

POLLUTION AND SELF PURIFICATION STUDIES OF RIVER ROMI, CHIKUN LOCAL GOVERNMENT AREA KADUNA STATE

BY

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M.Sc / ENG / 10667 / 2007-08

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A THESIS SUBMITTED TO THE POSTGRADUATE SCHOOL IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE AWARD OF THE DEGREE OF MASTER OF SCIENCE [M.SC.] IN WATER RESOURCES AND ENVIRONMENTAL ENGINEERING IN THE DEPARTMENT OF WATER RESOURCES AND ENVIRONMENTAL ENGINEERING, AHMADU BELLO UNIVERSITY, ZARIA

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DECLARATION

I hereby declare that the research work presented in this thesis, for the award of Master of Science in Water Resources and Environmental Engineering in the Department of Water Resources and Environmental Engineering has been written and compiled by me, **Mr. OGBONNAYA IKENNA EMEASO**. The research is exclusively the report of the investigation conducted by me. I also declare, that this thesis has not been written or submitted in any form whether partly or wholly for any other degree. All sources of publications and other related reports cited in this research have been identified in the reference section.

_____ _____

EMEASO, Ogbonnaya Ikenna **Date**
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CERTIFICATION

This Thesis entitled: "**Pollution and Self Purification Studies of River Romi. Chikun Local Government Area Kaduna State,** by **EMEASO, Ogbonnaya Ikenna** meets the regulations governing the award of Master of Science in Department of Water Resources and Environmental Engineering, Faculty of Engineering of Ahmadu Bello University, Zaria, Nigeria and is approved for its contribution to knowledge and literary presentation.

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DEDICATION

This work is dedicated to my father, late Mr. **ELUWA EMEASO** (I always remember your advice and those days, but GOD knows best. I miss you) and mother, Madam **BLESSING EMEASO** who gave me the best education from their scarce resources. May the Good Lord and GOD almighty bless them forever! Amen and also to my wife Madam **NONYEREM EMEASO** and my son**, RHEMA.** May GOD bless you! Amen.

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ABSTRACT

Angwan Romi is a place in the Chikun Local Government Area of Kaduna State in Nigeria at 10°25'48" north of the equator and 7°25'12" east of the Greenwich Prime Meridian. Romi River is a body of running water moving to a lower level in a channel on land. It is on Latitude 10.45 decimal degrees, Longitude 7.37 decimal degrees, DMS Latitude 10° 27 min 0 sec, DMS Longitude7° 22 min 0.012 sec. Universal Transverse Mercator (UTM): LS25. The people living in Angwan Romi village and environ use the water of River Romi to supplement their daily water demand which has not been met by government. They may be at health risk as a result of usage of Romi River water. The study was carried out to determine the extent of pollution and self purification of River ROMI. The study covered a distance of 15Km from the point of effluent discharge from the Kaduna Refining Petrochemical Company to the point of outflow into the River Kaduna. The data was collected from July 2009 to February 2010, to capture the dry and wet seasons and repeated again in July 2011 for validation. The number of sampling points was four with six different samples collected for each, with composite sampling at site 1 employed. The samples were analyzed for Dissolved Oxygen (DO), chemical oxygen demand (COD), Biological oxygen Demand (BOD),pH , nitrogen nitrate, ammonia nitrate, phosphates, coliform count (serial dilution), heavy metals, total dissolved solids, temperature, electrical conductivity and discharge and self-purification capacity. The methodologies employed for the analysis were according to the standard methods for the analysis of water and waste water.

Most of the water quality parameters were depleted especially at site 3 where a tributary from Nigerian National Petroleum Company Housing estate flows into the river. The observed die-off for bacteria colony count along the Romi River 15 Km course suggested that the stream still can purify itself. The results show deterioration

in river water quality for the stretch with only a figment of recovery for some parameters seen at site 4. A model of BOD against Distance was developed from the results obtained. The average DO value was 6.8 mg/L,6.5 mg/L,6.7 mg/L and 6.8 mg/L at sites 1,2,3 and 4 respectively in the rainy season and in the dry season it was 5.5 mg/L,6.0 mg/L,6.5 mg/L and 6.3 mg/L respectively. The de-oxygenation rate was 1.143 d^{-1}. The re-aeration rate was 0.934d^{-1} which shows that there is appreciable self purification within this 15Km course. Also the results show that the concentration of the heavy metals at each site is in the order of Pb>Cu>Cd. All the parameters monitored indicate serious water quality impairment along the 15km stretch studied. The deterioration is due to discharges from KRPC Plant and NNPC housing estate.

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CHAPTER ONE

INTRODUCTION

1.1 GENERAL

Rivers have many tributaries that may spare them from pollution as much as possible. Rivers provide a myriad of in-stream and consumptive uses; they support flora and fauna, improve aesthetic and landscape quality, moderate climate and even generate hydropower. However many rivers are not able to provide some of these because of pollution.

The primary objective of water quality monitoring is to deliver clean safe water. Water is essential to sustain life, and a satisfactory (adequate, safe and accessible) supply should be available to all.

Seven people died and twenty three hundred people became ill in the town of Walkerton, Ontario in May of 2000 because the drinking water became contaminated with a lethal strain of bacteria. This tragedy cost the government of Ontario $65 million to conduct the inquiry. The loss of life and suffering is estimated at an additional $91 million with costs totaling more than $156 million. This tragedy could have been prevented with an effective water quality monitoring program that included the use of continuous water quality surveillance Colin N Perkel (2002).

An overview of the multiple use character of water resources (which includes community /industrial water supply, electric power generation, recreation, navigation, irrigation , fishing and disposal of residual waste) and the impact on waste assimilation capacity of streams provides an orientation to the science and art of applied stream sanitation.(Oguejiofor, 1995)

The pollution profile of a stream is easily determined by either measuring levels of pollution at reasonable intervals along the river course or by using the Streeter-Phelps

dissolved oxygen sag equation. It is also possible to forecast the waste assimilation capacity and resultant water quality of a stream using the rational method of stream analysis. This can be obtained for any residual waste effluent loadings under the range in hydrological variations expected and the impact of man-made river developments and uses (Oguejiofor, 1995)

1.2 STATEMENT OF THE RESEARCH PROBLEM

Angwan Romi is a place in the Chikun Local Government Area(see Figure1.1) of Kaduna State in Nigeria at 10°25'48" north of the equator and 7°25'12" east of the Greenwich Prime Meridian. Romi River is a body of running water moving to a lower level in a channel on land (see Figures 1.2,1.3 and 1.4). It is on Latitude 10.45 decimal degrees, Longitude 7.37 decimal degrees, DMS Latitude 10° 27 min 0 sec, DMS Longitude7° 22 min 0.012 sec. Universal Transverse Mercator (UTM): LS25. The people living in Angwan Romi village and environ with a population of 60,000 (Nigeria, 2006 Census figures) use the water of River Romi to supplement their daily water demand which has not been met by government..They may be at health risk as a result of usage of Romi River water. Diseases related to contamination of drinking-water constitute a major burden on human health. Interventions to improve the quality of drinking-water provide significant benefits to health.

1.3 JUSTIFICATION

Access to safe drinking-water is essential to health. The importance of water, sanitation and hygiene to health and development has been reflected in the outcomes of a series of international policy, especially the Millennium Development Goals (MDGs) adopted by the General Assembly of the United Nations (UN) in 2000.

