indication of sewage pollution or pollution from human sources. This is measured in Most Probable Number (MPN) per 100ml which is determined statistically from samples (Shaw, 1994).

2.3 SURFACE WATER POLLUTION

In water quality monitoring, concern is centered on keeping impurities within safe limits. Water pollution is the contamination of aquatic environment in such a way that it interferes with the intended use of water. Thus while water may contain certain pollutants, it may not be described as polluted, provided it meets the intended use for which it was designated. Pollution is caused when a change in the physical, chemical or biological condition in the environment harmfully affect quality of human life including other animals' life and plant (Okoye et al., 2002). Water pollution may derive natural processes from sources such as weathering and soil erosion. In the vast majority of cases, however, impairment of water quality is either directly or indirectly the result of human activities. Industrial, sewage, municipal wastes are being continuously added to water bodies hence affecting the physicochemical quality of water making them unfit for use of livestock and other organisms (Pandey, 2005).

Stream water pollution is broadly categorized into Point and non-point sources. Point sources discharge pollution from specific sources such as drain pipes, ditches, or sewer outfalls. Examples of point sources are factories, power plants, sewage treatment plants, underground coal mines and oil wells. Non-point sources or diffused sources on the other hand have no specific location where they discharge into a principal body of water. Examples of non-point sources of pollution include run off from farm fields and feed lots, golf courses, lawns and gardens, construction sites logging areas, roads, streets and parking lots.

Chapman (1996) asserts that an important difference between a point source and a diffused source is that a point source may be collected, treated or controlled. Non-point sources of pollution pose a major challenge to environmental management due to the diverse sources of pollution and multiple and often complicated pathways of pollutant transport. Nitrogen (N) and Phosphorus (P) inputs from agricultural fields and urban lawns greatly increase the N and P pollution in agricultural and urban watersheds (Zhu et al., 2008).

In less developed countries, many rivers and streams are heavily polluted due to anthropogenic activities (Jonnalagadda and Mhere, 2000). In Malaysia for example, forty-two (42) of fifty (50) major streams are reported to be "ecological disasters". Residues from palm oil and rubber manufacturing along with heavy erosion from logging of tropical rainforests have destroyed all higher forms of life in most of the STREAM' (Cunningham and Saigo, 2005).

A study by Bichi and Anyata (1999) revealed that three major streams in the Kano basin - The Salanta, Challawa and Kano streams had been heavily polluted by the discharge of industrial effluents from the Sharada and Challawa industrial estates. Though these streams were being used for water supply and fishing at the time of the study, the quality of the water was found to be unsuitable for these purposes (Bichi and Anyata, 1999).

Similarly, a study to look at the effect of anthropogenic activity on water quality of the Odzi River, concluded that water quality in the upper reaches of the Odzi River was medium to good. After collecting and analyzing water samples from six (6) sampling sites for nine (9) months, the results showed that water quality dwindled due to seepage from abandoned mine dumps and discharges from farm lands.

Another study of the impact assessment of industrial influent on the Alaro River in Nigeria was carried out to assess the water quality upstream and downstream after the point of influent discharge with the view to determining the effect of industrial influent on water quality. It was realized from the study that the levels of most of the water quality parameters in the influent exceeded the influent guidelines for discharge into surface water. Water quality of the Alaro River were adversely affected and impaired by the discharge of industrial effluents. Furthermore, levels of parameters downstream were significantly elevated and the quality of influent did not meet requirements to be discharged into surface water (Fakayode, 2005).

2.4 WASTE EFFLUENTS FROM SLAUGHTER HOUSES

One of the greatest threats to surface water quality and general environmental safety and health is the waste from slaughterhouses also known as abattoirs. This is because they pollute all phases of the environment namely land, water and air. Wastes emanating from slaughtered animals are basically in solid and liquid states. However, the gases and the odor emitted from putrefying wastes become very offensive to the nostrils.

2.4.1 Characterization of Slaughterhouse Wastes

Wastes from slaughterhouses include fat, grease, hair, feathers, flesh, manure, grit and undigested feed, blood, bones, and the process or wastewater (Bull et al, 1982). A World Bank report of 1998 informs that the total amount of waste produced per animal (cow) slaughtered is approximately 35% of the animal weight. The matured animal weighs 400kg (thin), 550kg (moderate) or 750kg (extremely fat). Scahill, 2003, also informed that if a cow weighs 400kg, the carcass would be about 200kg after slaughter (50%). After passing through the butcher, it looses about one-third in fat and bone. So, a 400kg live weight animal should give 140kg (35%) of edible meat.

Gannon et al., (2004) also showed from studies carried out by them that each cow slaughtered produces 13.6kg of blood (with bovine blood density ranging between 0.01g/cc – 0.15g/cc). Moreover, the amount of water that is required for the rendering (processing) of slaughtered animals ranges from 1.5 - 10m^3/tonne of product for hogs, 2.5 - 40 m^3/tonne of product for cattle and 6 - 30 m^3/tonne of product for poultry. Scahill, (2003), believes 2.5m^3 of water is used to process each cow slaughtered. Verheijen et al, (1996), also informed from their studies that for every tonne of carcass weight, a slaughtered beef produces 5.5kg of manure (not including rumen contents or stockyard manure) and 100kg of paunch manure (partially digested food).

2.4.2 The Nigerian Experience

Improper management and supervision of the activities of abattoir operators in Nigeria is a source of great risk to public health. Most abattoirs are located near water bodies because of the high demand for water needed for the processing. Not only is most of the animal blood and wash water released untreated into the flowing river, consumable parts of the slaughtered animal are washed with water drawn from the water or the beef is washed directly into the flowing water (Adelegan, 2002). A catalogue of risks to which the environment and people are exposed to is derivable from the following facts:

(a) Raw blood has a COD of 375,000mg/L (Tritt et al, 1992) and the impact which such a pollutant has on the dissolved oxygen content of the water body can only be imagined considering the number of animals slaughtered per day with the attendant volume of blood released.

(b) Due to improper waste disposal systems, zoonotic diseases (i.e. animal diseases that are transmitted to humans) are yet to be controlled in 80% of the public abattoirs in Nigeria (Cadmus et al, 1999). Such diseases include Tuberculosis, Coli Bacillosis, Salmonellosis, Brucellosis and Helminthes.

In a study conducted by Sangodoyin and Agbawhe on five abattoirs in Ibadan, it was shown that although pH levels were within acceptable range, all other standards were found to be in excess of 2000mg/l, suspended solids were between 590 to 1050 times the acceptable limits and phosphate levels ranged from 115-175 mg/l. Nitrate levels were not as extreme but all the sites were within six times the general discharge standard of 20mg/l. BOD and metals were not determined in the study for surface water.

The downstream water quality parameters showed that river bodies were well able to assimilate the pollutants without significant modification of the aquatic ecosystem. At 500m downstream, COD levels were similar to those upstream. The groundwater near two slaughterhouses was however adversely impacted through abattoir wastewater leachates. The wastewater samples were characterized by high pH, Ca, Mg, Na and Chlorides. It was found however that the soil matrix removed solids and nitrates well. Comparatively, in a study conducted on some abattoirs by Mittal in Quebec, Canada, the COD-TS was found to be between 2333-8620mg/l; SS was between 736-2099mg/l, Nitrogen and Phosphorus were 6.0 and 2.3g/l of COD. The COD of fresh blood that is universally put at 375, 000mg/l was compared to the COD of manure put at 15,000-30,000 mg/l.

2.5 WASTEWATER AND SEWAGE DISCHARGE EFFLUENTS

Waste water and sewage is a term applied to any type of water or waste that has been utilized in some capacity that can negatively impact the quality of the water and the environment. Any water that has been adversely affected in quality due to human activities can be regarded as wastewater (Oyebode and Afe, 2015). According to Ichobanoglous et al., (2003), every community produces both liquid and solid waste and air emissions. The liquid waste is essentially the water supply of the community after it has been used in a variety of applications. Depending on their origin, wastewaters can be classed as sanitary, commercial, industrial or surface runoff.

Sanitary Sewage dispense water from residences and institutions carrying body wastes, ablution wastes, food preparation wastes, laundry wastes and other waste products of normal living, is classed as domestic or sanitary sewage. Commercial Wastes are liquid-carried wastes from stores and service establishment serving the immediate community, termed commercial wastes are included in the sanitary or domestic sewage category if their characteristics are similar to household flows. Surface Run-Off also known as storm flow or overland flow is that portion of precipitation that runs rapidly over the ground surface to a defined channel (Punmia et al., 2007).

Municipal wastewater contains a variety of inorganic substances from domestic and industrial sources. Pathogenic virus, bacteria, protozoa and helminthes may be present in raw municipal wastewater at certain levels and will survive in the environment for long periods, as pathogenic bacteria will be present in wastewater at much lower levels than the coliform group of bacteria, which are much easier to identify and enumerate. Escherichia coli are the most widely adapted indicator of faecal pollution and they can also be isolated and identified fairly simply with their numbers usually being given in the form of Faecal coliforms (Fc) 100ml of wastewater (Punmia et al., 2007).

Research studies have shown that waste effluents from wastewater and sewage discharge leading to water pollution has become an issue of considerable public and scientific concerns in the light of evidence of their extreme toxicity to human health and ecosystems. Uncontrolled domestic wastewater discharge into streams and streams without any form of treatment has resulted in eutrophication of the water bodies as evidence by substantial algal bloom; dissolve oxygen depletion in the subsurface water leads to large fish kill and other oxygen requiring organisms (Qadir et al., 2008; Pandey, 2006). Sewage discharge into the environment with enhanced concentration of nutrients, sediments and toxic substances may have a serious negative impact on the quality and life forms of the receiving water body when discharged untreated or partially treated (Schulz and Howe, 2000).

Davis et al., (2008) were of the opinion that when a biodegradable organic waste is discharged into an aquatic ecosystem such as stream, estuary or lake, oxygen dissolved in the water is consumed due to the respiration of microorganisms that oxidize the organic matter. The more the biodegradable a waste is, the more rapid is the rate of its oxidation and the corresponding consumption of oxygen. Hence the organic content of waste waters is usually measured in terms of the amount of oxygen consumed during its oxidation. In an aquatic ecosystem, a greater number of species of organisms are supported when the dissolved oxygen concentration is high. It was observed that oxygen depletion due to waste discharge has the effect of increasing the numbers of decomposer organisms at the expense of others. When oxygen demand of a waste is so high as to eliminate all or most of the dissolute oxygen from a stretch of a water body, organic matter degradation occurs through the activities of anaerobic organisms, which do not require oxygen (Mosley et al (2004).

Mathuhu et al, (2000), found out that water pollution due to discharge of untreated industrial effluents into a body of water is a major problem in the global context. The problem of water pollution is being experienced by both developing and developed countries. Human activities give rise to water pollution by introducing various categories of substances or waste into a water body. The more common types of polluting substances include; pathogenic organisms, oxygen demanding organic substances, plant nutrients that stimulate algal blooms, inorganic and organic toxic substances (Cornish and Mensahh, 1999).

Other impacts of discharging untreated or inadequately treated wastewater into the environment include increased nutrient levels (eutrophication), often leading to algal blooms; depleted dissolved oxygen, sometimes resulting in fish kills; destruction of aquatic habitats with sedimentation, debris, and increased water flow; and acute and chronic toxicity to aquatic life from chemical contaminants, as well as bio-accumulation and bio-magnification of chemicals in the food chain (Okoh, et al., (2007).

Water associated diseases which are associated with ingestion of contaminated water with human or animal faeces are the major source of faecal microorganisms, including pathogens and microbial intestinal infections such as cholera, typhoid fever and bacillary dysentery (Cabral, 2010). These diseases caused by bacteria, viruses and protozoa are the most common health risks associated with contaminated water sources (WHO, 2008). These contain wide varieties of viruses, bacteria, and protozoa that may get washed into drinking water supplies or receiving water bodies. Virus concentrations present in raw water receiving faecal matter from humans are often high, although these viruses cannot reproduce in water; however, they are still capable of causing diseases when ingested even at low doses (Okoh et al., 2010).

Many microbial pathogens in wastewater can cause chronic diseases with costly short and long-term effects, such as degenerative heart disease and stomach ulcer. Bacteria cause a wide range of infections, such as diarrhea, dysentery, skin and tissue infections. Disease-causing bacteria found in water include different types of bacteria, such as E. coli, Listeria, Salmonella, Leptospirosis, Vibrio and Campylobacter (Absar, 2005). The most common and widespread health risks associated with drinking poor quality water in developing countries are of biological origin and diarrhoeal disease globally has been attributed to unsafe water, sanitation and water hygiene.

2.6 DISSOLVED OXYGEN

Dissolved oxygen refers to the level of free, non-compound oxygen present in water or other liquids. It is an important parameter in assessing water quality because of its influence on the organisms living within a body of water. In limnology (the study of lakes), dissolved oxygen is an essential factor second only to water itself (Wetzel, 2001). A dissolved oxygen level that is too high or too low can harm aquatic life and affect water quality. Non-compound oxygen, or free oxygen (O_2), is oxygen that is not bonded to any other element. Dissolved oxygen is the presence of these free O_2 molecules within water. The bonded oxygen molecule in water (H_2O) is in a compound and does not count toward dissolved oxygen levels (Wetzel, 2001).

Dissolved oxygen enters water through the air or as a plant by-product through photosynthesis. From the air, oxygen can slowly diffuse across the water's surface from the surrounding atmosphere, or be mixed in quickly through aeration, whether natural or man-made (EPA, 2012). The aeration of water can be caused by wind (creating waves), rapids, waterfalls, ground water discharge or other forms of running water.

In a stable body of water with no stratification, dissolved oxygen will remain at 100% air saturation. 100% air saturation means that the water is holding as many dissolved gas molecules as it can in equilibrium. At equilibrium, the percentage of each gas in the water would be equivalent to the percentage of that gas in the atmosphere – i.e. its partial pressure. The water will slowly absorb oxygen and other gasses from the atmosphere until it reaches equilibrium at complete saturation.

2.6.1 Importance of Dissolved Oxygen

Dissolved oxygen is necessary to many forms of life including fish, invertebrates, bacteria and plants. These organisms use oxygen in respiration, similar to organisms on land. Fish and crustaceans obtain oxygen for respiration through their gills, while plant life and phytoplankton require dissolved oxygen for respiration when there is no light for photosynthesis.

Microbes such as bacteria and fungi also require dissolved oxygen. These organisms use DO to decompose organic material at the bottom of a body of water. Microbial decomposition is an important contributor to nutrient recycling. However, if there is an excess of decaying organic material (from dying algae and other organisms), in a body of water with infrequent or no turnover (also known as stratification), the oxygen at lower water levels will get used up quicker (EPA, 2013).

2.6.2 Solubility of Dissolved Oxygen

The actual amount of dissolved oxygen (in mg/L) will vary depending on temperature, pressure and salinity (Wetzel, 2001). Firstly, the solubility of oxygen decreases as temperature increases (Wetzel, 2001). This means that warmer surface water requires less dissolved oxygen to reach 100% air saturation than deeper, cooler water. For example, at sea level (1atm or 760mmHg) and 4°C (39°F), 100% air-saturated water would hold 10.92 mg/L of dissolved oxygen. But if the temperature were raised to room temperature, 21°C (70°F), there would only be 8.68 mg/L DO at 100% air saturation (Wetzel, 2001). Secondly, dissolved oxygen decreases exponentially as salt levels increase (Wetzel, 2001). That is why, at the same pressure and temperature, saltwater holds about 20% less dissolved oxygen than freshwater. Thirdly, dissolved oxygen will increase as pressure increases. This is true of both atmospheric and hydrostatic pressures (Wetzel, 2001).

According to Henry's Law, the dissolved oxygen content of water is proportional to the percentage of oxygen (partial pressure) in the air above it (EPA, 2012). As oxygen in the atmosphere is about 20.3%, the partial pressure of oxygen at sea level (1atm) is 0.203atm. Thus the amount of dissolved oxygen at 100% saturation at sea level at 20°C is 9.03 mg/L.