This study would help to establish any risks that may be associated with the use of River Romi water by the adjacent communities. This study can help provide general Guidiance in the development of a water quality monitoring plan for this water body



Figure 1.1 Map of Local Government Areas in Kaduna State.

1.4 AIM AND OBJECTIVES OF STUDY:

The aim of this study is to determine the extent of pollution and the self purification capacity of River Romi at stretch covering a distance of 15km from the point of discharge of effluents from Kaduna Refining and Petrochemical Company

This aim will be achieved through the following objectives:

a) Study the presence of heavy metals: copper, lead, manganese, copper. Iron, cadmium,

b) Study the biochemical oxygen demand, chemical oxygen demand, oxygen generation and consumption, riverbed temperature and the total dissolved solids of the stream

c) Study the bacterial contamination, that is, the fecal coliform count of the river.

1.5 SCOPE OF STUDY

The study involves the characterization (physical, chemical and biological) of the pollution profile of Romi River as well as the assessment of the extent of its self purification within a 15 Km stretch. The study covered both the rainy and dry seasons between July 2009 and August 2011 in order to capture variations in pollution trends that are influenced by seasonal factors.

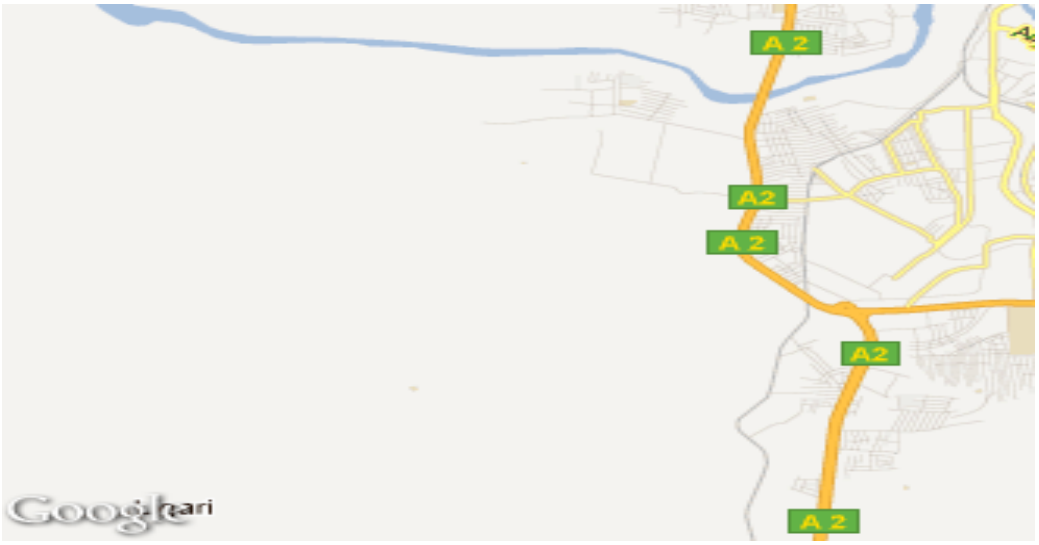


Figure 1.2 River Romi

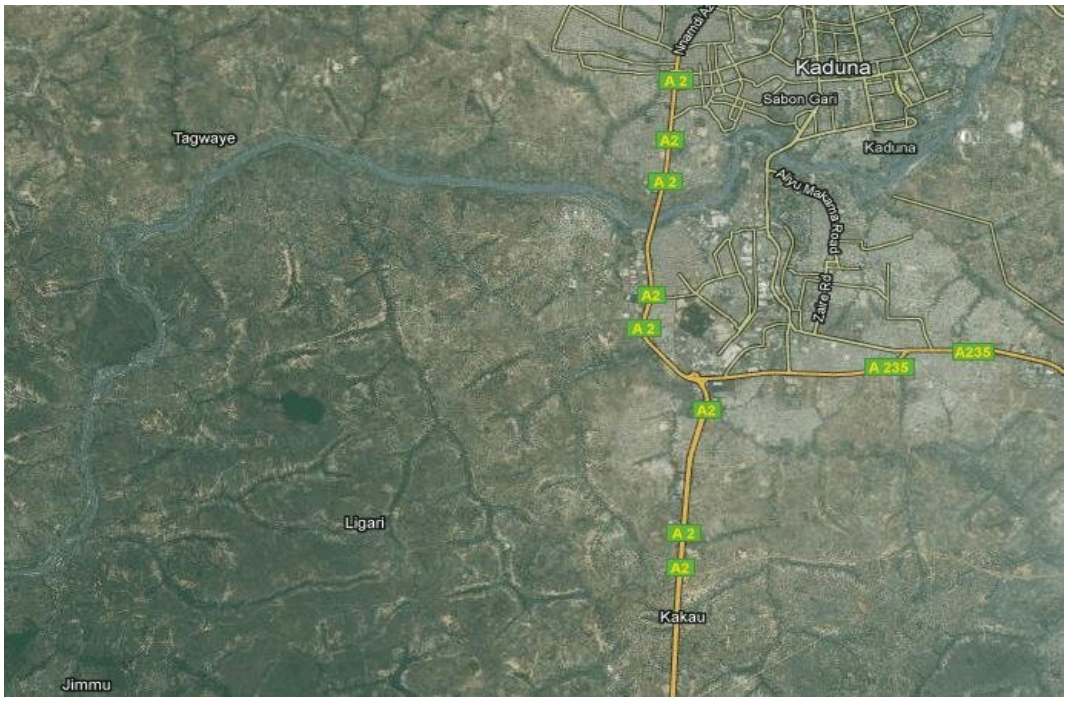


Figure 1.3 River Romi(Imagery ©2011 TerraMetrics)



Figure 1.4 Satelite Image of Romi River(Imagery ©2011 GeoEye

CHAPTER TWO

LITERATURE REVIEW

2.1 SOURCES OF URBAN RIVERS POLLUTION

Urban rivers are prone to pollution mainly due to their proximity to many pollution sources like waste water discharge points, on-site sanitation systems for domestic institutional sources, industrial effluent discharge points, solid waste disposal sites and agricultural uses they can be grouped into natural, agricultural, industrial and urban sources

Natural pollution arises from storm wash, seepage ground water, swamp drainage and aquatic life of stream. Storm wash usually carries large quantities of organic matter from decaying flora and fauna and inorganic silt from soil erosion into streams.

Seepage from ground water may contribute a variety of chemical components dissolved from the soil and geologic formations through which the seepage water passes to reach the water course.

Water quality is often described in terms of a number of physico-chemical and biological parameters depending on the intended use of water. River water quality is described for instance by parameters such as Dissolved Oxygen (DO), pH, Temperature, Most Probable Number (MPN) of coliforms, and analyzed in field and laboratory for various physico-chemical characteristics as per the APHA standards. Kaduna River Pollution Study Project (Beecroft, 1987) has been considered for comparison of water quality of Romi River within the influence zone. Following the Koko toxic waste episode in Delta state, the Federal Government of Nigeria promulgated the Harmful Waste Decree 42 of 1988, which led to the establishment of the Federal Environmental Protection Agency (FEPA) through Decree 58 of 1988. In

the wisdom of Government, FEPA and other relevant Departments in other Ministries were merged to form the Federal Ministry of Environment in 1999, but without an appropriate enabling law on enforcement issues. This situation, created a vacuum in the effective enforcement of environmental laws, standards and regulations in the country. To address this situation, the National Environmental Standards and Regulations Enforcement Agency (NESREA) were established as a parastatal of the Federal Ministry of Environment, Housing and Urban Development. The NESREA Act was accented to by Mr. President on 30th July, 2007. By the NESREA Act, the FEPA Act Cap F 10 LFN 2004 was repealed.

NESREA is charged with the responsibility of enforcing all environmental laws, guidelines, policies, standards and regulations in Nigeria. It also has the responsibility to enforce compliance with provisions of international agreements, protocols, conventions and treaties on the environment. The vision of the Agency is to ensure a cleaner and healthier environment for all Nigerians, while the mission is to inspire personal and collective responsibility in building an environmentally conscious society for the achievement of sustainable development in Nigeria.

The natural elements which cause water pollution are gases, soil, minerals, humus materials, waste created by animals and other living organisms present in water. During rain, surface water with soil, mud and humus enter into the river, tanks and other water bodies. The inorganic minerals like sodium, potassium, calcium, magnesium and heavy metals like iron, manganese, lead, mercury, chromium, cadmium, nickel, cobalt, beryllium copper *etc*., when present above the permissible limit are harmful. Agricultural water pollution is caused by fertilizers, insecticides, pesticides, farm animal wastes and sediments. Research findings indicate that application and heavy doses of fertilizers pollute ground water through leaching of nitrate from nitrogenous

fertilizers and of cadmium from single super phosphate and of fluoride from rock phosphates. The use of various types of pesticides and insecticides in agriculture cause water pollution. Careless deposit of animal waste closed to the wells and ponds situated in the backyards cause pollution of water through leaching. The pathogenic organisms of these wastes transmit to the water and pose serious problems

2.2 BIOCHEMICAL OXYGEN DEMAND

The BOD test measures the amount of oxygen consumed in breaking down organic matter using both aerobic biological and chemical degradation processes, giving an indication of the organic strength of a wastewater. The test has its widest application in measuring waste loadings to treatment plants and in evaluating the BOD-removal efficiency of such treatment systems.BOD is determined by incubating a water sample in a sealed container for a specified time and measuring the loss of oxygen that occurs between the beginning and end of the test. Samples must often be diluted prior to incubation. (Jay Lehr *et al.,* 2005)

Biodegradable organic matter is a composite substrate and is difficult to quantify directly. The BOD test estimates the amount of dissolved oxygen used during the degradation of organic waste as a surrogate for measuring the waste itself. The amount of molecular oxygen measured during the incubation period can accrue from three sources:

1. The oxygen used for the biochemical degradation of organic material
2. The oxygen used to oxidize inorganic materials such as sulfides and ferrous iron.
3. The oxygen used to oxidize reduced forms of nitrogen (nitrogenous demand), although a nitrifying inhibitor is often used to suppress the nitrogenous demand. (Jay Lehr *et al.,* 2005)

In a report prepared by the Royal Commission on Sewage Disposal in the United Kingdom at the beginning of the last century, it was recommended that a five-day, 18.3°C, BOD value be used as a reference in Great Britain. These values were selected because British rivers do not have a flow time to the open sea greater than five days and the average long-term summer temperatures do not exceed 18.3 ◦C. The temperature has been rounded upward to 20 ◦C, but the five-day time period has become the universal scientific and legal reference. (Jay Lehr *et al.,* 2005)

The BOD_5 test is still the most important and most widely used environmental index for monitoring organic pollutants in waters, mainly as proof of compliance with relevant legislation. Most developed countries strictly regulate the permissible BOD loadings of water as it is discharged from a treatment plant into receiving waters (e.g., sea or river), which is typically required to be less than 20 mg /L. The BOD_5 value for potable water is close to zero; domestic wastewater effluent entering a treatment plant typically has a BOD_5 of around 300 mg /L; and industrial effluents can have BOD_5 values greater than 20,000 mg /L (Jay Lehr *et al*., 2005)

2.3 CHEMICAL OXYGEN DEMAND (COD)

The COD test measures the chemical oxidation of wastewater by using a strong oxidizing agent under acid conditions. As for BOD, it measures the amount of oxygen required as a surrogate for measuring the organic waste component directly. The COD test does not differentiate between biologically available and inert organic matter and measures the total quantity of oxygen required to oxidize all organic matter into carbon dioxide and water. (Jay Lehr *et al.,* 2005)

COD values are always greater than BOD values, but the results can be obtained within two hours and the presence of toxic compounds in the sample does not affect

COD measurements. In many cases, the BOD/COD ratio is used to provide an indication of the biodegradability of the wastewater. However, the chemicals used, such as acid, chromium, silver, and mercury, produce liquid hazardous waste that requires careful handling and disposal. Finally, the precision and accuracy of the COD test are questionable at low BOD values. (Jay Lehr *et al.,* 2005)

2.4 OXYGEN GENERATION AND CONSUMPTION

Dissolved oxygen is the amount of oxygen dissolved in water, measured in milligrams per liter (mg/L). This component in water is critical to the survival of various aquatic lives in streams, such as fish. The ability of water to hold oxygen in solution is inversely proportional to the temperature of the water. For example, the cooler the water temperature, the more dissolved oxygen it can hold (Chehalis River Council, 2008)

Biodegradable means that a substance can be converted into simpler compounds by biologically mediated reactions. The second law of thermodynamics predicts that oxidation of high energy level organics (relative to low energy level CO_2) is favored. Oxygen is one of the strongest oxidizing agents found in natural aquatic systems. Oxidation reactions are thermodynamically favored, but kinetically slow unless microbially mediated. The end products of complete aerobic biodegradation are CO_2 and H_2O (Ellis *et al.,* 1996)

2.4.1 Dissolved Oxygen Saturation (%)

Oxygen saturation is calculated as the percentage of dissolved O_2 concentration relative to that when completely saturated at the temperature of the measurement depth. Recall that as temperature increases, the concentration at 100% saturation decreases. The

elevation of the lake, the barometric pressure and the salinity of the water also affect this saturation value but to a lesser extent. In most lakes, the effect of dissolved solutes (salinity) is negligible; but the elevation effect due to decreased partial pressure of oxygen in the atmosphere as you go up (recall the breathing difficulties faced by Mt. Everest climbers) is about 4% per 300 meters (1000 feet). The DO concentration for 100% air saturated water at sea level is 8.6 mg O_2/L at 25°C (77°F) and increases to 14.6 mg O_2/L at 0°C. Use the chart below for nomagrams for calculating saturation. (Mortimer, 1956)

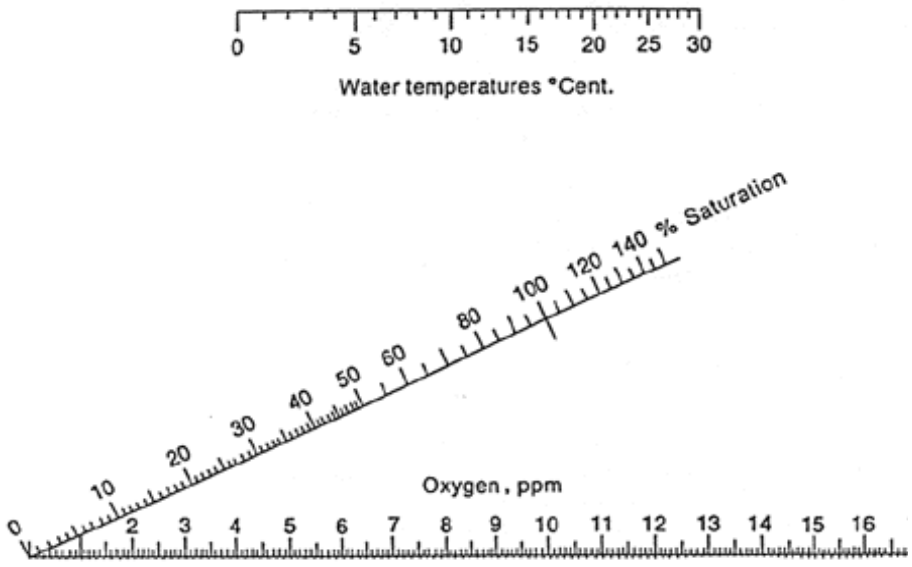


Figure 2.1 Oxygen Saturation at Temperatures

(a) Application to a River

The oxygen deficit as a function of distance down a stream is explained by an approximation of a cross section of a river as a completely stirred reactor that is slowly moving downstream. The relation between time in a batch reactor and distance down the river is simply (Ellis *et al.,* 1996)

$t = x/u$ …….. 2.1

where u is stream velocity and x is distance.