2.6.3 Measurement of Dissolved Oxygen

Dissolved oxygen is usually reported in milligrams per liter (mg/L) or as a percentage of air saturation. However, some studies will report DO in parts per million (ppm) or in micromoles (umol). 1mg/L is equal to 1ppm. The relationship between mg/L and percentage air saturation has been discussed above, and varies with temperature, pressure and salinity of the water. One micromole of oxygen is equal to 0.022391 milligrams, and this unit is commonly used in oceanic studies. Thus 100umol/L O_2 is equal to 2.2mg/L O_2 (EPA, 2012).

2.6.4 Calculating DO from Percentage Air Saturation

To calculate dissolved oxygen concentrations from air saturation, it is necessary to know the temperature and salinity of the sample. Barometric pressure has already been accounted for as the partial pressure of oxygen contributes to the percent air saturation (EPA, 2012). Salinity and temperature can then be used in Henry's Law to calculate what DO concentration would be at 100% air saturation. However, it is easier to use an oxygen solubility chart. These charts show the dissolved oxygen concentration at 100% air saturation at varying temperatures, and salinities. This value can then be multiplied by the measured percent air saturation to calculate the dissolved oxygen concentration (EPA, 2012).

2.7 SELF-PURIFICATION OF STREAM

The self-purification of natural water systems is a complex process that often involves physical, chemical, and biological processes working simultaneously. The amount of dissolved Oxygen (DO) in water is one of the most commonly used indicators of a river health. As DO drops below 4 or 5 mg/L the forms of life that can survive begin to be reduced. A minimum of about 2.0 mg/L of dissolved oxygen is required to maintain higher life forms. A number of factors affect the amount of DO available in a river. Oxygen demanding wastes remove DO; plants add DO during day but remove it at night; respiration of organisms removes oxygen. In summer, rising temperature reduces solubility of oxygen, while lower flows reduce the rate at which oxygen enters the water from atmosphere.

2.7.1 Factors Affecting Self Purification

Dilution: When sufficient dilution water is available in the receiving water body, where the wastewater is discharged, the DO level in the receiving river may not reach to zero or critical DO due to availability of sufficient DO initially in the river water.

Current: When strong water current is available, the discharged wastewater will be thoroughly mixed with river water preventing deposition of solids. In small current, the solid matter from the wastewater will get deposited at the bed following decomposition and reduction in DO.

T6emperature: The quantity of DO available in river water is more in cold temperature than in hot temperature. Also, as the activity of microorganisms is more at the higher temperature, hence, the self-purification will take less time at hot temperature than in winter.

Sunlight: Algae produces oxygen in presence of sunlight due to photosynthesis. Therefore, sunlight helps in purification of river by adding oxygen through photosynthesis.

Rate of Oxidation: Due to oxidation of organic matter discharged in the river DO depletion occurs. This rate is faster at higher temperature and low at lower temperature. The rate of oxidation of organic matter depends on the chemical composition of organic matter.

2.7.2 Oxygen Sag Analysis

The oxygen sag or oxygen deficit in the river at any point of time during self-purification process is the difference between the saturation DO content and actual DO content at that time.

$$\text{Oxygen deficit, } D = \text{Saturation DO} - \text{Actual DO} \qquad (2.1)$$

The saturation DO value for fresh water depends upon the temperature and total dissolved salts present in it; and its value varies from 14.62 mg/L at $0^{o}C$ to 7.63 mg/L at $30^{o}C$, and lower DO at higher temperatures. The DO in the river may not be at saturation level and there may be initial oxygen deficit 'D_0'. At this stage, when the influent with initial BOD load L_0, is discharged in to stream, the

DO content of the stream starts depleting and the oxygen deficit (D) increases. The variation of oxygen deficit (D) with the distance along the river, hence with the time of flow from the point of pollution is depicted by the 'Oxygen Sag Curve'. The major point in sag analysis is point of minimum DO, i.e., maximum deficit. The maximum or critical deficit (D_c) occurs at the inflexion points of the oxygen sag curve (Kiely, 1998).

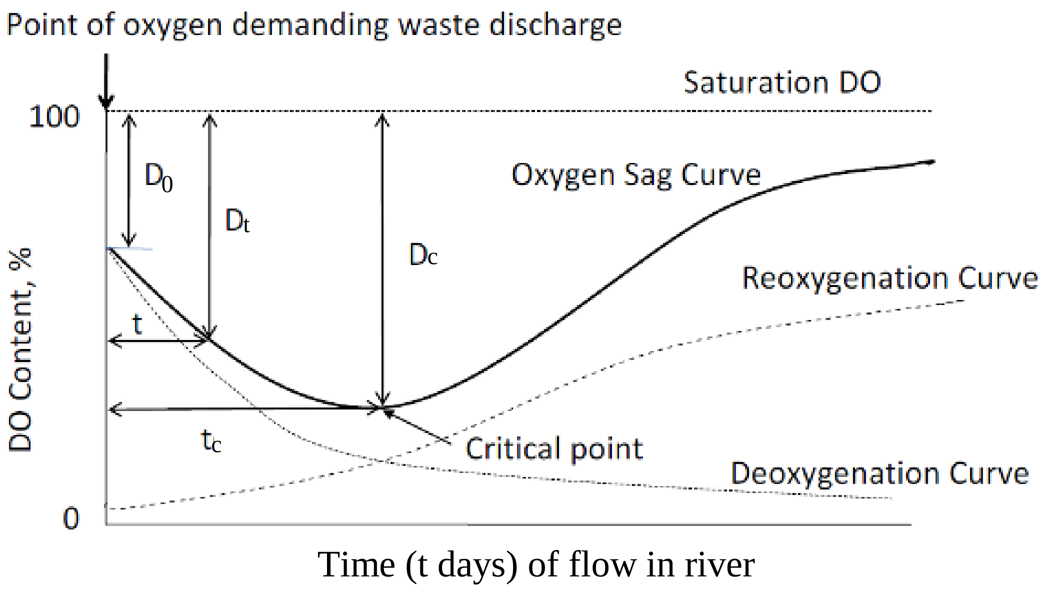


Figure 2.1: Variation of DO with time of flow (Kiely, 1998)

2.7.3 Deoxygenation and Reoxygenation Curves

When wastewater is discharged into the stream, the DO level in the river goes on depleting. This depletion of DO content is known as deoxygenation. The rate of deoxygenation depends upon the amount of organic matter remaining (L_t), to be oxidized at any time t, as well as temperature (T) at which reaction occurs. The variation of depletion of DO content of the stream with time is depicted by the deoxygenation curve in the absence of aeration. The ordinates below the deoxygenation curve indicate the oxygen remaining in the natural stream after satisfying the bio-chemical demand of oxygen (Kiely, 1998).

When the DO content of the stream is gradually consumed due to BOD load, atmosphere supplies oxygen continuously to the water, through the process of re-aeration or reoxygenation, i.e., along with deoxygenation, re-aeration is a continuous process.

The rate of re-oxygenation depends upon:

i. Depth of water in the river: more for shallow depth.
ii. Velocity of flow in the river: less for stagnant water.
iii. Oxygen deficit below saturation DO: because solubility rate depends on difference between saturation concentration and existing concentration of DO.
iv. Temperature of water: solubility is lower at higher temperature and also saturation concentration is less at higher temperature.

2.7.4 DO Sag Equation (Streeter - Phelps)

The classical way of solving for the dissolved oxygen sag equation is the Streeter-Phelps equation, which dates back to 1925 (Streeter-Phelps, 1925; Tchobanoglous and Schroeder, 1984). The analysis of oxygen sag curve can be easily done by superimposing the rates of deoxygenation and reoxygenation as suggested by the Streeter - Phelps analysis. The rate of change in the DO deficit is the sum of the two reactions as explained in Equations (2.2a) and (2.2b) respectively:

$dt = f$ (deoxygenation and reoxygenation) (2.2a)

Or $\frac{dD_t}{dt} + R'L_t - R'D_t$ (2.2b)

Where,

D_t = DO deficit at any time t,

Lt = amount of first stage BOD remaining at any time t

K' = BOD reaction rate constant or deoxygenation constant (to the base e)

R' = Reoxygenation constant (to the base e)

t = time (in days)

dD_t/d_t = rate of change of DO deficit

Now, $L_t = L_o.e^{-K't}$ (2.3)

Where, L_o = BOD remaining at time, t = 0

Hence, $$\frac{dD_t}{dt} = K'L_o.e^{-K't} - R'D_t \quad (2.4)$$

Or $\frac{dD_t}{dt} + R'D_t = K'L_o.e^{-K'L}$ (2.5)

This is first order, first degree differential equation and the solution of this equation is as given in Equation (2.6).

$$D_t = \frac{K'L_0}{R' - K'}[e^{-K't} - e^{-R't}] + D_0.e^{-K't} \quad (2.6)$$

Changing base of natural log to logarithm in base10, the equation can be expressed as:

$$D_t = \frac{KL_0}{R-K}[10^{-K\prime t} - \quad 10^{Rt}] + D_0.10^{-K\prime t} \tag{2.7}$$

Where,

K = BOD reaction rate constant, to the base 10

R = Reoxygenation constant to the base 10

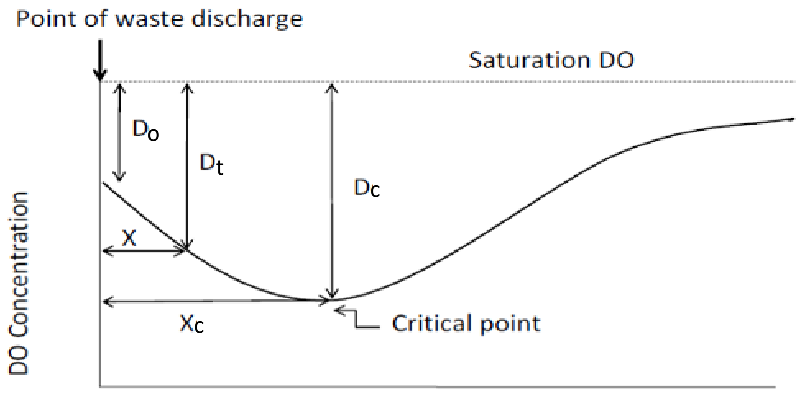
D_o = Initial oxygen deficit at the point of waste discharge at time t = o

t = time of travel in the stream from the point of discharge = x/u

x = distance along the stream

u = stream velocity

This is Streeter-Phelps oxygen sag equation. The graphical representation of this equation is shown in Figure 2.2.



Distance downstream

Figure 2.2 Variation of DO Sag curve of Streeter-Phelps equation

Note: Deoxygenation and reoxygenation occurs simultaneously. After critical point, the rate of re-aeration is greater than the deoxygenation and after some distance the DO will reach to original level and river will not have any effect due to addition of wastewater. At time t=0 and at x = 0.

2.7.5 Critical DO deficit (D_c) and distance X_c

The value of D_c can be obtained by putting $dD_t/dt = 0$ in Equation (2.5) hence,

$$D_c = \frac{K'}{R'} L_o . e^{-K' t_c} \tag{2.8}$$

$$D_c = \frac{K}{R} L_o . 10^{-K t_c} \tag{2.9}$$

Where, t_c is time required to reach the critical point.

The value of t_c can be obtained by differentiating Equation (2.6) or (2.7) with respect to t and setting $dD_t/dt = 0$.

Therefore, $$t_C = \frac{1}{R' - K'} \log e \frac{R'}{K'} \left[1 - D_O . \frac{(R' - K')}{K' L_O} \right] \tag{2.10}$$

Or $$t_C = \frac{1}{R - K} \log 10 \frac{R}{K} \left[1 - D_O . \frac{(R - K)}{K L_O} \right] \tag{2.11}$$

The distance X_c is given by $X_c = t_c . u$

Therefore, the critical time, lag time or time of concentration T_c can expressed using NRCS lag Equation which is as follows:

$$T_c = \frac{L}{0.6} \; and \; L = \frac{\ell^{0.8}(S+1)^{0.7}}{1900 Y^{0.5}} \tag{2.12}$$

Where,

L = lag, hr

$\ell = Flow\ lenght, ft$

Υ = Average land slope of teh watershed in percent (%)

S = Maximum potential retention in = $\frac{1000}{CN} - 10$

NRCS 1985 (Haan, Barifield and Hayes, (1994, McCuen, 1998).

The deoxygenation constant K, is obtained by laboratory test or field tests, and varies with temperature as given in Equation (2.13) (Peavy et al., 1985):

$$K_T = K_{20}.(\theta)^{T-20} \quad (2.13)$$

Where, θ varies with the temperature = 1.056 in general or 1.047 for 20°C to 30°C temperature, and 1.135 for 4°C to 20°C

K = 0.1 to 0.3 for municipal sewage, base 10,

= 0.23 to 0.70 for municipal sewage, base e

The reoxygenation constant R also varies with the temperature and can be expressed in Equation (2.14).

$$R_T = R_{20}.(1.024)^{T-20} \quad (2.14)$$

Where, R'/R = 2.303

R = 0.15 to 0.20 for low velocity large stream

= 0.20 to 0.30 for normal velocity large stream

= 0.10 to 0.15 for lakes and sluggish stream

The ratio of R/K (or R'/K') is called the self-purification constant f_s and it is equal to 0.50 to 5.0 (Peavy et al., 1985).

2.7.6 Re-aeration Constant K_r using O' Connor Model

The Streeter-Phelps oxygen sag equation can also be expressed as:

$$D_t = \frac{K_d L_o}{K_r - K_d}\left(e^{-K_d t} - e^{-K_r t}\right) + D_o\left(e^{-K_r t}\right) \quad (2.15)$$

Where D_t = oxygen deficit in the river at time t,

L_o = initial ultimate BOD at mix,

D_o = initial oxygen deficit at mix,

K_d = de-oxygenation rate constant,

K_r = re-aeration rate constant,

t_c = critical time.

The re-aeration constant, K_r is determined by tracer study using O' Connor model as:

$$K_r = \frac{3.9V^{0.5}\sqrt{(1.037)^{(T-20)}}}{H^{\frac{3}{2}}} \quad (2.16)$$

Where V = mean stream velocity

H = average depth of river

T = temperature (at 20°C).

Since the value of T is 20°C, Equation (2.16) can also be written as:

$$K_r = \frac{3.9V^{0.5}}{H^{\frac{3}{2}}} \qquad (2.17)$$

2.7.7 De-oxygenation constant K_d and ultimate (BOD) L_o, using Thomas Slope Method

The linear form of Thomas Slope Equation is expressed as,

$$\left(\frac{t}{y}\right)^{\frac{1}{3}} = (KL_o)^{\frac{1}{2}} + \left(\frac{K^{\frac{2}{3}}}{6L_o^{\frac{1}{3}}}\right)t \qquad (2.18)$$

Modifying Equation (2.18) by putting $K = 2.3\ K_d$ yields:

$$\left(\frac{t}{y}\right)^{\frac{1}{3}} = (2.3K_dL_o)^{\frac{1}{2}} + \left(\frac{K_d^{\frac{2}{3}}}{2.43L_o^{\frac{1}{3}}}\right)t \qquad (2.19)$$

Comparing Equation (2.19) with the straight line formula, $Z = bt + a$, gave the following relationships:

$$Z = \left(\frac{t}{y}\right)^{\frac{1}{3}} \qquad (2.20)$$

Intercept, $$a = (2.3K_dL_o)^{\frac{1}{2}} \qquad (2.21)$$

Slope, $$b = \left(\frac{K_d^{\frac{2}{3}}}{2.43L_o^{\frac{1}{3}}}\right) \qquad (2.22)$$

Plotting $\left(\frac{t}{y}\right)^{\frac{1}{3}}$ as a function of t, the slope b and the intercept a of the line of best fit can be used to estimate the values of K_d and L_o as follows:

$$K_d = (2.61)\frac{b}{a} \qquad (2.23)$$

$$L_o = \frac{1}{2.3K_d a^3} \quad (2.24)$$

where y = exerted BOD,

K_d = de-oxygenation rate constant,

L_o = ultimate BOD,

a, and b are constants

The values of the function of exerted BOD with time $\left(\frac{t}{y}\right)^{\frac{1}{3}}$ can be obtained from the application of BOD_5 values and time (days) from experimental analysis

2.8 IMPACT OF WASTE EFFLUENTS ON WATER BODIES

Assessing the danger in the use of water bodies as sink for industrial influent, Anetor et al., (2003), emphasized that population explosion, hazardous rapid urbanization, industrial and technological expansion, energy utilization and wastes generation from domestic and industrial sources have rendered many water resources unwholesome and hazardous to man and other living resources.