2.5 SELF PURIFICATION

Self-purification of aquatic system is a pathless process that frequently combines different physicochemical and biological processes. The main process in this phenomena is biochemical activity that it transfer the organic substances to biological matter and some finally productions. This procedure could repeat several times until these productions sediment or they are transformed to the gas and enter to atmosphere. . (Nazari –Alavi *et al.,* 2007)

With knowledge of aquatic parameters and pollutants, it is possible to model Self-purification process. Adsorption and composition of organic matter in a river is depended to relationship between oxygen and ecosystem. . (Nazari –Alavi *et al.,* 2007)

Dissolved oxygen is the most important part of an aquatic system. While biodegradable organic substances are discharged to a river which contains the dissolved oxygen, the microorganisms oxidize the organic matter with consumption of oxygen. The new cells of microorganisms are the final product. Oxygen consumption rate is related to organic loading, biodegradability and river rarefactional. The oxygen consumed must be replaced otherwise the anaerobic process installs in aquatic system. The stream reaeration in natural water is dominated by two procedures, oxygen transfer from atmosphere and generation by photosynthesis. The first mechanism is predominant.

Many investigators have developed formulas for predicting reaeration in streams and rivers and after numerous formulas have been proposed to model self-purification. The models are complex and often they are solved with numerical analysis by using informatic programs. The base of these models is Streeter-Phelps model (Streeter and Phelps, 1925; Nemerow, 1978).

The Streeter-Phelps model ties together the two primary mechanisms governing dissolved oxygen in a stream receiving sewage, decomposition of organic matter and

oxygen reaction. As such it provides an analytical framework for predicting the effect of both point and non-point sources of organic wastewater on stream and estuary dissolved oxygen. Streeter-Phelps model is founded on three principal formulas Nemerow, (1978).

$K_1 = \frac{}{\Delta} \log (L_A/L_B)$…… (2.2)

$K_2 = K_1(L/D) - (\frac{\Delta}{\Delta})$…….. (2.3)

$D_t =$ ——— ..... (2.4)

The upper equations permit to calculate de-oxygenation rate/day (K_1), re-aeration rate/day (K_2) and dissolved oxygen deficit ($D_{t)}$. For determining error rate and comparing the results between analytical method and a numerical method, we chose this model because it can be solved very easily by traditional integration methods. First of all, we compare analytical method and numerical analysis for an identified sample and after determination error of numerical analysis, we apply the analytical method to our case.

2.6 FECAL BACTERIA

A number of bacteria occur naturally in freshwater streams. Some are found living in the water and sediments as photosynthetic autotrophs or a saphrophytes living on dead matter. Others exist in or on other organisms as mutual symbiosis (providing some benefit to the host organisms in exchange for a place to live), commensals (neither helping nor harming the host), or parasites (utilizing the host in a way that causes harm). Doyle and Erickson (2006)

Rather than test water directly for pathogens, which can be difficult, expensive and even hazardous, researchers use indicator organisms to assess the possibility of fecal contamination. Fecal coliform bacteria, members of the family *Enterobacteriacea*,

which include *Escherichia coli, Citrobacter*, *Enterobacter* and *Klebsiella* species, are often used as indicators. These gram negative bacilli (rod shaped bacteria) are found in the digestive tracts of all warm-blooded animals.

Most are not pathogenic. However, because they are eliminated with feces, they are sometimes associated with pathogens such as *Vibrio cholera* bacteria or a form of Hepatitis virus that is found in the digestive tract. Total coliform bacteria counts are sometimes used to test for water contamination also. U S Environmental Protection Agency EPA (2008).

Despite the fact that they cannot be linked directly to contamination by human sewage, fecal coliform bacteria counts are often used to regulate surface waters for recreational use, shellfishing, and potability (ability to be safely consumed). Federal regulations stipulate maximum allowable numbers of these bacteria for various uses. If fecal coliform counts are high (over 200 colonies per 100 ml of water sample) in the river or stream, there is a greater chance that pathogenic organisms are also present. A person swimming in such water has a greater chance of getting sick from swallowing disease-causing organisms, or from pathogens entering the body through cuts in skin, the nose, mouth, or the ears. Diseases and illnesses such as typhoid fever, hepatitis, gastroenteritis, dysentery, and ear infections can be contracted in waters with high fecal coliform counts .U S Environmental Protection Agency EPA(2008).

Cities and suburbs sometimes contribute human wastes to local rivers through their sewer systems Storm sewers carry rain and snow melt from streets, and discharge untreated waters directly into rivers. Doyle and Erickson(2006)

Heavy rains and melting snow wash bird and pet wastes from sidewalks and streets into storm drains, after a heavy rain, untreated or inadequately treated waste may be diverted into the river to avoid flooding the wastewater treatment plant.

To avoid this problem, some cities have built retention basins to hold excess wastewater and prevent untreated waste from being discharged into rivers. Without retention basins, heavy rain conditions can result in high fecal coliform counts downstream from sewage discharge points. That is why it is important to note weather conditions on the days before a fecal coliform measurement. Doyle and Erickson(2006)

CHAPTER THREE

MATERIALS AND METHODS

3.1 SITE DESCRIPTION

One of the tributaries to River Kaduna is the Romi River in Chikun local government area and that is where Kaduna Refining and Petrochemical Company discharges its waste water into. See plate I below which shows discharge tunnel of KRPC to the stream.



Plate I : Waste Water Discharge Channel of KRPC

River Romi runs through Angwan Romi village with human settlements, informal sector activities (car washing), agriculture ,industries and solid waste disposal sites. People bathe as well as fish in it and water from it is used for irrigation and drinking by animals and to a limited extent for domestic purposes.Plates II and III below shows the upstream route to the stream



Plate II: Road to Upstream of Romi River



Plate III: Upstream Romi River

Four stations were located on the river stretch as sampling points (see map below)

Site 1 is located just after the discharge of waste water treatment plant of KRPC before the effluents from the plant enters the river. The water here is clear and running fast. There is no visible disturbance or siltation to this location. There were no extensive shrubs and herbaceous plants here and no visible plant debris at this sample location. See pictorial view in Plate IV below.



Plate IV: Site 1 at Romi River

Site 2 is located just after the confluence with another discharge coming from the River Rido. The water is clear and running fast. There were sparsely spaced trees around this sampling site which is primarily in a grassy field area. It is 3.5km from site 1.See pictorial view in Plate V below.



Plate V: Site 2 at Romi River

Site 3 located about 7 km from site 1 to study the self purification between sites 1 and site 3. There is storm drain from NNPC Housing estate that enters at the site. The water here is not clear, a bit slow as it is covered with green flora on the bottom and green flora on the sides. There are many shrubs and herbaceous plants beside the sampling site and no visible plant debris in this sample location. See pictorial views in Plate VI(a-c) below.



(a)



(b)



(c)

Plate VI(a-c): Site 3 at Romi River

Site 4 is located about 8 km from site 3. Samples collected here are to conclude the self purification capacity of the river. The water here is clear and running fast. The banks on this site are sparsely covered with visible plant debris. There is also a grassy field around it. See pictorial views in Plates VII(a-c) below.

:



(a)



(b)



(c)

Plate VII(a-c): Site 4 at Romi River

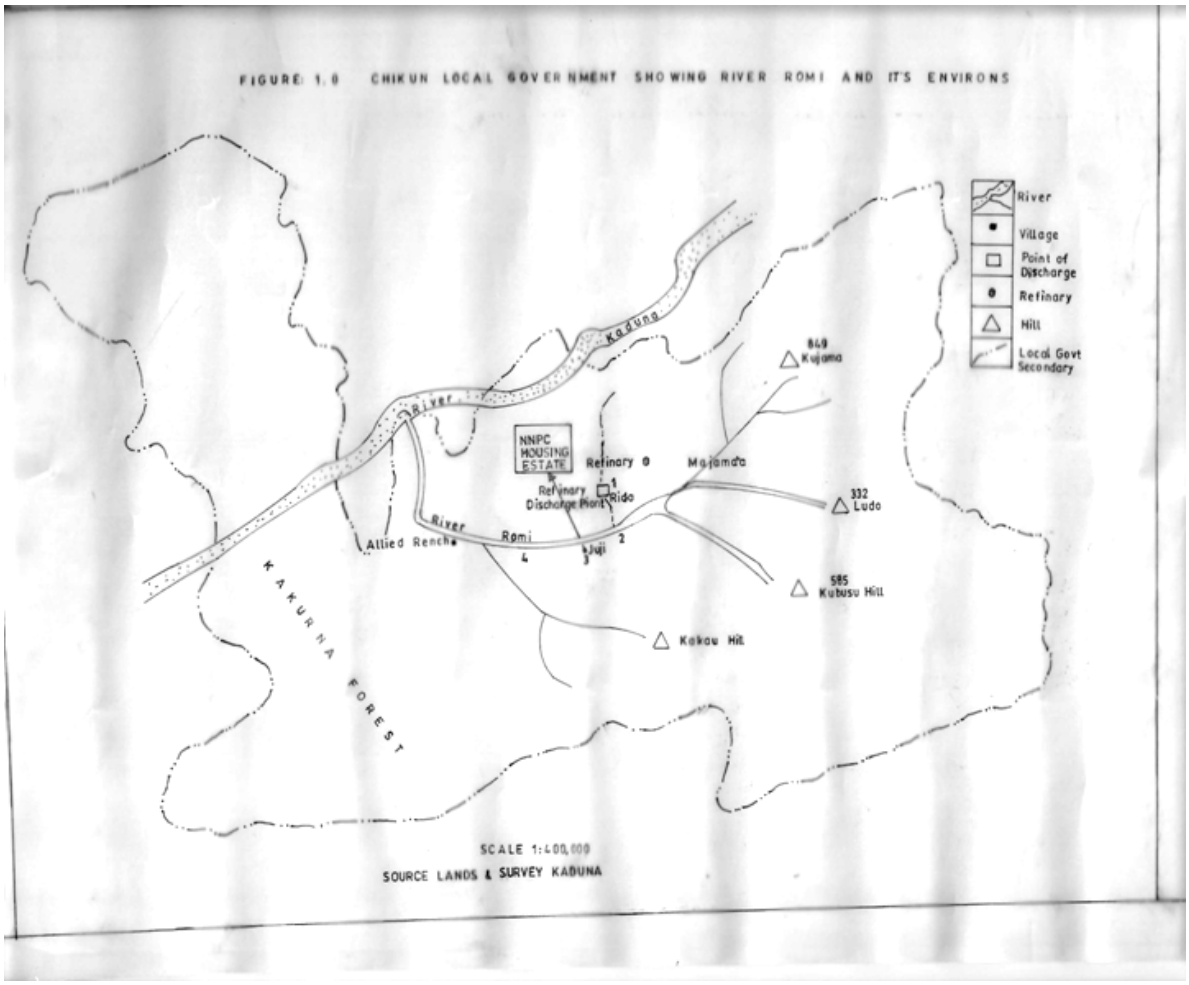


Figure 3.1: Sampling Sites

3.2 MATERIALS

The following equipment and meters were used for measuring the parameters listed against them:

A liquid tracer dye (Rhodamine WT 20-percent dye [0.1 $\times 10^7$ µg/L) : used to measure the flow velocity in a relatively uniform stretch of the stream.

All glass wares are manufactured by pyrex

Autoclave

A stop watch: used to time the dye traveling from one point of the river to another

BOD bottles

Conical flask

Dissolved Oxygen Meter by The Yellow Spring Instrument Model 57 was used to measure dissolved oxygen

Double Beam Spectrophotometer CECIL 7500: was used to measure phenol, sulphates, nitrates ,phosphates, total dissolved solids and all UV of 190 -110nm range.

Dual Beam Infrared Spectrophotometer WGH 30/30A:was used to measure oil and grease

Dry Seal Vacuum Dessicator from Wheaton Science Product

HORIBA pH meter model M13: was used to measure pH and temperature.

Hanna Instrument Micro Processor Conductivity Meter model H1 9932: was used to measure electrolytic conductivity and total dissolved solids

Hanna Instrument LP 2000 Turbidity meter: was used to measure turbidity

HACH DR/5000 Spectrophotometer: will be used to measure nitrate, phosphate and sulphate.

HACH DR/2000 spectrophotometer: was used to measure ammonia nitrate

Incubator set at $37^{o}C$

Meter rule: used to measure the length, surface width and depth of the river

Magnetic stirrer

Precision Water bath Model 182

Sterile collection container (sterile bottle or test tube) with water sample

Sterile pipettes or sterile transfer pipettes (dropper pipettes)

Sterile test-tubes serial dilution.

Sterile petri dish

3.2.1 Reagents

Ammonia nitrogen solution, standard (1m/l =0.01mg n) Ammonium chloride solution (analytical grade) by BDH UK

Ammonium hydroxide (analytical grade) by BDH UK

Alkaline iodine solution (analytical grade) by BDH UK

Buffer solution: 21.75g dipotassium phosphate,8.5g of potassium phosphate.33.4g of disodium phosphate (heptahydrate) and 1.7g of ammonium chloride dissolved in water to 1 litre.