According to Perry et al, (2007), nitrogen or phosphorus or both may cause aquatic biological productivity to increase, resulting in low dissolved oxygen and eutrophication of lakes, stream, estuaries and marine waters. Mott and Associates (2001), stressed that many serious human diseases are caused by water borne pathogens. In developed countries, the spread of water borne disease has been largely arrested through the introduction of water and sewage facilities and through hygiene. But in many developing countries, such diseases are still major causes of death especially among the young ones.

The measure of the acid balance of a Solution (pH) changes can trip the ecological balance of the aquatic system and excessive acidity can result in the hydrogen sulfide. The pH of water affects the solubility of many toxic and nutritive chemicals; hence, the availability of the substances to aquatic organisms is affected. Mosley et al (2004) observed that water with $pH > 8.5$ indicates that the water is hard. Most metals become more water soluble and more toxic with increase in acidity. Toxicity cyanides and sulfides also increase with a decrease in pH. The content of toxic forms of ammonia to the untoxic form also depends on pH dynamics. Examining the place of electrical conductivity in determining the quality of water, Tariq et al (2006), opined that it is a function of total dissolved solids known as ions concentration which determine the quality of water.

Mosley et al (2004), were of the opinion that electrical conductivity is a measure of how much total salt (Inorganic ions such as sodium, chloride, magnesium, calcium) is present in the water. According to them, the more ions the higher the conductivity. Conductivity itself is not of human aquatic health concern, but because it is easily measured, it can serve as an indicator of other water quality problem. If the conductivity of a stream suddenly increases, it indicates that there is a source of dissolved ions in the vicinity. Therefore, conductivity measurements can be used as a quick way to locate potential water quality problems.

All natural waters contain some dissolved solids due to the dissolution and weathering of rocks and soils. Some, not the entire dissolved solids, however, act potentially unhealthy. Nadia (2006) noted that discharge of waste water with a high total dissolved solids level would have adverse impact on aquatic life, rendering the receiving water unfit for drinking and domestic purposes. It also reduces crop yield if used for irrigation, as well as exacerbate corrosion in water networks.

Nyanda (2000), was of the view that plant nutrients, particularly nitrogen and phosphorus are important determinants of the biological productivity of aquatic ecosystems. Industrial effluences, animal waste and sewage contain high levels of nitrogen and phosphor using – other major sources of fertilizer run off from urban and agricultural catchments. While the long term cultural entrophication accelerates, the natural successional progress of aquatic ecosystems towards a terrestrial system in the short term, problems arise due to cyclic occurrences of algal blooms and decay. In warm weather, nutrients stimulate rapid growth of algae and floating aquatic weeds. The water often becomes opaque and has unpleasant taste and odour. Apart from adding to nutrient content of water, addition of some forms of nitrogen and phosphorus will increase BOD and COD (Mahdieh and Amirohossein, 2009).

Increased nitrogen levels adversely affect cold water fish more than warm water ones. The result of the study carried out by Barnes et al, (1998) on sedimentation and Georgia fishes revealed that nitrogen concentrations of 0.5 mg /1 liter are toxic to rainbow trout. Through discharge of waste water, while phosphorus ends up in surface waters near the factories that use it, phosphorus is generally the limiting nutrient in fresh water systems and any increase in phosphorus usually results in more aquatic vegetation.

Agedengbe et al (2003) noted that an important pollution index of industrial waste waters is the oxygen function measured in terms of chemical oxygen demand and biological oxygen demand while the nutrients status of waste water are measured in terms of nitrogen and phosphorous. However, Ezenobi et al (2004) added that pH, temperature and total suspended solids are other important quality parameters. The influent total hardness concentrations of a chemical-biological treatment plant were found greater then the effluents (Ogunfokowokan, 1998).

In a study to assess the seasonal variation in bacterial heavy metal biosorption in a receiving river as affected by industrial effluents, Kanu et al (2006) observed an overall seasonal variation of heavy metals such as lead and zinc in the rainy season as compared to other metals for dry season. The concentrations of heavy metals were also generally low in some sample and no similar trends were observed in the control samples. Except for iron and zinc, the concentrations of the heavy metals were relatively low. Moreover, influent from the soap manufacturing plant contained significant concentrations of oil and grease amounting to 563mg.

Waste water from brewery industry originates from liquors pressed from grains and yeast recovery, and have the characteristic odour of fermented malt and slightly acidic. (Kanu et al, 2006). Ekhaise and Anyasi (2005) were of the opinion that introduction of waste water high in organic matter and essential nutrients bring about changes in the microflora. They reported high counts of bacterial population in Ikpoba River in Benin City of Nigeria receiving a brewery industrial effluent. Similar results were reported by Kanu and Others in 2006 of the effect of brewery discharge into Eziama River Aba, Nigeria.

Onwuka et al (2004) studied eighty-eight samples of the ground water near industrial effluent discharges in Enugu in order to evaluate its probability. The parameters of interest are common waste; derivable chemical constituents such as nitrates. The results showed that eight out of ten samples analysed tested that the bacteriological quality of the ground water showed evidence of sewage and industrial effluent contaminations. The identification of E. Coli in the water indicates faecal contamination. Improvement in the management of domestic wastes, such as the use of central sewer was suggested as a means of preserving the aquifer and consequently improving the quality of the ground water.

Ibekwe et al (2004) analysed the waste water in the accumulation pond and final discharge point of Nigerian Bottling company Plc. in Owerri, Nigeria to determine their bacteriological and physio-chemical characteristics. Species of organisms isolated include; staphylococcus, bacillus, lactobacillus, and streptococcus. Bacteria count after 72 hours was higher with a maximum count $6x10^7$ Cfu/ml in the final discharge point. The final discharge contained more dissolved solids which was double that of the accumulation pond. It was also found that the dissolved oxygen was slightly higher in the final discharge point than accumulation pond. Although, these findings were found to be within the permissible limits of influent discharge specified by the federal ministry of Environment in Nigeria, the consequent long term bioaccumulation effects on microbial ecosystem were not reported.

CHAPTER THREE

METHODOLOGY

3.1 STUDY AREA

This study was carried out on the Woji/Okujagu Stream in Port Harcourt Local Government Area of Rivers State. The river is cut-across by an overhead bridge around Okujagu community at the Trans-Amadi Industrial Layout in Port Harcourt. The study area is located in the Niger Delta area of south-south Nigeria between longitude 7°2'40"E and latitude 4°49'0"N.

The river is generally used for fishing and maritime activities such as building of houseboats and small ships for transportation of crude oil, goods and heavy construction equipment to various locations. However, the major activities identified around the river include the dumping of wastes from the abattoir and slaughter market (Okujagu). The abattoir is located on the upper right bank of Woji Stream, facing downstream near the Port Harcourt Zoo. The abattoir has three outdoor concrete platforms for butchering and meat rendering. Each platform is designated for a class of animal, the largest being for cattle, followed by those for goats and pigs. On a daily basis, the average numbers of animals butchered are 800 goats, 80 cattle and 30 pigs. Waste parts of the slaughtered animals and abattoir wastewater are released into the river. The slaughter complex lacks a wastewater treatment plant with very poor sanitary conditions. A nearby market also produces diverse wastes that are also disposed off into

Woji Stream. The study site and the anthropogenic activities were shown in Plates 3.1 - 3.5.

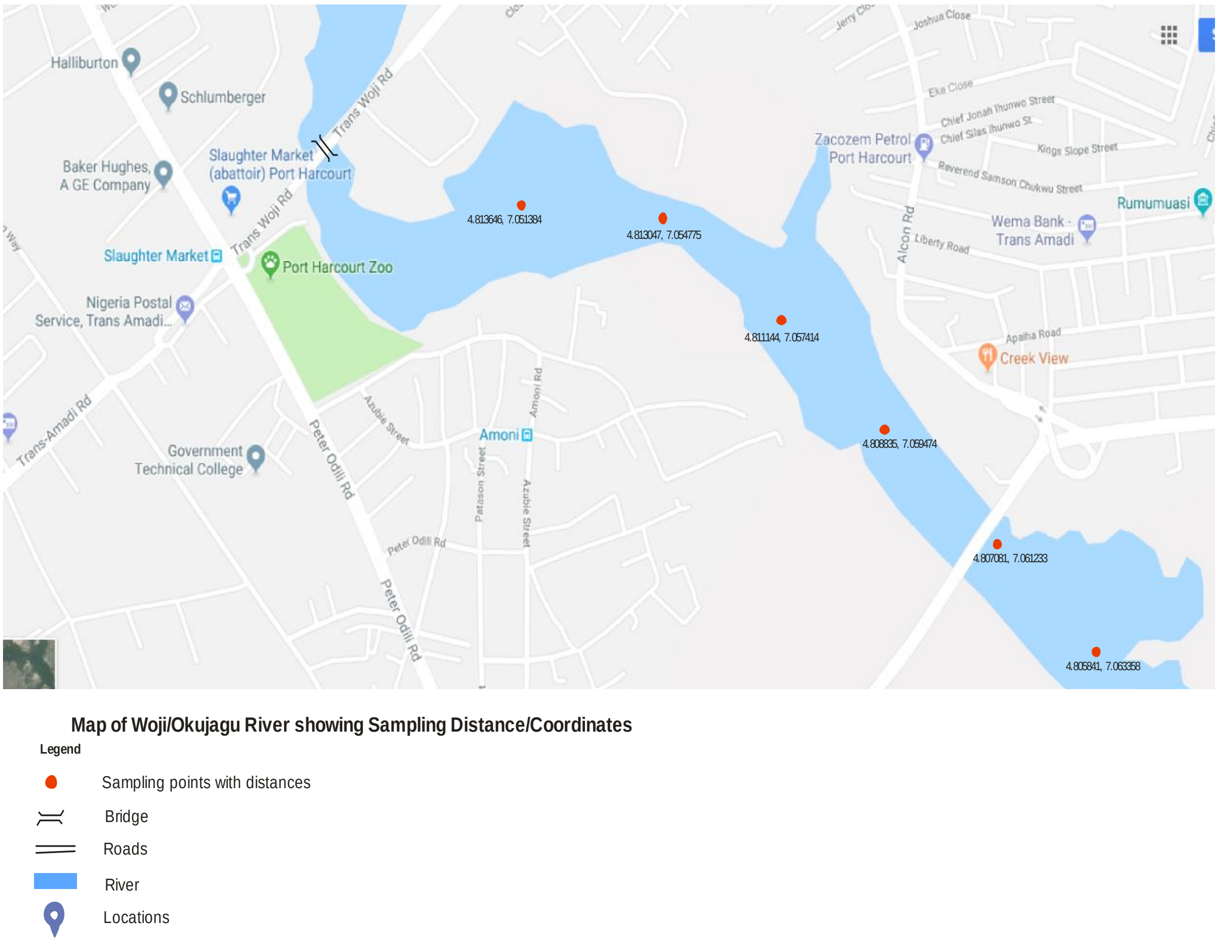


Plate 3.1: Google Map showing the Study Area

Plate 3.2: Stream Cut-across by an Overhead Bridge around Okujagu Community at the Trans-Amadi Industrial Layout in Port Harcourt

Plate 3.3: Waste Food Products from Activities of the Slaughter Market Discharged Directly into Woji/Okujagu Stream in Port Harcourt

Plate 3.4: Discharge of Effluents were Channelled into Woji/Okujagu Stream

Plate 3.5: Some Activities carried out in the Slaughter Area

3.2 SAMPLING

In order to achieve the objectives of this study, the following were carried out:

i. A site survey of a pre-selected river segment was done to observe the uses to which people put the river resource and if there is any abuse.

ii. A point source/pollution zone caused by the abattoir effluent discharge into the stream was identified.

iii. The water samples that represent the various points affected by the pollution were obtained from six (6) selected stations (stations A, B, C, D, E and F) along the stream located at 200m interval from the discharge point.

iv. The geometric and hydraulic parameters of the river segment such as depth, cross-sectional area, temperature and velocity were obtained at the points where water samples were taken.

The water samples were thereafter transported without delay to the Chemistry Laboratory, Faculty of Science, Rivers State University Nkpolu, Port Harcourt for sample analysis.

3.2.1 Sampling Design

Sampling was done using random grab sampling. The water samples were collected during the dry season (February, 2017) and wet season (August, 2017) from six (6) selected stations (stations A, B, C, D, E and F) along the stream at 200m interval upstream and downstream from the point of influent discharge.

Sampling was carried out three times during each month from each of the selected sites to improve reliability of data. Water samples were collected from the mid-width of the stream using one-litre plastic bottles that had previously been cleaned, soaked in 10% nitric acid and rinsed thrice with distilled water. Three one-litre samples were collected at each of the six sampling sites designated A - F. The full description of sampling locations is shown in Table 3.1.

Table 3.1: Description of Sampling Stations

Designation	**Sampling points**
Station A	200m upstream with respect to the point of effluent discharge.
Station B	Point of effluent discharge.
Station C	200m downstream from point of effluent discharge.
Station D	400m downstream from point of effluent discharge
Station E	600m downstream from point of effluent discharge
Station F	800m downstream from point of effluent discharge

3.2.2 Quality Control and Assurance

Quality assurance was considered during field sampling operations by taking utmost care in order to obtain representative samples. Certain parameters such as pH, temperature, Dissolved Oxygen and conductivity are best determined in-situ (Canadian Government, 1983). This is because their values can easily change within a relatively short time on isolation from its parent body.

However, it is not always practicable to take equipment to site. Adequate logistic plans must have therefore been made prior to field sampling operation so as to transport the samples to the laboratory with minimum loss of time. Some of the samples may also require chemical reagents to preserve them while some parameters of concern require that special containers (be it opaque glass or plastic as the case may be) be provided. Details of these are provided in Table 2.3. The bottles themselves have to be new and/or properly cleaned before use. This is because certain microorganisms, elements or compounds could still remain inside a container even after being thoroughly rinsed with distilled water.

3.3 GEOMETRIC AND HYDRAULIC PARAMETERS

The geometric and hydraulic parameters of the stream at each pre-selected distance location namely, river width, depth and velocity were obtained at the very points where the samples were taken. In the absence of current meter, used for obtaining velocity, a distance of 200m was marked along the riverbed and a small cork was dropped at starting point. At the very instant the leaf was dropped, a stopwatch was activated. The time it took the cork to travel the 2m-distance was then recorded in seconds. Also, the stream morphology was estimated by taking three measurements of the depth at three equally spaced intervals (A, B, C) as well as the width, D using a line (rope) tied to a 2kg pendulum bulb and fastened to a measuring tape.