Cyclohexane (analytical grade) by BDH UK

Disodium dihydrogen ethylenediamine tetra acetate solution (EDTA) (9500g/l) Diethyl ether(pesticide quality containing 2 % ethanol) (analytical grade) by BDH UK

Florisil(PR grade 60 -100 mesh) (analytical grade) by BDH UK

Ferrous sulphate solution(analytical grade) by BDH UK

Methylated spirit for disinfection of premises

Methylene chloride (analytical grade) by BDH UK

Methylene chloride(analytical grade) by BDH UK

n-hexane(analytical grade) by BDH UK

Nessler reagent (analytical grade) by BDH UK

Pentane (analytical grade) by BDH UK

Petroleum ether(analytical grade) by BDH UK

Reagent EMB Agar gel (Microbiology Laboratories)

Sodium thiosulphate solution (analytical grade) by BDH UK

Starch indicator solution

Sodium hydroxide (analytical grade) by BDH UK

Sulphuric acid (sp. gr. 1.84) (analytical grade) by BDH UK

Silca gel (analytical grade) by BDH UK

Note: All reagents are supplied from BDH UK.

3.3 METHODS

3.3.1: Site Surveys and Investigations

Romi river was presented as a series of reaches with constant hydraulic characteristics (e.g. slope bottom width etc) where both point and non point sources and point and non point withdrawals can be positioned anywhere along the channels length.

Surveys and investigations in the study area were carried out to identify and select sampling sites, flow measurement points, and points of discharge of effluents into the Romi River. The sampling period was six months.

3.3.2 Discharge Measurements

(a) Velocity area method

- In the velocity area method, where the river is wadeable, the 0.6-depth method, an observation of velocity made in the vertical at 0.6 of the depth below the surface is used as the mean velocity in the vertical. This depth gives the nearest velocity to the mean velocity (see Table 3.1 below)

Table 3.1.- Coefficients for standard vertical velocity curve

Ratio of observation depth to depth of water in the vertical	Ratio of point velocity to mean velocity in the vertical
0.05	1.16
0.1	1.16
0.2	1.149
0.3	1.13
0.4	1.108
0.5	1.067
0.6	1.02
0.7	0.953
0.8	0.871
0.9	0.746
0.95	0.648

Source: USGS fact sheet (2005-3131)

(b) Calculation of Cross-sectional Area

- Use the raw data to draw the river cross-section(s) on graph paper, By maintaining the same scale for both the vertical and horizontal axes, calculation of the wetted perimeter and cross-sectional area is simplified.
- Either calculate the area of the smallest graph square (in m^2) and then count how many lie within the cross-section (part squares count as ½) or divide the cross-section into a series of trapeziums and apply the formula ½(a+b)y to each trapezium, where a and b are the two parallel sides of unequal length, and y the *shortest* side between them.

(c) Discharge

- In hydrology, **discharge** is the volume rate of water flow, including any suspended solids (i.e. sediment), dissolved chemical species (i.e. $CaCO_{3(aq)}$) and/or biologic material (i.e. diatoms), which is transported through a given cross-sectional area.[1] Frequently, other terms synonymous with discharge are

used to describe the volumetric flow rate of water and are typically discipline dependent.

- A commonly applied methodology for measuring, and estimating, the discharge of a river is based on a simplified form of the continuity equation. The equation implies that for any incompressible fluid, such as liquid water, the discharge (Q) is equal to the product of the stream's cross-sectional area (A) and its mean velocity ($\bar{u}$), and is written as:

$$Q = A\bar{u}$$ .....equation (3.1)

where

- Q is the discharge (m^3/s)
- A is the cross-sectional area of the portion of the channel occupied by the flow (m^2)
- $\bar{u}$ is the average flow velocity (m/s)

An average of all the 4 discharges measured in different sections was taken as the discharge for the stream.

3.3.3 In Situ Measurements

Apart from flow measurements, in situ measurements included Dissolved oxygen (DO), Temperature, and pH, electrolytic conductivity, total dissolved solids and turbidity. DO and pH was measured using DO and pH Meters that also gave temperature readings.

The measurements covered both the dry and rainy seasons and was synchronized as much as possible.

During each season, at least three measurements were taken for each parameter at each site.

3.3.4 Chemical and Bacteriological Laboratory Analysis

24 hourly Composite Samples of water and wastewater discharging into the River Romi was collected during both the dry and rainy seasons at the same time of the day at the point of discharge of effluents into the river by KRPC while at the other sites, samples of water and wastewater discharging into the River Romi were collected.

Composite Sampling, Sample storage, and analysis techniques was in accordance with the Standard Methods for the Examination Of Water and Wastewater (APHA 1995) and ASTM (2001).

All laboratory analyses were carried out in the Kaduna Refinery And Petrochemical Company Environmental Engineering laboratory.

Notably, samples for fecal and total coliforms was analysed within 6 h of being collected.

3.3.4.1 Direct Nesslerisation method: The ASTM D 1426-98 was used for ammonia nitrogen because of its simplicity.

- 25ml of sample was filtered and collected into a boiling tube.
- 1ml of solution of Nessler's reagent was added and the mixture agitated for 20 seconds.
- A yellow colour indicates presence of ammonical nitrogen which.
- The concentration of ammonia was assessed with the aid of the spectrophotometer.

3.3.4.2 Double Beam Spectrophotometer: CECIL 7500 was used to determine phosphates using the stannous chloride colorimetric procedure.

- 25ml of water sample was collected into a boiling tube
- 1 drop of ammonium molibdate/H_2SO_4) was added and followed by 1 drop of 5% stannous chloride solution and agitated for 20 seconds

- A blue colour indicates phosphate presence
- A spectrophotometer was used to assess its concentration

3.3.4.3 Double Beam Spectrophotometer: CECIL 7500 was used to determine nitrates using phenol disulphonic acid (PDA) method.

- A filtered sample was neutralized to a pH of 7.0
- 100ml of sample was evaporated to dryness on a water bath
- The residue was dissolved using glass rod with 2 ml of phenol disulphonic acid reagent and diluted to 100ml and transferred to Nessler tubes
- 7 ml of NH_4OH (ammonium solution) was added and where turbidity developed ethylene diamine tetraacetic acid reagent was added drop wise until it dissolves.
- The solution was filtered and made up to 100ml
- End colour development at wavelength of 410nm

Organic nitrogen increases due to plant death. It is lost via hydrolysis and settling.

3.3.4.4 Double Beam Spectrophotometer: CECIL 7500 was used to determine COD using standard methods 13^{th} edition (1971) pp405 for Dichromate Oxygen Demand

- 50mls of distilled water was measured into a reflux flask as blank.
- 10mls of the sample was measured into another reflux and made up to 50mls with distilled water. The reflux was kept in an ice bath.
- 1g of mercuric sulphate and 5 mls of sulphuric acid were added with several boiling stones in each flask.
- 25mls of 0.25N potassium dichromate was added to the sample and the blank, both were refluxed for 2 hrs.
- 300mls of distilled water was added to each flask and allowed to cool to room temperature.

- 10drops of phenolphthalein indicator were added and titrate with 0.25N ferrous ammonium solution to a colour change of bluish green to reddish colour.

3.3.4.5 BOD: This was determined in accordance with standard method APHA (1995).

- Here the sample was filtered to remove particulate organic carbon
- The filtered sampled was incubated for 5 days.
- Nitrification will be inhibited by adding an inhibiting agent, 2 chloro-6 trichloro methyl pyridine.
- 0.025N Sodium thiosulphate solution was titrated against 200ml of the sample
- A colour change of golden yellow to pale yellow was obtained.
- 2mls of starch indicator was added and continued the titration process continue until a colour change from blue to colourless.
- The same process was used for the incubated sample

3.3.4.6 Isolation and enumeration of Escherichia coli in water: serial dilution method with an autoclaved media reagent of L-EMB Agar at 124^{o}C for 15 minutes according to APHA (1995).

- Incubation was at 37^{o}C for 24 hours and inoculation in the portions of 1.0, 0.1 and 0.01 ml.

Procedure:

1 media autoclaved at 121^{o}C for 15minutes

2 It was then inoculated with sample

3 It was then incubated for 24 hours at 37^{o}C

4 Colonies were counted afterwards.

3.3.4.7 Heavy metals: This was measured using Atomic Absorption Spectrophotometer Method according to manufacturer's instruction. The heavy metals analysis was carried

out in the Analytical Laboratory of the National Institute for Chemical Research, Basawa, Zaria.

3.4 SELF PURIFICATION

The critical state in Romi River occurs in dry and wet season. So the necessary experiments were carried out in these seasons. We did the experiments using readings from two stations, Site 1 (upstream) and Site 4(downstream).The reasons for selecting these stations is to capture the change/recovery in the water quality due to existence of KRPC plant wastewater discharge to river after treatment between these stations. The distance between the two stations is 15 km. The needful parameters for Streeter-Phelps formula are DO, BOD_5 and temperature (T) and Residence Time. They were measured by standard methods (APHA, 1991). BOD_5 (mg/l), DO (mg/l), and T(^{0}C) were measured for six times at different days.

The simulation was done by Streeter-Phelps model with B_{in}= 0 condition. The solutions were determined by exact integration without using numerical analysis method (Nazari-Alavi *et al*., 2007).

CHAPTER FOUR

RESULTS AND DISCUSSION

The results obtained in this study are presented in three sections as physical, chemical and bacteriological parameters measured between July 2009 and July 2011.

4.1 PHYSICAL PARAMETERS

The measured parameters include: discharge, time of travel between stations, electrolytic conductivity and temperature. Table 4.1 shows the range and the average values of these parameters obtained from six different samples.

Table 4.1: The Result of Physical Parameters

site	River dist.(m)	Discharge(m3/s)		time of travel(s)		Temperature(0c)		electrolytic conductivity(µS/cm)	
		Replications	average	Replication	average	Replications	average	Replications	average
1	0	.075-.250	0.141	0	0	22.9-30.7	26.7	44.4-505	209.15
2	3500	0.245-2.203	1.130	1800-850	4356	22.7-29.9	26.5	50.0-402.0	154.78
3	7000	0.303-2.249	1.629	4560-31200	16425	22.8-31.2	26.68	38.4-181.5	85.42
4	15000	0.387-4.533	2.343	7440-54720	28656	22.8-31.9	26.85	39.2-946.0	250.25

4.1.1 Discharge

The discharge was found to be 0.141m^3/s at site 1. This increased to 1.13 m^3/s at site 2, it was 1.629 m^3/s at site 3 and 2.343 m^3/s at site 4. The increase could be as a result of contributions from tributaries from KRPC and the river morphology (the river is deepest here). It increased again at site 4 due to contributions from NNPC housing estate waste stream.

The flow of wastewater from KRPC into the river at site 1 was found to be 1:15 in October; 1:20 in November; 1:5 in December and 1:9 in January.

4.1.2 Electrolytic Conductivity

The electrolytic conductivity decreased downstream from 209.15 µS/cm at site 1 to 85.42 µS/cm at site 3. There was a contrasting peak of 250.25µS/cm at site 4. It was high at site 1 and site 4 due to increased pollution load from the contributing tributaries as shown by the high dissolved solids at these sites.

Table 4.2: Comparison of electrolytic conductivity and dissolved solids contents downstream

Site	1	2	3	4
Electrical conductivity (µs/cm)	209.15	154.78	85.42	250.25
Dissolved solids (mg/l)	310.41	198.28	128.06	140.95

Table 4.2 shows the correlation between dissolved solids and electrical conductivity as the results show that an increase in one amounted to an increase in the other and vice versa. The peak values for these sites (1 and 4) occurred in early November and early December respectively due to increased river temperature. WHO (1988) recommends a value of 2500µhos/cm for potable water.

4.1.3 Temperature

The temperature variations along the stream as shown in Table 4.3 were between 26.7^0C at site 1 and a peak of 26.85 ^{0}C at site 4.

Table 4.3: Result of Temperature Profile of River Romi from Oct. 2009 to April 2010

Site	1	2	3	4
Range of 6 data	22.9-30.7	22.7-29.9	22.8-31.2	22.8-32.9
Average of 6 data	26.7	26.5	26.7	26.9

Water temperature influences the density, conductivity and pH of a water column. In addition, solubility of gases (e.g. dissolved oxygen and carbon dioxide) decreases with

increasing temperature. Water is more likely to become anoxic or hypoxic under warmer conditions because of increased bacterial respiration and a decreased ability of water to hold dissolved oxygen.

The major cause of water temperature change in River Romi is due to the change in solar insolation in addition to currents and local hydrodynamics. Also, temperature in surface waters varies during the day and tends to be highest in the late afternoon as the sun sets.

Some more specific causes of water temperature variation in waters may include:.

- Discharges of 'cooling' waters from power plants and municipal or industrial effluent are sources of thermal pollution in the coastal zone.
- Changes in air temperature and shifts in currents occurring in response to global warming.

A similar result was obtained by Olajire and Imeokparia (1999) on water quality assessment of Osun River.

4.1.4 pH

The pH as shown in Table 4.4 below decreased downstream from 7.42 at site 1 to 6.97 at site 2, at site 3 it was 6.94 and 6.85 at site 4. This values are less than WHO (1993) recommended values of 7.0-8.5 for safe drinking.

Table 4.4: Result of pH values

site	River distance (m)	pH replications(6)	Average
1	0	6.5-9.22	7.42
2	3500	6.63-7.45	6.97
3	7000	6.49-7.19	6.94
4	15000	6.44-7.13	6.85
well	15200	5.84-7.14	6.29

This 15Km course of River Romi is acidic. The average pH values along the stretch reduced from site 1 to site 4. The pH of a body of water is affected by several factors;

1. The bedrock and soil composition over which the water moves, both in its bed and as groundwater,
2. The amount of plant growth and organic material within the body of water. When this material decomposes carbon dioxide is released. The carbon dioxide combines with water to form carbonic acid. Although this is a weak acid, large amounts of it will lower the pH.
3. The dumping of chemicals into the water by individuals, industries, and communities, for example Shampoo-rinsed water is actually a chemical brew that can affect the pH along with other chemical parameters of water. Many industrial processes require water of exact pH and thus add chemicals to change the pH to meet their needs. After use, this altered pH water is discharged as an effluent, either directly into a body of water or through the local sewage treatment plant.
4. The amount of acid precipitation that falls in the watershed. Acid rain is caused by nitrogen oxides (NO_x) and sulfur oxides (SO_x) in the air combining with water vapor. These pollutants are primarily from automobile and coal-fired power plant emissions. Acid rain is responsible for many of our first order streams becoming acidic.

This condition is probably due to the acid rain, industrial waste from KRPC (with pH of 4) and swamp drainage discharge from farmlands along the river. A similar situation was noticed by Oguejiofor (1995). He observed that river Kubani has a pH of 6.3 or lower.

4.1.5 Total Dissolved Solids

Table 4.5 shows that the total dissolved solids increased from 310.41 mg/L at site 1 to 140.95mg/L at site 4 while the related COD decreased from 480 at site 1 to360 at site 2 before increasing to 410 at site 3 then decreased again to 370 at site 4.