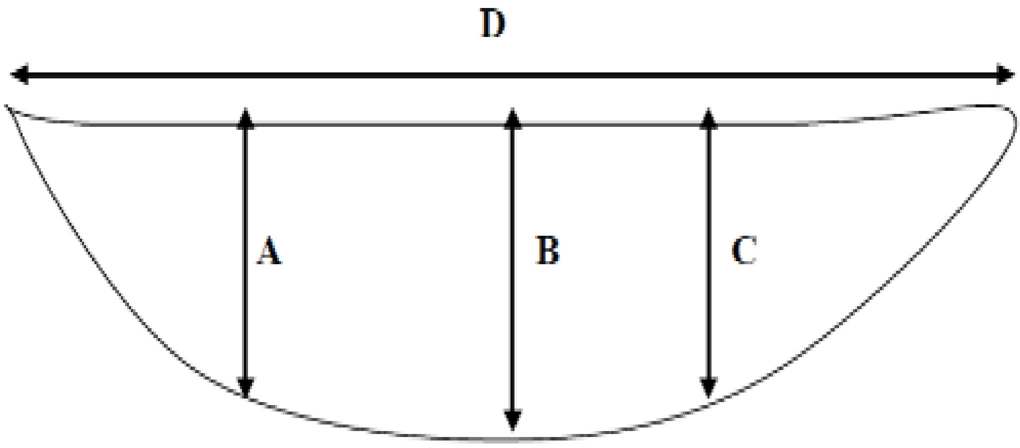


Figure 3.1: Measurement of the Geometric Parameters of the Stream

Plate 3.6: Collection of Water Samples from Woji/Okujagu Stream

Plate 3.7: Laboratory Analysis of Water Sample Obtained from Woji/Okujagu Stream

3.4 EVALUATION OF WATER QUALITY PARAMETERS

Samples were analyzed for the following physico-chemical parameters: Temperature, Turbidity, Hydrogen ion Concentration (pH), Total Dissolved Solid (TDS), Dissolved Oxygen (DO), Biochemical Oxygen Demand (BOD_5), nitrates and phosphates. The tests were conducted in accordance with the standard methods for the examination of water and waste water (APHA, 1998) as follows.

3.4.1 Temperature

Temperature was determined in situ by dipping the thermometer of 110^0C calibration range into the water and the reading is taken after 5 minutes interval (APHA, 1998).

3.4.2 Turbidity

This was measured using the sample water taken in the small tube of the turbidity meter. The switched was on and then the reading was taken from the meter (APHA, 1998).

3.4.3 Total Solids (TS)

This was measured using gravimetric method involving filtration and evaporation. Ten (10) milliliters of the samples were measured into a pre-weighed evaporating dish which was then dried in an oven at a temperature of

103 to 105°C for two and half hours. The dish was transferred into a desiccator and was allowed to cool at room temperature and was weighed.

The total solid was represented by the increase in the weight of the evaporating dish (APHA, 1998).

$$TS\ (mg/l) = \frac{(W2-W1)}{V} \tag{3.1}$$

Where W_1 = initial weight of evaporating dish (mg)

W_2 = Final weight of the dish (dish + residue) (mg)

V = Volume of sample filtered (L)

3.4.4 Total Dissolved Solids (TDS)

This was also determined by Gravimetric Method. A portion of water was filtered out and 10ml of the filtrate was measured into a pre-weighed evaporating dish. Following the procedure for the determination of total solids above, the total dissolved solids content of the water was calculated (APHA, 1998).

$$TS\ (mg/l) = \frac{(W2-W1)}{V} \tag{3.2}$$

Where W_1 = initial weight of evaporating dish (mg)

W_2 = Final weight of the dish (dish + residue) mg

V = Volume of sample filtered (L)

3.4.5 Total Suspended Solids (TSS)

This is calculated as follows: $TSS = TS - TDS$ (3.3)

3.4.6 Electrical Conductivity (EC)

This was done using a conductivity meter. The probe was dipped into the container of the samples until a stable reading was obtained and recorded (APHA, 1998).

3.4.7 The pH

The pH was carried out in-situ at the site of sample collection using electronic portable pH meter. The pH meter was calibrated with phosphate buffer of known pH. It uses electrodes that are free from interference. At constant temperature, a pH change produces a corresponding change in the electrical property of the solution. This change was read by the electrode and the accuracy was the greatest in the middle pH ranges (APHA, 1998).

3.4.8 Dissolved Oxygen (DO)

This was done using Winkler's method (APHA, 1998). The samples were placed in the DO bottles ensuring that no air was trapped. A fifth DO bottle was filled with distilled water and acted as control for the experiment. To each bottle, the stopper was removed and the 2ml of manganous sulphate solution and alkali acid iodide solution were added in quick succession and the stopper carefully replaced. The contents were mixed several times and the precipitate allowed to settle halfway. They were then mixed again and the precipitate allowed to settle halfway for the second time.

Two (2)ml of concentrated sulphuric acid was added to each bottle, the stopper replaced and the contents mixed again until all the precipitate dissolved.

Two hundred and three (203)ml was measured from the bottle and transferred to an Erlenmeyer flask and titrated against standard sodium thiosulphate solution till the colour changed to pale yellow. One (1)ml of starch indicator solution was then added and titration continued till the blue colour disappeared. This was done for each sample and the blank. The dissolved oxygen concentration in mg/l was reported as the ml of titrant used (APHA, 1998).

3.4.9 Biochemical Oxygen Demand (BOD_5)

The method involves filling the samples to overflowing, in an airtight bottle of the specified size and incubating it at the specified temperature for 5days. Dissolved oxygen (DO) was measured initially and after incubation and the BOD were computed from the difference between initial and final (DO). Because the initial (DO) was determined shortly after the dilutions was added, all oxygen uptake occurring after this measurement was included in the BOD measurement. One milliliter (ml) of $MgSO_4$, $CaCl_2$, phosphate buffer, $FeCl_3$ were added to 1L of water. The solution was then shaken thoroughly to saturate the dissolved oxygen. This solution was used to dilute samples. One hundred milliliters (100ml) of the samples were measured into different one Liter flasks and were made up to (1L) mark with the dilution water previously prepared. The dilution sample solution was then poured into BOD bottles and subsequently incubated at 20ºC in the dark for 5 days (APHA, 1998).

Determination of initial dissolved oxygen: Three hundred milliliters (300ml) BOD bottles were filled with the diluted samples previously prepared and the initial dissolved oxygen (DO) was determined using the Winkler's method (APHA, 1998).

Determination of Final Dissolved Oxygen: After incubation for 5days, the final dissolved oxygen (DO) was determined using the same procedure above

$$\text{BOD (mg/L)} = \frac{DO_2 - DO_1}{V} \quad (3.4)$$

Where DO_1 = initial dissolved oxygen (immediately after preparation)

DO_2 = final dissolved oxygen (after 5days of incubation)

V = volumetric fraction of sample used (APHA, 1998).

3.4.10 Nitrates (NO^{3-}) (Cadmium Reduction Method

Nitrite (NO^{2-}) is reduced to nitrate (NO^{3-}) in the presence of Cadmium (Cd). This method uses commercially available Cd granules coated with 2% copper sulphate ($CuSO_4$) packed in a glass column. The Nitrate (NO^{3-}) produced is determined by diazotizing it with colour reagent containing sulfanilamide coupled with N-(1-naphthyl)-ethylenediamine dihydrochloride (NEDD) to form highly coloured. naphthyl)-ethylenediamine dihydrochloride (NEDD) to form highly coloured azo dye. The colour developed is measured colorimetrically at 410nm. A correction was made for any NO^{3-} present in the sample by analyzing the sample without the reduction step. A standard graph was plotted to obtain the factor (APHA, 1998).

3.5 STATISTICAL ANALYSIS AND DO DETERMINATION

Mean and standard deviation were used to present the results of laboratory analysis obtained from the physicochemical parameters of the stream samples. The changes in the levels of physicochemical parameters of receiving stream were subjected to data analysis using Microsoft Excel 2010. Further analysis was taken into account to determine water pollution index (WPI) and depletion of dissolved oxygen in the River using the application of extended version of Thomas slope and O′Connor re-aeration and Streeter-Phelps models respectively, to determine the decomposition characteristics of the receiving river.

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 SOURCES OF POLLUTION ALONG WOJI/OKUJAGU STREAM

The major sources of pollution identified along the stream, include the following:

i. Dumping of wastes such as blood and other waste from butchered animals are washed into shallow gutters encircling the platforms, which drain into the Woji Stream.

ii. Waste parts of the slaughtered animals such as flesh, bones, fat, grease, undigested feed, hair, feathers, manure, grit and abattoir wastewater were also released into the stream.

iii. Activities from the slaughter market also produce diverse wastes that are also disposed off into the stream.

iv. Agricultural wastes originate in the form of runoff from fields and the animal farms.

v. Industrial wastes from nearby industries such as Baker Hughes, Halliburton, Schlumberger, Coca Cola Bottling Company, WW white Rivoc etc.

4.2 GEOMETRIC AND HYDRAULIC PARAMETERS OF WOJI /OKUJAGU STREAM

In the development and prediction of the DO sag curve for solving Woji/Okujagu Stream quality problems, the following necessary procedures were observed:

i. Presentation of the hydraulic data and picture of the present situation and Identifying every condition given in the problems;
ii. Estimating the dissolved oxygen and biochemical oxygen demand after the influent mix with the stream;
iii. Estimating travel time and rate constants necessary for the stream;
iv. Applying appropriate equations to calculate the oxygen deficit and the dissolved oxygen at desired locations;
v. Calculating the critical time and the critical deficit.

Table 4.1: The geometric and hydraulic data obtained from Woji/Okujagu Stream

Sampling Stations	Distance *x* (m)	Depth, d (m)	Width, *w* (m)	Area *A* = *w* × *d* (m^2)	Velocity, *V* (m/s)	Flow Rate Q = *AV* (m^3/s)
A	0	5.25	14.25	74.81	0.014	1.047
B	200	6.32	10.45	66.04	0.015	0.991
C	400	6.85	7.84	53.70	0.018	0.967
D	600	7.32	12.30	90.04	0.016	1.441
E	800	8.20	21.54	176.63	0.019	3.356
F	1000	8.54	20.40	174.22	0.017	2.962
Average		7.08	14.46	105.91	0.017	1.794

4.3 PHYSICAL AND CHEMICAL PARAMETERS OF THE STREAM

Tables 4.2 - 4.3 presented below show the results of the physical and chemical tests carried out on the water samples from the stream. The results were expressed in mean ± standard deviation for dry season (February, 2017) and wet season (August, 2017) while Tables 4.4 - 4.5 compare the range and mean values of physicochemical parameters of dry and wet seasons with WHO and NESREA standards. The physicochemical parameters examined include Temperature, Hydrogen ion Concentration (pH), Total Suspended Solids (TSS), Electrical Conductivity (EC), Nitrates, Biochemical Oxygen Demand (BOD_5), and Dissolved Oxygen (DO).

Table 4.2: Physical and chemical parameters at various sampling stations at Woji/Okujagu Stream during dry season (February, 2017)

Water Parameters	Station A	Station B	Station C	Station D	Station E	Station F
Temp. (^{0}C)	27.8 ± 0.6	29.5 ± 1.6	28.7 ± 0.8	27.6 ± 0.2	27.5 ± 0.5	26.5 ± 0.2
TSS (mg/L)	145.6±21.2	247.9±21.2	183.8±81.4	176.9±48.0	158.0±33.6	162.0±25.1
EC (µS/cm)	435.5± 3.2	905.3± 9.4	741.1± 5.1	588.0± 3.2	422.7± 3.7	430.5± 2.8
pH	6.1 ± 0.2	6.0 ± 0.2	6.0 ± 0.2	6.1 ± 0.1	6.2 ± 0.1	6.4 ± 0.5
Nitrates (mg/L)	17.6 ± 0.2	97.3 ± 1.2	85.9 ± 0.3	65.8 ± 0.6	32.6 ± 0.8	25.5 ± 0.8
BOD_5 (mg/L)	62.4 ± 1.8	75.2 ± 3.8	65.8 ± 3.2	52.2 ± 2.5	42.5 ± 1.2	44.2 ± 2.2
DO (mg/L)	4.5 ± 0.2	2.2 ± 0.1	3.6 ± 0.1	4.1 ± 0.1	5.8 ± 0.2	6.2 ± 0.5

Table 4.3: Physical and chemical parameters at various sampling stations at Woji/Okujagu Stream during wet season (August, 2017).

Water Parameters	Station A	Station B	Station C	Station D	Station E	Station F
Temp. (^{0}C)	25.6 ± 0.7	27.1 ± 1.2	26.5 ± 0.5	25.8 ± 0.6	25.4 ± 0.2	25.0 ± 0.4
TSS (mg/L)	285.1±35.4	484.4±47.6	418.2±68.2	334.5±72.8	296.6±24.1	250.2±32.1
EC (µS/cm)	541.2± 4.2	982.2± 9.5	852.5± 3.8	618.0± 5.1	565.4± 4.3	522.5± 3.5
pH	7.3 ± 0.4	6.7 ± 0.1	6.9 ± 0.5	7.1 ± 0.5	7.2 ± 0.2	7.5 ± 0.6
Nitrates (mg/L)	12.5 ± 0.3	58.5 ± 1.1	42.2 ± 0.5	36.8 ± 0.6	21.4 ± 0.4	18.5 ± 0.8
BOD_5 (mg/L)	38.2 ± 0.8	45.6 ± 2.1	36.5 ± 2.5	30.5 ± 1.6	22.5 ± 0.2	21.2 ± 1.4
DO (mg/L)	6.2 ± 0.5	3.2 ± 0.2	4.5 ± 0.1	5.6 ± 0.2	6.5 ± 0.4	6.8 ± 0.8

Table 4.4: Comparison of the range and mean values of physical and chemical parameters of dry and wet seasons from all sampling stations with WHO and NESREA standards

Water Parameters	Dry Season		Wet Season		WHO Limits	NESREA Limits
	Range	Mean	Range	Mean		
Temp. (^{0}C)	26.5 - 29.5	27.93	25.0 - 27.1	25.90	30	40
TSS (mg/L)	145.6-247.9	179.03	250.2-484.4	344.83	30	30
EC (µS/cm)	422.7-905.3	587.18	522.5-982.2	680.30	250	1000
pH	6.0 - 6.4	6.13	6.7 - 7.5	7.12	6.5 - 8.5	6 – 9
Nitrates (mg/L)	17.6 - 97.3	54.12	12.5 - 58.5	31.65	50	50
BOD_5 (mg/L)	42.5 - 75.2	97.70	21.2 - 45.6	37.23	10	30
DO (mg/L)	2.2 – 6.2	4.30	3.2 - 6.8	5.30	10	4 – 6

Table 4.5: Comparison of the ranges and mean values of physical and chemical parameters for both dry and wet seasons from all sampling stations with WHO and NESREA standards

Water Parameters	Range (Dry and wet)	Mean Values (Dry and wet)	WHO Limits	NESREA Limits
Temp. (^{0}C)	25.0 – 29.5	26.92	30	40
TSS (mg/L)	145.6 – 484.4	261.93	30	30
EC (µS/cm)	422.7 – 982.2	633.74	250	1000
pH	6.0 – 7.5	6.63	6.5 - 8.5	6 – 9
Nitrates (mg/L)	12.5 – 97.3	42.88	50	50
BOD_5 (mg/L)	21.2 – 75.2	67.47	10	30
DO (mg/L)	2.2 – 6.8	4.80	10	4 – 6

Tables 1 - 7 from appendix and Figures 4.1 – 4.7 presented below show the variation of physical and chemical parameters with sampling distance (m).

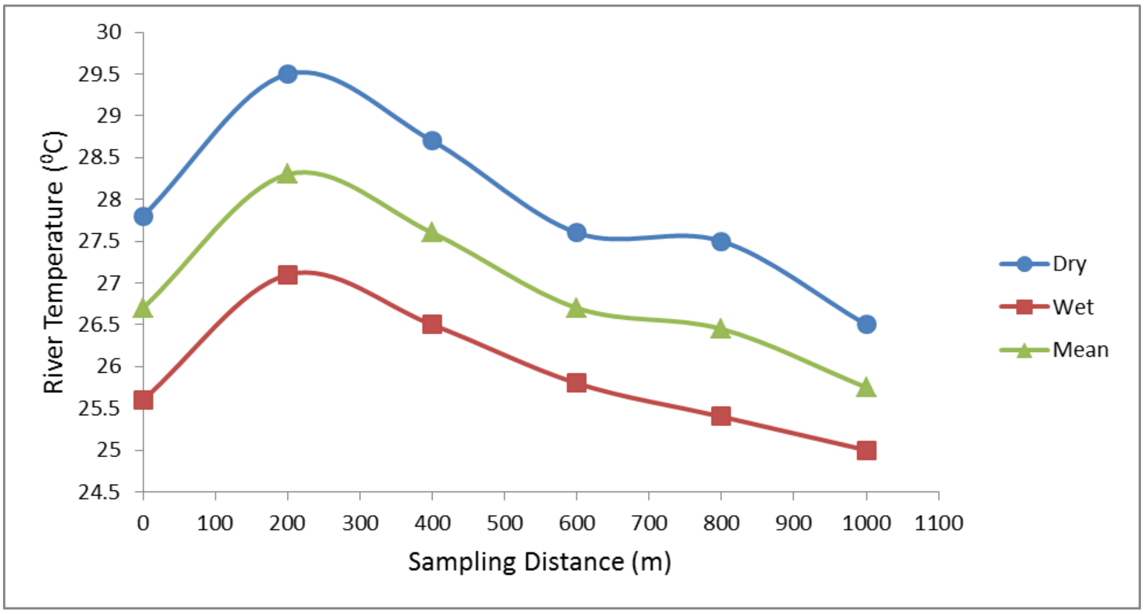


Figure 4.1: Variation of Stream Temperature with Sampling Distance (m)

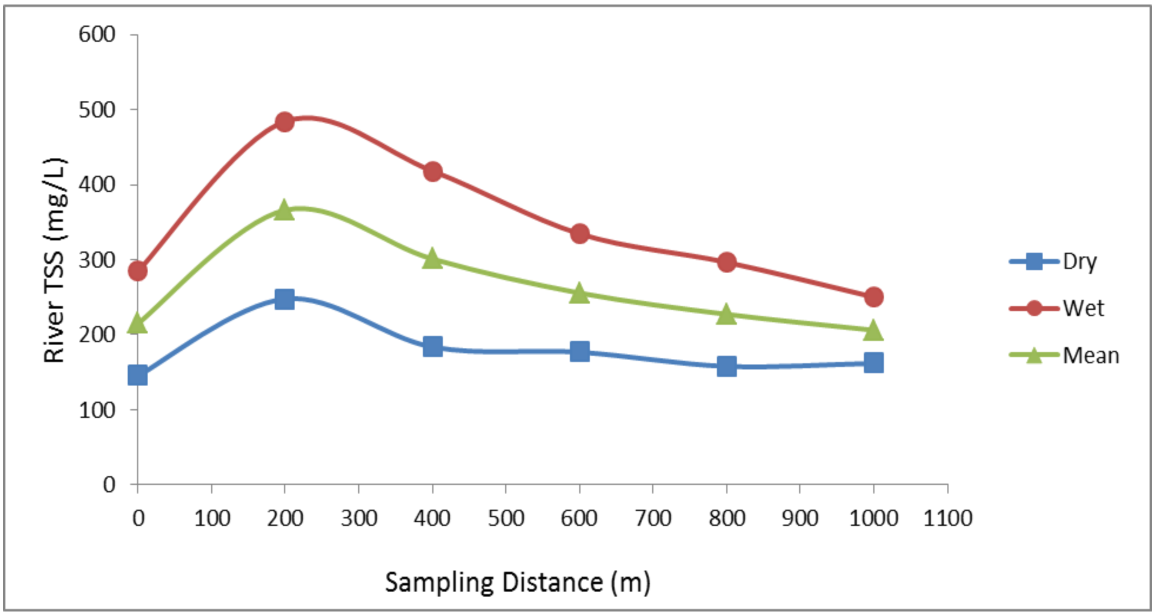


Figure 4.2: Variation of Stream TSS with Sampling Distance (m)

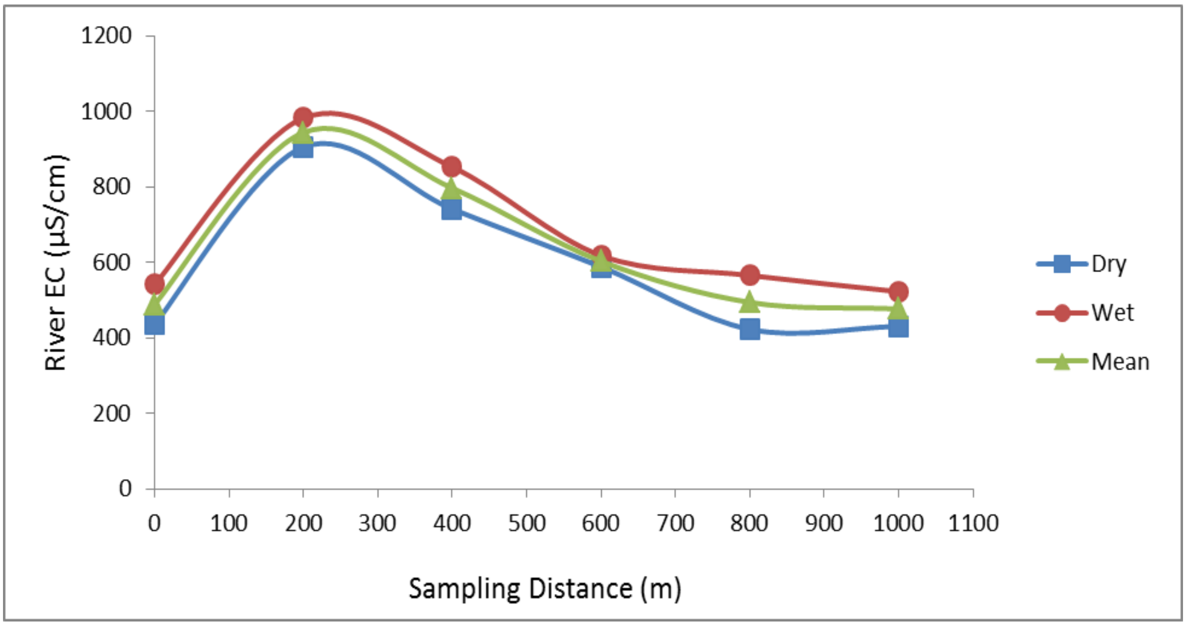


Figure 4.3: Variation of Stream EC with Sampling Distance (m)

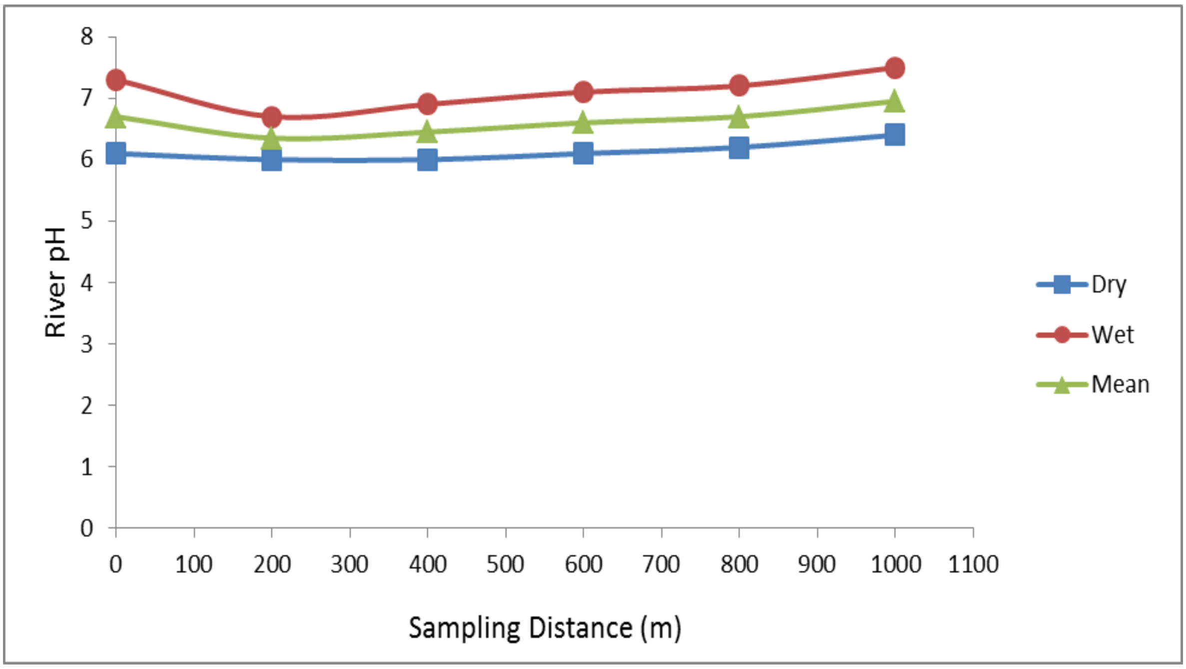


Figure 4.4: Variation of Stream pH with Sampling Distance (m)

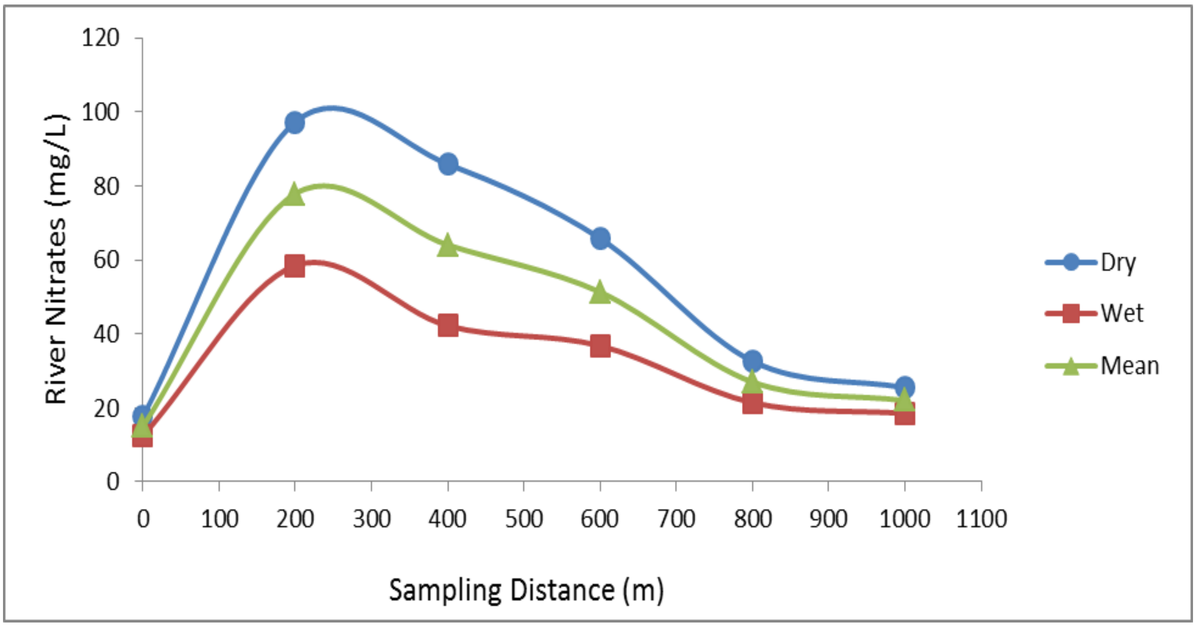


Figure 4.5: Variation of Stream Nitrates with Sampling Distance (m)

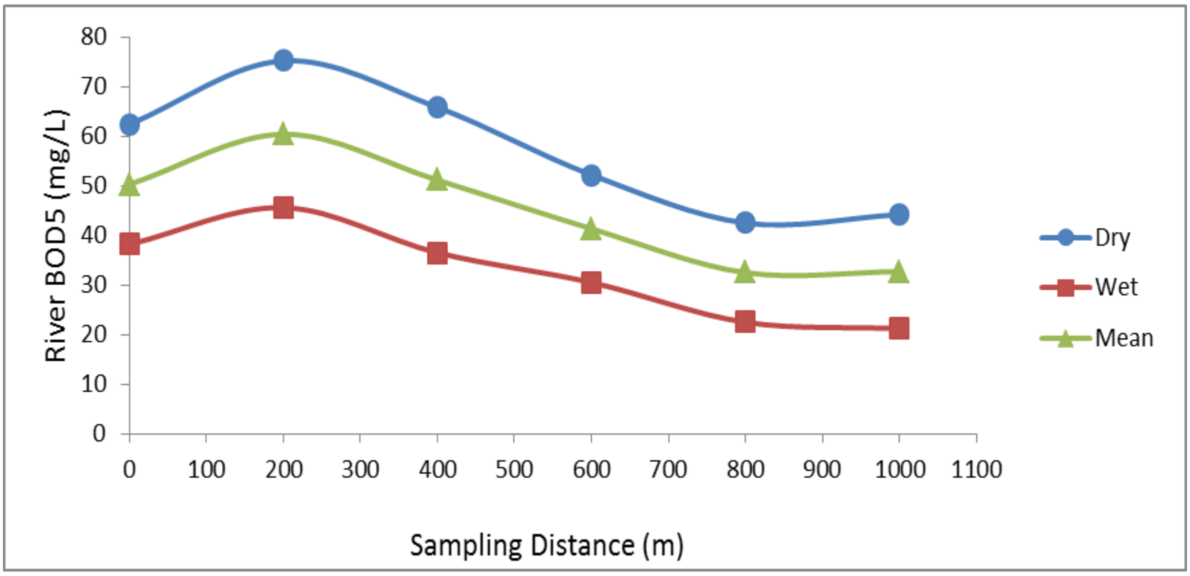


Figure 4.6: Variation of Stream BOD_5 with Sampling Distance (m)

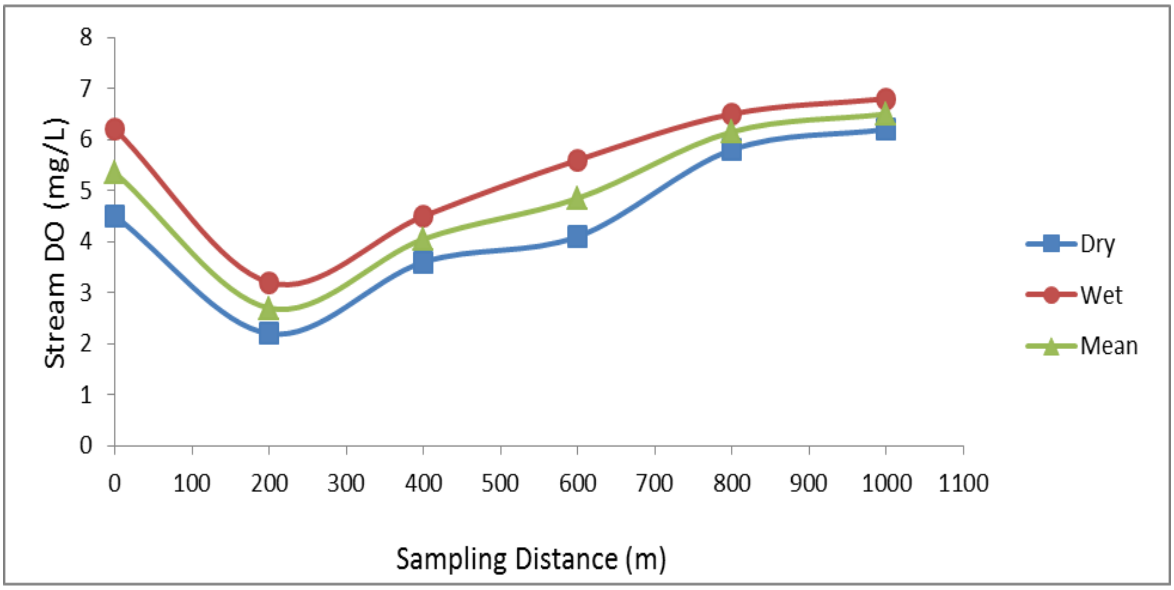


Figure 4.7: Variation of stReam DO with Sampling Distance (m)

4.4 POLLUTION INDEX OF WOJI/OKUJAGU STREAM

In order to ascertain the extent of pollution as it affects the aquatic environment, the pollution index (PI) of the water samples was estimated as follows:

$$PI = 1/n[M_1/T_1 + M_2/T_2 + M_3/T_3 + \ldots M_n/T_n] \quad (4.1)$$

Where:

$M_1, M_2 \ldots. M_n$	are the mean concentration of the parameters
$T_1, T_2 \ldots. T_n$	are the tolerable levels for each parameter
"n"	is the number of parameters considered.

PI value greater than 1.0 indicates that average concentration of the parameter is above the permissible limit. PI is classified as low contamination (PI≤1), moderate contamination (1<PI≤3) or high contamination (PI>3). Mean values of dry and wet seasons for each sampling stations were used to compute the PI of the water samples as shown in Table 4.6. The results of the pollution index indicate that the pollution index is greater than 1.0 in all sites. Therefore, the river is classified as moderate contamination ($1<PI\leq3$) or class 4.

Table 4.6: The pollution index (PI) of the water samples of physical and chemical parameters from all sampling stations

Water Parameters	**Mean Values (M_n)**	**Tolerable Levels (T_n)**	**Sub-Index (M_n/T_n)**
Temp. (^{0}C)	27.15	27	1.0056
TSS (mg/L)	273.1	30	9.1033
EC (µS/cm)	665.19	200	3.3259
pH (unitless)	6.56	9	0.7289
Nitrates (mg/L)	47.06	30	1.5687
BOD5 (mg/L)	47.14	30	1.5713
DO (mg/L)	4.46	6	0.7433
Pollution Index (PI) (unitless)			2.5781

Table 4.7: Pollution Indices (PI) of the water samples from each sampling station

Water Parameter	Station A	Station B	Station C	Station D	Station E	Station F	NESREA Standard
Temp. (^{0}C)	26.7	28.3	27.6	26.7	26.45	25.75	40
TSS (mg/L)	215.35	366.15	301	255.7	227.3	206.1	30
EC (µS/cm)	488.35	943.75	796.8	603	494.05	476.5	1000
pH	6.70	6.35	6.45	6.60	6.70	6.95	9
Nitrates (mg/L)	15.05	77.90	64.05	51.30	27.0	22.0	50
BOD_5 (mg/L)	50.3	60.4	51.15	41.35	32.5	32.7	30
DO (mg/L)	5.35	1.90	4.05	4.85	6.15	6.50	6
PI	1.950	3.8927	3.0797	2.5077	2.1101	2.050	

4.5 DO SAG CURVE OF WOJI/OKUJAGU STREAM

Figure 4.8 shows the oxygen sag curve developed for Woji/Okujagu Stream on a plot for dissolved oxygen concentration DO against distance, x from the sampling stations in the direction of flow. The sag curve is similar to the typical deoxygenation and reoxygenation oxygen sag curves shown in Figure 2.1 of chapter two.

Figure 4.8: Variation of DO concentration with sampling distance (m)

As contaminant enters the stream at point of $x = 0$ and t = 0, decomposition process utilizes oxygen at a faster rate than re-aeration occurring to replenish the oxygen. This causes the DO to drop sharply reducing it to minimum at some point near the point of discharge downstream and this process occurs at the critical time t_c. At this point, re-aeration gradually exceeds de-oxygenation and the stream recovers its natural state steadily, as a result of self-purification.

The Critical time, t_c was determined from Equation (2.12) as:

$$T_c = \frac{L}{0.6} \; and \; L = \frac{\ell^{0.8}(S+1)^{0.7}}{1900\Upsilon^{0.5}} \qquad (2.12)$$

$\ell = Flow\ lenght, ft$

Υ = Average land slope of teh watershed in percent (%)

S = Maximum potential retention in = $\frac{1000}{CN} - 10$

4.5.1 Thomas Slope's De-oxygenation Constant K_d and Ultimate (BOD), L_o

The Thomas Slope method can be used to determine the de-oxygenation constant $\boldsymbol{K_d}$ and ultimate (BOD), $\boldsymbol{L_o}$, by plotting $\left(\frac{t}{y}\right)^{\frac{1}{3}}$ as a function of t. The slope b and the intercept a of the line of best fit can be used to estimate the values of $\boldsymbol{K_d}$ and $\boldsymbol{L_o}$ using Equations (2.23) and (2.24) as follows:

$$K_d = (2.61)\, b/a$$

$$L_o = \frac{1}{2.3 K_d a^3}$$

where y = exerted BOD,

K_d = de-oxygenation rate constant,

L_o = ultimate BOD,

a, and b are constants.

The values of the function of exerted BOD with time $\left(\frac{t}{y}\right)^{\frac{1}{3}}$ is obtained from the application of BOD_5 values and time (days) from experimental analysis presented in Table 6 from appendix.

Table 4.8: Computation of $\left(\frac{t}{y}\right)^{\frac{1}{3}}$ from BOD_5 mean values obtained from experimental analysis

Time (days)	BOD (y) (mg/l)	$(t/y)^{1/3}$
1	50.3	0.2709
2	60.4	0.3211
3	51.15	0.3885
4	41.35	0.4590
5	32.5	0.5358

Using the values from the Table 4.8, the graph of $(t/y)^{1/3}$ with time is plotted in order to determine the values of $\boldsymbol{K_d}$ and $\boldsymbol{L_o}$ in Figure 4.9.

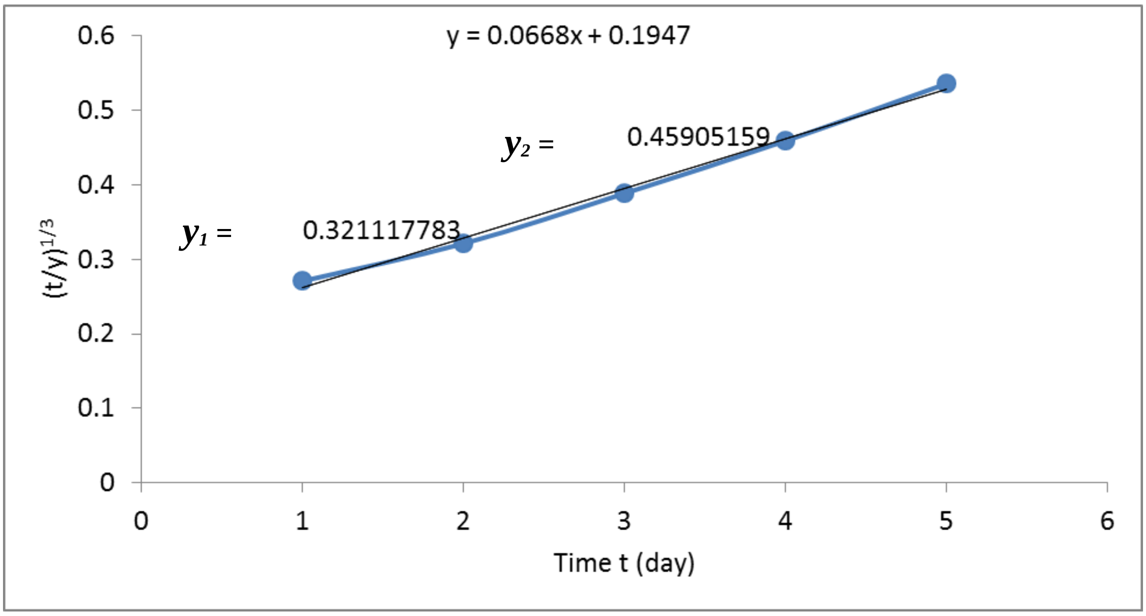


Figure 4.9: Variation of the Function of Exerted BOD $(t/y)^{1/3}$ with time (t)

The linear equation of the graph is $y = 0.0668x + 0.1947$

The intercept is obtained when x = 0

Intercept $\boldsymbol{a} = 0.1947$

Slope $\boldsymbol{b} = \frac{y2-y1}{x2-x1}$

Slope $\boldsymbol{b} = \frac{0.4590 - 0.3211}{4 - 2}$

Slope $\boldsymbol{b} = 0.683$

From Equation (2.23), $K_d = (2.61)\, b/a$

$$K_d = (2.61)\frac{0.1947}{0.683}$$

$$K_d = 0.744$$

From Equation (2.24), the ultimate BOD is $L_o = \frac{1}{2.3 K_d a^3}$

$$L_o = \frac{1}{2.3 \times 0.744 \times 0.1947^3}$$

$$L_o = 79.2 mg/l$$

4.5.2 Re-aeration Constant K_r using O' Connor Model

The re-aeration constant, K_r is determined by tracer study using O' Connor model from Equation (2.16).

$$K_r = \frac{3.9V^{0.5}}{H^{3/2} \; or \; H^{1.5}}$$

Where V = mean stream velocity = 0.0164 m/s (Table 4.7)

H = average depth of river = 6.788m (Table 4.7)

$$K_r = \frac{3.9 \times (0.0164)^{0.5}}{(6.788)^{\frac{3}{2}}} = \frac{0.4994}{17.685}$$

$$K_r = 0.0282$$

4.5.3 Dissolved Oxygen using Streeter - Phelps model

The Streeter-Phelps model from Equation (2.15) was used to estimate the dissolved oxygen of Woji/Okujagu Stream as follows:

$$D_t = \frac{K_d L_o}{K_r - K_d}\left(e^{-K_d t} - e^{-K_r t}\right) + D_o\left(e^{-K_r t}\right)$$

Where D_t = oxygen deficit in the river at time t,

L_o = initial ultimate BOD at mix,

D_o = initial oxygen deficit at mix,

K_d = de-oxygenation rate constant,

K_d = re-aeration rate constant,

t_c = critical time.

In estimating the dissolved oxygen deficit of Woji/Okujagu Stream, the critical time of the deficit was first estimated from Equation (2.12) as shown in Table 4.9:

Table 4.9: The Critical time for DO deficit occurrence

Station	x (m)	U (m/s)	t_c (days)
A	0	0.017	0
B	200	0.017	0.1362
C	400	0.017	0.2723
D	600	0.017	0.4085
E	800	0.017	0.5447
F	1000	0.017	0.6808

From the estimation of the critical time in Table 4.9, the dissolved oxygen at the different points can also be estimated from the Streeter-Phelps equation using a developed Excel template as presented in Table 4.10.

Table 4.10: Dissolved Oxygen (DO) Deficit Estimation

Stations	**t (days)**	K_d	K_r	L_o	$K_r - K_d$	$\frac{K_d L_o}{K_r - K_d}$	$e^{-K_d t}$	$e^{-K_r t}$	$(e^{-K_d t}) - (e^{-K_r t})$	D_o	$D_o(e^{-K_r t})$	D_t
A	0	0.744	0.0282	79.2	-0.716	-82.30	2.718	2.718	0	5.35	5.35	5.350
B	0.1362	0.744	0.0282	79.2	-0.716	-82.30	0.924	0.990	-0.066	5.35	2.375	3.45
C	0.2723	0.744	0.0282	79.2	-0.716	-82.30	0.883	0.984	-0.101	5.35	2.361	4.13
D	0.4085	0.744	0.0282	79.2	-0.716	-82.30	0.849	0.978	-0.130	5.35	2.348	4.73
E	0.5447	0.744	0.0282	79.2	-0.716	-82.30	0.816	0.973	-0.158	5.35	2.336	5.28
F	0.6808	0.744	0.0282	79.2	-0.716	-82.30	0.785	0.962	-0.176	5.35	2.412	5.76

Combining the results from the last column Table 4.11 with the measured mean values of dissolved oxygen from Table 7 from Appendix, a dissolved oxygen sag curve was plotted and compared with the curve generated by Streeter-Phelp simulated model and measured DO values. The predicted values of dissolved oxygen were also plotted against the measured value of dissolved oxygen and the correlation (R^2) between the two values was determined a shown in Figure 4.10.

Table 4.11: Comparison of Measured and Simulated DO over Time

Station	t (days)	D_o (Measured)	D_t (Predicted)
A	0	5.35	5.350
B	0.1362	2.7	3.45
C	0.2723	4.05	4.13
D	0.4085	4.85	4.73
E	0.5447	6.15	5.28
F	0.6808	6.50	5.76

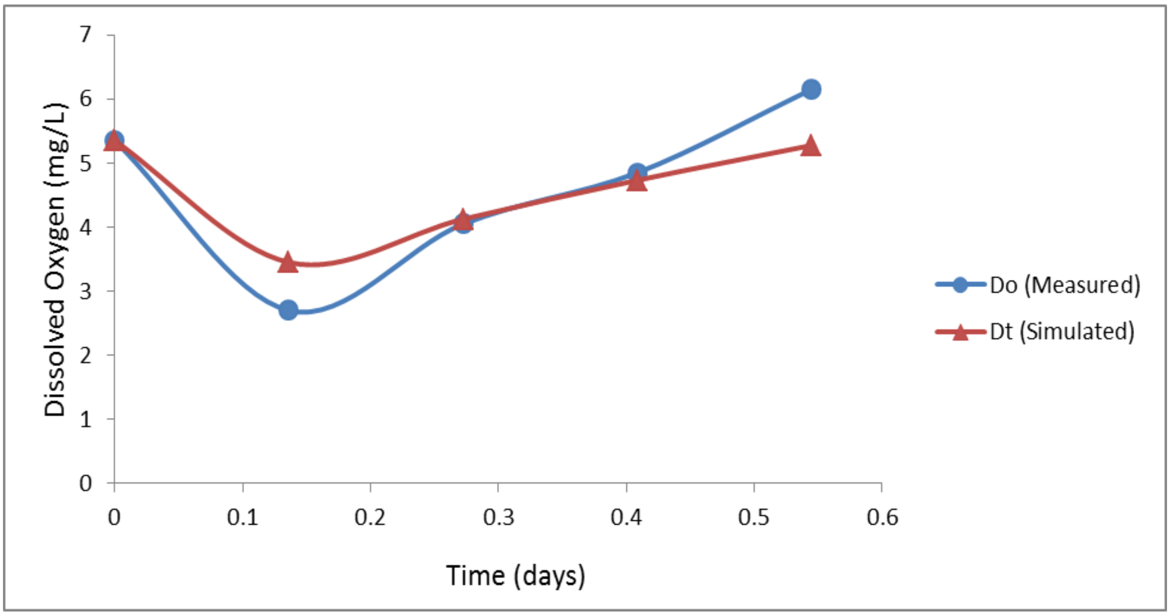


Figure 4.10: Variation of Simulated and Measured DO Sag Curve for Woji/Okujagu Stream

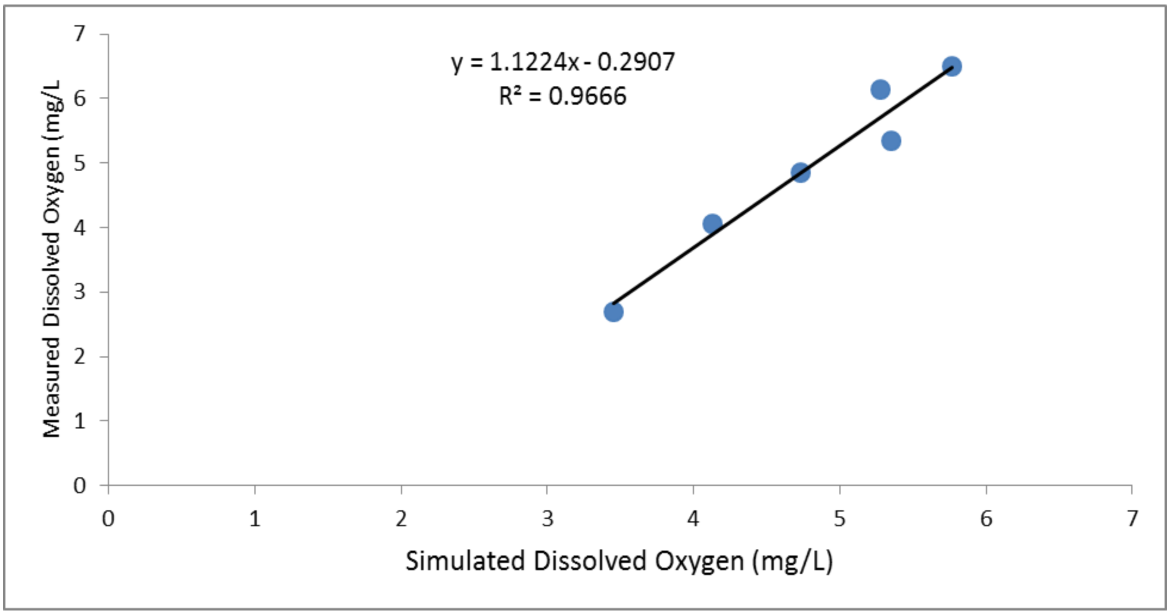


Figure 4.11: Variation of the Simulated and Measured DO for Woji/Okujagu Stream

4.6 DISCUSSION OF RESULTS

The water quality parameters of Woji/Okujagu Stream for both dry and wet seasons in relation with the sampling stations were compared with the standard values of the World Health Organization (WHO, 2004) and the Nigerian Environmental Standard and Regulation Enforcement Agency (NESREA, 2007) as shown in Table 4.3. Temperature ranged from 27.5 to 29.5°C with mean value of 28.22°C for dry season and 25.4 to 27.1°C with mean value of 26.08°C for wet season. The observed difference in the two seasons was due to the fact that temperature tends to be higher in dry season as reported by NIMET (2009). The mean temperature obtained from the sampling stations at the Woji/Okujagu Stream during the dry and wet seasons was low at the upstream with 26.7^{0}C, but increased steadily from the point of discharge to midstream and downstream with temperature values of 28.3^{0}C, 27.6^{0}C and 26.4^{0}C respectively. The mean temperature was within permissible limits of WHO and NESREA. This observation agrees with the findings of Igbinosa et al. (2012).

TSS varied from 145.6 to 247.9mg/L with mean value of 182.4mg/L for dry season and also varied from 285.1 to 484.4mg/L for the wet season with mean value of 363.8mg/L. The mean values of TSS was low at the upstream with a value of 215.3mg/l and higher at the point of discharge with 366.1mg/l, but reduced substantially at the downstream with a value of 227.3mg/l. The deposition of solid particulates from the influent at the point of discharge through the Creek course could have led to the increase in the volume of TSS from the upstream to downstream (lower course). These values were above the permissible limits of WHO and NESREA. This is in agreement with the study of Raman et al. (2009).

The EC for the dry season ranged from 422.7 to 905.3 with mean value of 618.52/µscm, while the wet season ranged from 541.2 to 982.2 with mean value of 711.86/µscm. The mean EC values increased from the upstream with mean value of 488.3µScm^{-1} to 943.7µScm^{-1} at the point of discharge as a result of the sewage discharge. The mean value decreases to 494.0µScm^{-1} at the downstream. The reduction may be due to little amounts of dissolve solids in water due to dilution. Electrical conductivity is used to indicate the dissolved solids in water because the concentration of ionic species determines the conduction of current in an electrolyte (Hayashi, 2004). The mean EC values were above the WHO and NESREA standard values which is in agreement with the findings of Anwar et al. (2011).

The pH ranged from 6.0 to 6.2 for the dry season with mean value of 6.08, while for the wet season, the pH range between 6.7 to 7.3 with mean value of 7.04 which are within the permissible limits with standard limits of WHO and NESREA. These results were similar to the findings of Charkhabi and Sakizadeh (2006). Nitrate (NO_3) values varied from 17.6 to 97.3mg/L and 12.5 to 58.5mg/L with mean values of 59.84mg/L and 34.28mg/L for dry and wet seasons, respectively. It is important to note that nitrate level in the stream could be a source of eutrophication for receiving water. The values were above the WHO and NESREA standard permissible limits. The mean values of nitrates varied from 17.6mg/L upstream to 97.3mg/L at the point of discharge and reduce to 32.6mg/L downstream. The reduced level of nitrate in the downstream point could be as a result of conversion of nitrates to nitrites along the length of the stream.

Similar observations were recorded for BOD which ranged from 42.5 - 75.2mg/L and 22.5 - 45.65mg/L with average values of 58.02mg/L and 32.66mg/L for dry and wet seasons, respectively. Mean BOD values were above permissible limits for WHO and NESREA standards. The mean values of BOD varied from 50.3mgL^{-1} upstream and increased to 60.4mgL^{-1} at the point of discharge while at downstream it reduces to 32.5mgL^{-1}. The observed high values especially at the point of discharge might be due to the infiltration of abattoir wastes into the river which might result in high demand for oxygen for decomposition of organic pollutants. Nevertheless, the mean values of BOD downstream exceed the recommended value of 28 - 30mgL^{-1} and may be partly due to other non-point pollution sources or that the microbial load far exceeds the self-purification capacity of the stream. This agrees with the findings of Ololade and Ajayi (2009).

DO variations range from 2.2 - 5.8mg/L with mean value of 4.04mg/L for dry season and 3.2 - 6.5mg/L with mean value of 5.20mg/L for wet season, respectively. The mean values of DO were not within NESREA permissible limits. The reduction in DO during the dry season might be due to the higher influx of wastes thereby reducing the biological life of the river. The mean value of DO upstream was 5.35mgL^{-1} and decreased to the lowest mean value of 2.7mgL^{-1} at the point of discharge. The low DO concentration at the point of discharge is as a result of high influx of organic load from the abattoirs and traders. The mean DO level however, improve downstream to 6.15mgL^{-1}. This could be attributed to both the flow and recovery capacity of the stream.

The results of the pollution index from this study indicate that the river pollution index is greater than 1 unity in all sites due to the high level of influent pollution from the abattoirs and traders operating around the area of discharge. However, the level of pollution was classified as moderate contamination ($1<PI\leq3$) or class 4. The high pollution index at the point of discharge is attributed to the high influx of effluents into the river due to different anthropogenic activities which has led to the depletion of dissolved oxygen at the area of effluent discharge in the receiving stream. This observation is consistent with the findings of Al-Obaidy et al. (2015) and Umunnakwe et al. (2011). Similarly, Rim-Rukeh (2013) observed that the water quality index (WQI) of Oguta lake, Omuku pond, Ugheghe pond, Karabodone lake and Abua lake are 67.46, 65.64, 65.87, 50.77, and 67.01, respectively and belong to class III and empirically described as average or medium.

The determination of DO in this study yielded L_o, K_d and K_r values of $79.2mg/l$, 0.744 and 0.0282, respectively. The simulated DO values ranged from 2.921 to 5.856 from upstream to downstream. These findings agree with other studies done by other researchers. Omole, (2006) assessed the impact of abattoir effluent discharge on the water quality of river Illo, Ota revealed that pollution from the abattoir caused a drop in dissolved oxygen level of the river from an ambient value of 4.6mg/l to 0.01mg/l at the point of discharge. The contaminant also caused an increase of 447.5mg/l to 1071.5mg/l in TS. and 170mg/l to 670mg/l in BOD. Result from the dispersion modeling shows the self-purification capacity of the stream, f, to be 1.1 within 30m distance from the point of discharge and 0.8 between 30m and 100m from the point of discharge. The results from the application of the Streeter-Phelps model showed that the eutrophication occurring between 30m – 80m is interfering adversely with the self-purification processes of the river. The percentage compliance of each of the eight water samples with Guideline Values (GLV) of WHO and NESREA was performed. None of the samples met the minimum requirements for BOD, COD and TSS, which are indicators of pollution.

Canale and Ownes (1995) estimated K_d in the stream receiving secondary treated effluent as 0.1 day^{-1}. Lung (1998) studied the effects of primary and secondary treatment without nitrification and with nitrification on the DO levels in Upper Mississippi Stream. Significant improvements were observed in the DO levels at higher levels of treatment. The river deoxygenation rate (K_d) was reduced from 0.27 day^{-1} for primary treated effluent to 0.19 day^{-1} for effluent that received secondary treatment. The K_d further reduced to 0.057 day^{-1} for secondary treated effluent with nitrification.

CHAPTER FIVE

CONCLUSION AND RECOMMENDATION

5.1 CONCLUSION

This thesis evaluates the depletion of dissolved oxygen in receiving streams at Woji/Okujagu Stream in Port Harcourt Local Government Area of Rivers State.

The study revealed that there was a significant effect on TSS, EC, Nitrates, BOD_5, and DO parameters of water quality of the receiving stream due to the activities that result in the discharge of waste effluents from slaughter houses.

This study revealed that most of the parameters assessed in the receiving stream are above limits recommended by the Nigerian Environmental Standard and Regulation Enforcement Agency (NESREA) and the World Health Organisation (WHO). It also showed that although the stream was already polluted from upstream activities, there was a significant increase in the levels of BOD_5, TSS, DO, EC and Nitrates at the effluent discharge point, thereby, contributing to the pollution of the stream and endangering the ecosystem and the health of the people who rely on it for livelihood. Thus, there is need for proper management of the sewage wastewater entering receiving streams in order to improve its quality and minimize danger to the environment and its inhabitants.

5.2 RECOMMENDATION

The results from this study showed that the water quality of Woji/Okujagu Stream in Port Harcourt Local Government Area of Rivers State has deteriorated substantially and would continue if urgent measures are not put in place to control the fast continuous rate of waste discharge into the stream without adequate treatment of these wastes. Therefore, the following recommendations are made based on the research findings.

i. Existing enabling laws to restrict contaminants levels of effluent discharge to the stream should be enforced as there is possibility that the rate of DO reduction might be greater than the rate of self-purification, which in this case may result in the death of aquatic lives as well as the abandonment of the Stream.

ii. There is need for proper management of the abattoir/sewage wastewater entering receiving streams in order to improve its quality and minimize danger to the environment and to people.

iii. Simple physical treatment of effluent from the abattoir could be carried out by channeling effluents into the natural retention pond. This method is known to have reduced the level of BOD and COD considerably. Installation of screens before the natural pond will also enhance the reduction in the levels of TSS and TS of the stream.

iv. Relevant authorities should embark on regular monitoring activities of streams and STREAM in STREAM State to ensure the safety of human and aquatic population and the environment.

v. It is suggested that further research should be carried out in the low flow season where minimum or near zero flows are observed as the stream is ephemeral in nature.

5.3 CONTRIBUTIONS TO KNOWLEDGE

i. The study has provided a framework for the application of extended version of Thomas slope and O′Connor re-aeration and Streeter-Phelps models to determine the depletion of dissolved oxygen in the Stream by the decomposition characteristics of the discharged effluent. So far most studies in Nigeria focused on the impact of effluent on physicochemical parameters and water quality of Stream.

ii. The results obtained from this study will be useful for studying the depletion of oxygen in receiving streams and will benefit Civil and Environmental Engineers and Researchers in the management of dissolved oxygen in receiving streams.

iii. The study has also provided basic information on the stream use and evaluates the current water quality and degree of pollution of the river. The results also furnish information such as the values of ultimate BOD L_o de-oxygenation constant K_d, and re-aeration constants K_r (79.2mg/l, 0.744 and 0.0282 respectively), which will be useful to predict likely changes over time in the concentration levels of different contaminant. Possible solutions to the existing problems may form basis of adoption of engineering measures to arrest stream contaminant by abattoirs, commercial and industrial activities.

REFERENCES

Absar, A. K. (2005). *Water and Wastewater Properties and Characteristics*. In J. H. Lehr and J. Keeley (Eds.), Domestic, Municipal and Industrial Water Supply and Waste Disposal (pp. 903-905), New Jersey: John Wiley and Sons, Inc.

Adekunle, A. S. (2008). Impacts of Industrial Effluents on Quality of Well Water within Asa Dam Industrial Estate, Ilorin Nigeria. *Nature and Science*, 6(3), 1-5.

Adekunle, A. S. & Eniola, I. T, K. (2008). Impact of Industrial Effluents on Quality of Segment of Asa River within an Industrial Estate in Ilorin, Nigeria. *New York Science Journal*, 1 (1), 17-21.

Adelegan, J.A. (2002). *Environmental policy and slaughterhouse waste in Nigeria*. Proceedings of the 28th WEDC Conference, November 18-22, 2002, Calcutta, India, pp: 3-6.

Agedengbe, K., Akinwole, A. O. & Babatunde, A. O. (2003). Effluents Characteristics of Selected Industries in Western Nigeria and Implications for re-use in Agricultural Production. *Journal of Environmental Extension*, 4, 79-82.

Akpor, O. B. & Muchie, B. (2013). Environmental and public health implications of wastewater quality. *African Journal of Biotechnology*, 10(13), 2379-2387.

Akpor, O. B. & Muchie, B. (2013). Environmental and public health implications of wastewater quality. *African Journal of Biotechnology*, 10(13), 2379-2387.

Al-Ghamdi, A. Y. (2011). Review on Hospital Wastes and its Possible Treatments. *Egypt Academy Journal of Biological Science*, 3(1), 55-62.

Al-Obaidy, A. H. M. J. & Al-Khateeb, M. (2015). Application of Water Pollution Index for Assessment of Tigris River Ecosystem. *International Journal of Advanced Research*, 3(2), 219-223.

Anetor, J. I., Adeniyi, F. A. A. & Olaleye, S. B. (2003). Molecular Epidemiology: A Better Approach for the Early Detection of Pathophysiologic Response to Environmental Toxicants and Diseases. *African Journal of Biomedical Research*, 6, 113-118.

APHA. (1998). *Standard Methods of Examination of Water and Wastewater* (20th ed.). Washington D.C. Cabral, J. P. S. (2010). Water Microbiology. Bacterial Pathogens and Water. *International Journal of Environmental Research & Public Health*, 7, 3657-3703.

Barnes, K. H., Meyer, J. L. & Freeman B. J. (1998). *Sedimentation and Georgia's Fishes: An analysis of existing information and future research:* Georgia Water Resources Conference, University of Georgia, Athens Georgia.

Bichi, M. H. & Anyata, B. U. (1999). Industrial Waste Pollution in the Kano River Basin. *Journal of Environmental Management and Heath*, 10(2), 112-116.

Bull, M. A., Sterritt, R. M. & Lester, J. N. (1982). The treatment of wastewaters from the meat industry: A Review. *Environmental Technology Letters,* 3, 117-126.

Cabral, J. P. S. (2010). Water Microbiology. Bacterial Pathogens and Water. *International Journal of Environmental Research & Public Health*, 7, 3657-3703.

Cadmus, S. I. B., Olugasa, B. O. & Ogundipe, G.A.T. (1999). *The prevalence of zoonotic importance of bovine tuberculosis in Ibadan, Nigeria*. Proceedings of the 37th Annual Congress of the Nigerian Veterinary Medical Association, October 25-31, 1999, Kaduna, pp. 883-886.

Canale, R. P., Ownes, E. M. & Auer, M. T. (1995). Validation of Water Quality Model for Seneca River, N.Y. *Journal of Water Resources Planning and Management*, 121(3), 12-15.

Chapman, D. (1996). *Water Quality Assessments, A Guide to Use of Biota, Sediments and Water in Environmental Monitoring* (second ed.), London, F & FN Spon. Pp.3- 10.

Charkhabi, A. H. & Sakizadeh, M. (2006). Assessment of Spatial Variation of Water Quality Parameters in the Most Polluted Branch of the Anzali Wetland, Northern Iran. *Polish Journal of Environmental Studies*, 15 (3), 395.

Cornish, G. & Mensahh, A. (1999). *Water quality and Peri-urban irrigation*. Report OD/TN95HR Willing ford. UK.

Cunningham, W. P., Cunningham M. A. & Saigo, B. (2005). *Environmental Science: A Global Science*. New York. McGraw Hill.

Davies, O. A., Ugwumba, A. A. & Abolude, D. S. (2008). Physico-chemical Quality of Trans-Amadi (Woji) Creek Port Harcourt, Delta, Niger Delta, Nigeria. *Journal of Fisheries International*, 3(3), 92-97.

Ekhaise, F. O. & Omavwoya, B. P. (2008). Influence of Hospital Wastewater Discharged from University of Benin Teaching Hospital (UBTH), Benin City on its Receiving Environment. *American-Eurasian Journal of Agriculture & Environmental Science*, 4(4), 484-488.

Ekhaise, F. O. & Anyansi, C. C. (2005). Influence of breweries influent discharge on the microbiological and physiochemical quality of Ikpoba River, Nigeria. *African Journal of Biotechnology*, 4, 1062-1065.

EPA. (2012). *Dissolved Oxygen and Biochemical Oxygen Demand*. In Water Monitoring and Assessment. Retrieved from http://water.epa.gov/type/rsl/monitoring/vms52.cfm

EPA. (2013). *Dissolved Oxygen Depletion in Lake Erie*. In Great Lakes Monitoring. Retrieved from http://www.epa.gov/glindicators/water/oxygenb.html

Fakayode, S O. (2005). Impact of industrial effluents on water quality of the receiving Alaro River in Ibadan, Nigeria, *Ajeam-Ragee*, 10, 1-13.

Flores-Laureano J. S. & Navar, J. (2002). An assessment of stream water quality of the Rio San Juan, Nuevo Leon, Mexico, 1995-1996. *Journal of Environtal Quallity*, 31, 1256-1265.

Gannon, V.P., Hummenik, J. F., Rice, M., Cicmanec, J. L., Smith Jr. & Carr, R. (2004). *Control of Zoonotic Pathogens in Animal Wastes, Waterborne Diseases*: Identification, Causes and Control. 1st Edn., WHO, IWA, London, UK., pp. 409-425.

Ibekwe, V. I., Nwaiwu, O. I. & Offorbuike, J. O. (2004). Bacteriological and physicochemical qualities of wastewater from a bottling company in Owerri, Nigeria. *Global Journal of Environmental Science*, 3, 51-54.

Ichobaoglous, G., Burton, F. L. & Stensel, H. D. (2003). *Wastewater Engineering, Treatment and Reuse*. Metcalf and Eddy Tata McGraw Hill Publishing Company Limited, New Delhi India.

Ifabiyi, I. P. (2008). Self Purification of a Freshwater Stream in Ile-Ife: Lessons for Water Management. *Journal of Human Ecology*, 24(2), 131-137.

Kanu, I., Achi, O. K., Ezeronye, O. U. & Anyanwu E. C. (2006). Seasonal variation in bacterial heavy metal biosorption in water samples from Eziama river near soap and brewery industries and the environmental health implications. *International Journal of Environmental Science and Technology*, 3 (1), 95-102.

Kanu, I. A., Achi, O.K., Ezeronye, O.U. & Anyanwu, E.C. (2006). Seasonal variation in heavy metal biosorption in water samples from Eziama River near soap and brewery industries and environmental health implication. *International Journal of Environmental Science and Technology*, 3(1), 95-102.

Kiely, G. (1998). Environmental engineering technologies., McGraw-Hill, London, disapperance and sludge rising in a settling column system. *Water Resources*, 28(9), 1831-1872.

Koech, H.K., Ogendi, G.M. & Kipkemboi J., (2012). "Status of Treated Slaughter-House Influent and its Effects on the Physico-Chemical Characteristics of Surface Water in Kabuthi Stream, Dagoretti-Kenya", *Research Journal of Environmental and Earth Sciences*, 4(8), 789-796.

Lung, W. S. (1998). Trends in BOD/ DO modeling for wasteload allocations, *Journal of Environmental Engineering*, ASCE, 124 (10), 1004 -1007.

Mahdieh, E. & Amirhossein, M., (2009). *Water quality assessment of Bertam River and its tributaries in Cameron Highlands*, *Malaysia*: *World Applied Sciences Journal.* Tronh, Perak, Malaysia.

Mathuthu, S. Nwanga, K. & Simero A. (2000). "*Impact Assessment of Industrial and sewage effluents" Water Quality of Receiving Marimba River*. HARARE JOURNAL.

McAvoy D. C., Masscheleyn, P., Peng, C., Morrall, S. W., Casilla, A. B., Lim, J. M. U. & Gregorio E. G. (2003). Risk Assessment Approach for Untreated Wastwater using the QUAL2E Water Quality Model. *Chemospere,* 52, 55-66.

Morrison, G., Fatoki, O. S., Persson, L. & Ekberg, A. (2001). Assessment of the impact of point source pollution from the Keiskammahoek Sewage Treatment Plant on the Keiskamma River-pH, electrical conductivity, oxygen-demanding substance (COD) and nutrients. *Water SA*, 27(4), 475-480.

Mosley, L. Sarabject S., & Aalbersborg, B. (2004). *Water Quality Monitoring in Pacific Island Counties. Handbook for water quality*. Suva-Fiji Island. The University of South Africa Pacific, (1st Edition). p. 30-43.

Mott M. & Associates E. (2001) *Management of Industrial and Municipal effluents LWEMP Report 2001*.

Nadia, M. A. (2006). Study on effluents from selected sugar mills in Pakistan: Potential environmental, health, and economic consequences of an excessive C load: Sustainable Development Policy Institute. Islamabad, Pakistan.

NESREA (2009). *National Environmental Standards and Regulation Enforcement Agency*. Regulations Vol. 96, 65; the Federal Government Printer, Abuja, Nigeria.

Nyanda, M. (2000). *Report on the Study of Agrochemical use and handling in the Lake Zone*, Tanzania.

Odigie, D. & Fajemirokun, B. (2005). Water Justice in Nigeria: Crisis or Challenge. International Workshop on Water Poverty and Social Crisis Agadir, Morocco, 12-15 December 2005.

Ogbeibu, A. E. & Ezeunara, P. U. (2002). Ecological Impact of Brewery Influent on the Ikpoba River, Using the Fish Communities as Bioindicators. *Journal of Aquatic Sciences,* 17 (1), 35 – 44.

Ogunfowokan, O. A. & Fakankun, O. A. (1998). Physico-chemical characterization of effluents from beverage processing plants in Ibadan, Nigeria. *International Journal of Environmental Studies*, 54(2), 145-152.

Okoh, A. I. Odjadjare, E. E., Igbinosa, E. O., & Osode, A. N. (2007). Wastewater treatment plants as a source of microbial pathogens in receiving watersheds. *African Journal of Biotechnology*, 6(25).

Okoh, A. I., Sibanda, T. & Gusha, S. S. (2010). Inadequately treated wastewater as a source of human enteric viruses in the environment. *International journal of environmental research and public health*, 7(6), 2620-2637.

Okoye, P. A. C., Enemuoh, R. E. & Ogunjiofor, J. C. (2002). Traces of heavy metals in Marine crabs. *Journal of Chemical Society of Nigeria*, 27(1), 76-77.

Ololade, I. A. & Ajayi, A. O. (2009). Contamination profile of major STREAM along the highways in Ondo State, Nigeria. *Journal of Toxicology and Environmental Health Sciences*, 1(3), 038-053.

Omole, D. O. (2006). *Assessment of the impact of abattoir influent discharge on the water quality of river Illo, Ota*. An unpublished thesis submitted to the department of civil engineering, Covenant University, ota, Ogun State, Nigeria.

Onwuka, O. S. Uma, K. O., & Ezeigbo, H. I. (2004). Portability of shallow groundwater in Enugu town, south eastern Nigeria. *Global Journal of Environmental Science*, 3, 33-39.

Osibanjio, O. Daso, A. P. & Gbadebo, A.M. (2011). The Impact of Industries on Surface Water Quality of River Ona and River Alaro in Ibadan, Nigeria. *African Journal Biotechnology*, 10(4), 696.

Oyebode, O. J. & Afe Babalola (2015). Effective Management of Wastewater for Environment, Health and Wealth in Nigeria. *International Journal of Scientific and Engineering Research*, 6(7), 1028 - 1059.

Pandey, K. & Shukla, J. P. (2005). Fish and fisheries. Meerut India. *Rastogi*, 381-394.

Pandey, S. N. (2006). Accumulation of heavy metals (Cd, Cr, Cu, Ni and Zn) in Raphanus sativus L. and Spinacia oleracea L. plants irrigated with industrial effluents. *Journal of Environmental Biology*, 37(2), 381-384.

Payment, P., Waite, M. & Dufour, A. (2003). "*Introducing Parameters for the Assessment of Drinking water Quality", in assessing microbial safety in drinking water: Improving approaches and methods*, eds Dufour, A., Snozzi, M., Koster, W., Bartram, J., Ronchi E., and Fewtrell, IWA Publishing London.

Peavy, H. S., Rowe, D. R., & Tehobanoglous, G. (1985). *Environmental Engineering Pub. McGraw-Hill Int. Edition. Civil Engineering Series*.

Perry, R., Green, D. & Maloney, J. (2007). *Perry's Chemical Engineers Handbook*. New York. McGraw Hill.

Punmia, B.C.; Jain, A. K & Ashok, K. (2007). Environmental Engineering -2 Wastewater Engineering (Including Air Pollution) Laxmi Publications (D) Ltd New Delhi Madras Jalandhar Hyderabad.

Qadir, A., Malik, R. N. & Husain, S. Z. (2008). Spatio-temporal variations in water quality of Nullah Aik-tributary of the river Chenab, Pakistan. *Environmental Monitoring and Assessment*, 140(1-3), 43-59.

Rim-Rukeh, A. (2013). “Physico-Chemical and Biological Characteristics of Stagnant Surface Water Bodies (Ponds and Lakes) Used for Drinking and Domestic Purposes in Niger Delta, Nigeria". Journal of Environmental Protection, 4, 920-928.

Scahill, D., (2003). *Cow weight/cow meat ratio*. Retrieved from http://www.experts.about.com/q/Food-Science-1425/cowweight-cow meat.htm.

Schulz, K. & Huwe, B. (2000). Uncertainty and sensitivity analysis of water transport modelling in a layered soil profile using fuzzy set theory. *Journal of Hydroinformatics*, 1, 127-138.

Shaw, E. M. (1994). Hydrology in Practice (3rd ed.), London, Chapman and Hall: 8-10.

Streeter, H. W. & Phelps, E. B. (1925). *A study of the pollution and natural purification of the Ohio River*. III. Factors concerned in the phenomena of oxidation and reaeration. U.S. Public Health Service, Bulletin No. 146.

Suthar, S., Chhimpa, V. & Singh, S. (2009). Bacterial contamination in drinking water: a case study in rural areas of northern Rajasthan, India. *Environmental monitoring and assessment,* 159(1-4), 43-50.

Tchobanoglous, G. & Schroeder E. D. (1984). *Water quality: Characteristics, modeling, modification*. Addison-Wesley, Massachussets.

Tritt, W. P. & F. Schuchardt, (1992). Materials flow and possibilities of treating liquid and solid wastes from slaughterhouses in Germany. *A review. Bioresour. Technol.,* 41: 235-245.

Umunnakwe, J. E., Nnaji, A. O. & Ejimmaduekwu, P. I. (2011). Preliminary assessment of some physicochemical parameters during dredging of Nworie River, Owerri. *Pakistan Journal of Nutrition*, 10(3):269 – 273.

Verheijen, L.A., Wiersema, H.M., Hulshoff, D. L. & De Wit, J. (1996). *Management of wastes from animal product processing. Livestock and Environment, Finding a Balance*. International Agriculture Center, Wageningen, The Netherlands.

Wetzel, R. G., (2001). *Limnology-Lake and river ecosystems,* 3d ed.: New York, Academic Press, p.1006.

World Health Organization (WHO), (2004). *Guideline for Drinking Water Quality. 2nd Edition, Volume 2, Health Criteria and Other Supporting International Programme on Chemical Safety*, World Health Organization, Geneva.

WHO (Ed.) (2008). Guidelines for Drinking-water Quality, Incorporating 1st and 2nd Addenda (Vol.1). World Health Organization Press, Geneva, Switzerland.

Zhu Z. L., Chen, D. L. (2002). Nitrogen fertilizer use in China—Contributions to food production, impacts on the environment strategies. *Nutrient Cycling Agroecosystems*, 63, 117–127.

APPENDIX A

Table A.1: The Temperature of Woji/Okujagu Stream compared with WHO and NESREA standard for dry and wet seasons.

Sampling Stations	Temp.(^{0}C) Dry	Temp.(^{0}C) Wet	Mean Temp.(^{0}C)	WHO Limits	NESREA Limits
A	27.8	25.6	26.7	24 - 28	40
B	29.5	27.1	28.3	24 - 28	40
C	28.7	26.5	27.6	24 - 28	40
D	27.6	25.8	26.7	24 - 28	40
E	27.5	25.4	26.45	24 - 28	40
F	26.5	25.0	25.75	24 - 28	40

Table A.2: Total Suspended Solids (TSS) of Woji/Okujagu Stream compared with WHO and NESREA standard for dry and wet seasons.

Sampling Stations	TSS (mg/L) Dry	TSS (mg/L) Wet	Mean TSS (mg/L)	WHO Limits	NESREA Limits
A	145.6	285.1	215.35	30	30
B	247.9	484.4	366.15	30	30
C	183.8	418.2	301	30	30
D	176.9	334.5	255.7	30	30
E	158	296.6	227.3	30	30
F	162	250.2	206.1	30	30

Table A.3: Electrical Conductivity (EC) of Woji/Okujagu Stream compared with WHO and NESREA standard for dry and wet seasons.

Sampling Stations	EC (µS/cm) Dry	EC (µS/cm) Wet	Mean EC (µS/cm)	WHO Limits	NESREA Limits
A	435.5	541.2	488.35	250	1000
B	905.3	982.2	943.75	250	1000
C	741.1	852.5	796.8	250	1000
D	588	618	603	250	1000
E	422.7	565.4	494.05	250	1000
F	430.5	522.5	476.5	250	1000

Table A.4: The pH of Woji/Okujagu Stream compared with WHO and NESREA standard for dry and wet seasons.

Sampling Stations	pH Dry	pH Wet	Mean pH	WHO Limits	NESREA Limits
A	6.1	7.3	6.70	6.5 - 9	6 - 9
B	6	6.7	6.35	6.5 - 9	6 - 9
C	6	6.9	6.45	6.5 - 9	6 - 9
D	6.1	7.1	6.60	6.5 - 9	6 - 9
E	6.2	7.2	6.70	6.5 - 9	6 – 9
F	6.4	7.5	6.95	6.5 - 9	6 – 9

Table A.5: Nitrates of Woji/Okujagu Stream compared with WHO and NESREA standard for dry and wet seasons.

Sampling Stations	Nitrates (mg/L) Dry	Nitrates (mg/L) Wet	Mean Nitrates (mg/L)	WHO Limits	NESREA Limits
A	17.6	12.5	15.05	50	50
B	97.3	58.5	77.90	50	50
C	85.9	42.2	64.05	50	50
D	65.8	36.8	51.30	50	50
E	32.6	21.4	27.0	50	50
F	25.5	18.5	22.0	50	50

Table A.6: Biochemical Oxygen Demand (BOD5) of Woji/Okujagu Stream compared with WHO and NESREA standard for dry and wet seasons.

Sampling Stations	BOD_5 (mg/L) Dry	BOD_5 (mg/L) Wet	Mean BOD_5 (mg/L)	WHO Limits	NESREA Limits
A	62.4	38.2	50.3	10	30
B	75.2	45.6	60.4	10	30
C	65.8	36.5	51.15	10	30
D	52.2	30.5	41.35	10	30
E	42.5	22.5	32.5	10	30
F	44.2	21.2	32.7	10	30

Table A.7: Dissolved Oxygen (DO) of Woji/Okujagu Stream compared with WHO and NESREA standard for dry and wet seasons.

Sampling Stations	DO (mg/L) Dry	DO (mg/L) Wet	Mean DO (mg/L)	WHO Limits	NESREA Limits
A	4.5	6.2	5.35	10	4 – 6
B	2.2	3.2	2.70	10	4 – 6
C	3.6	4.5	4.05	10	4 – 6
D	4.1	5.6	4.85	10	4 – 6
E	5.8	6.5	6.15	10	4 – 6
F	6.2	6.8	6.50	10	4 – 6