Table 4.5: Result of Total Dissolved Solids

site	River distance (m)	COD(mg/l) Replications	COD(mg/l) Average	TDS(mg/l) Replication	TDS(mg/l) Average
1	0	38.31-960	480	100.55-706.8	310.41
2	3500	75-590	360	30.88-383.65	198.28
3	7000	60.0-640	410	36.78-198.59	128.06
4	15000	46-550	370	42.99-293.33	140.95

All natural waters contain dissolved and suspended inorganic and organic substances. The low levels of total solids (93.2- 263.08 mg/l) indicate the good quality of river water in project-affected area. Seasonal analysis of the results showed that low total dissolved solids recorded between December to February while maximum values September and October in due to addition of solids from surface runoff due to processes such as coagulation, sedimentation, and volatilization (Ongley, 1991).

The discharge from KRPC plant and NNPC Housing estate waste water which contains high concentrations of dissolved solids may also have contributed to high values of total solids, especially at site 1 and site 4 the vicinities of entry into the river.

This level of TDS may be an indicator of seepage of filtering surface into ground water or the weathering of rocks and soil beneath the ground surface as the water percolates through them.

A comparative look at the results indicate a correlation between the COD and total solids which indicates that most of the solids are chemically oxidizable and this is supported by a similar trend in the values obtained at corresponding sites.

4.2 CHEMICAL PARAMETERS

The chemical parameters measured are: DO, NH_3-N, NO_3-N phosphates and heavy metals.

4.2.1 Dissolved Oxygen

Table 4.6 below shows that dissolved oxygen decreased downstream from 6.833mg/L at site 1 to 6.733mg/L at site 2 and 6.683mg/L at site 3 then increased afterwards to 6.783mg/L at site 4 showing a recovery.

Table 4.6: Result of Dissolved Oxygen

site	River distance (m)	DO(mg/l) Replications	DO(mg/l) Average
1	0	5.5-8	6.833
2	3500	6-7.4	6.733
3	7000	6.3-7.0	6.683
4	15000	6.3-7.4	6.783
well	15200	5.0-8.8	7.133

The decrease downstream is due to; no dilution by volume and velocity of the water flow prior to data collection. In fast-moving streams, rushing water is aerated by bubbles as it churns over rocks and falls down hundreds of tiny waterfalls. These streams, if unpolluted, are usually saturated with oxygen. In slow or stagnant waters,

oxygen only enters the top layer of water while deeper water is often low in DO concentration due to decomposition of organic matter by bacteria that live on or near the bottom of the reservoir.

A similar result was obtained by Abowei (2009) when he worked on Salinity, Dissolved Oxygen, pH and Surface Water Temperature Conditions in Nkoro River, Niger Delta, Nigeria observing that the high DO levels was due a dilution factor from heavy rainfall prior to sampling.

The colder the water, the more oxygen can be dissolved in it. Therefore, DO concentrations at one location are usually higher in the winter than in the summer. For instance at site 1 the temperature and DO were 22.9^{o}C and 6.8 mg/L respectively on 09.10.2009 while for the same site it was 24.7^{o}C and 5.5mg/L respectively on 18.01.2010.More sunlight and warmer temperatures also bring about increased activity levels in plant and animal life; depending on what organisms are present, this may increase or decrease the DO concentration.

During dry seasons, water levels decrease and the flow rate of a river slows down. As the water moves slower, it mixes less with the air, and the DO concentration decreases. During rainy seasons, oxygen concentrations tend to be higher because the rain interacts with oxygen in the air as it falls.

Higher concentrations of DO were observed during December. This may be explained to be due to increased turbulence by the irrigation process of farmland along the river course which produces more re-aeration. A possible explanation for the lower mean dissolved oxygen values in the wet season could be the turbidity nature of the water at this period due to inflows from run-offs and decomposition of organic matter in the water. In fact, Braide *et al*. (2004) also had similar results in their study of water quality of Miniweja stream in Eastern Niger Delta, Nigeria.

The DO concentrations are lowest at sites 3 and 2, indicating that more biological activities are taking place here possibly waste carried into the stream from run-off from roads and other paved surfaces from NNPC housing estate that brought salts and sediments into stream water, increasing the dissolved and suspended solids in the water.

In considering the temperature profile of the Romi River, it is clear that the dissolved oxygen values recorded in this study are lower than the standard values (8.38mg/l and 7.64mg/l) quoted by Boyd and Lichktoppler (1979) at equivalent temperature range of 23ºC to 29ºC. However, since dissolved oxygen concentration are usually low in the morning and rises to

a maximum in the afternoon, the concentrations reported in this study show that the creek contains high concentration of dissolved oxygen as the readings were

taken in the morning.

4.2.2 Phosphates

Table 4.7 below shows that phosphates increased downstream from 4.21mg/L at site 1 to 11.69mg/L at site 3 before it dropped to 9.99mg/L at site 4

Table 4.7: Result of Phosphates concentration in River Romi

Site	River distance (m)	Phosphates(mg/l) Replications	Phosphates(mg/l) Average
1	0	0.4-12.89	4.21
2	3500	2.6-12.67	6.1
3	7000	2.2-34.33	11.69
4	15000	2.6-26.78	9.99
Well	15200	2.2-2.6	2.73

The sources of phosphates include the industrial and domestic wastes from KRPC plant and NNPC housing estate respectively and the fertilizer used in farming along the river course.

The values increased downstream from 4.21mg/L at site 1 to 11.69mg/L at site 3 then dropped to 9.99mg/L at site 4.The lower phosphate readings may reflect a dilution effect in addition to a seasonal variation. The high values show that the late run-off discharges a large amount chemical nutrients resulting in eutrophication of the stream.

The high variability in concentration of water chemistry is as a result of land use changes coupled with the impact of self purification processes, which has either increased of decreased concentration of water chemical parameters in the study area. Ajibade (2004) reported a similar trend in Nigeria.

4.2.3 Ammonium Nitrogen (NH_3-N)

Table 4.8 below shows that ammonia nitrogen content (ammonium and nitrite) increased downstream to 0.447mg/L at site3 then decreased at site 4 to 0.415mg/L.

The relatively high nitrate values observed could be due to oxidation of ammonia to nitrites and then to nitrates by bacteria during the nitrogen cycle. This nitrifying activity will deplete the dissolved oxygen in the river and may create anaerobic conditions in water. Nitrates result mainly from excreta and urine in domestic waste which were abundant and observed during the trips to the sites as cattle routes abound here.

Table 4.8: Result of Ammonia Nitrogen

Site	River distance (m)	NH_3-N(mg/L) Replications	NH_3-N(mg/L) Average	Discharge(m^3/s) Replications	Discharge(m^3/s) Average
1	0	0.1-0.34	0.162	0.075-0.250	0.141
2	3500	0.15-0.52	0.358	0.245-2.203	1.13
3	7000	0.3-0.89	0.447	0.303-2.249	1.629
4	15000	0.21-0.67	0.415	0.387-4.533	2.343

This might have contributed to the relatively high mean values of nitrates at sites.

The higher mean values in site 2 might also be related to surface runoffs from the surrounding farmlands and domestic wastes. This is supported by the report of Commins *et al.*(1983) that high nitrate concentration in some bodies of the water may be related to inputs from agricultural lands. The mean value of nitrate for all the sites obtained in this study is within the desirable limit of 20.0mg/l for drinking water recommended by (WHO, 1984).

4.2.4 Nitrate Nitrogen

Table 4.9 shows that Nitrate Nitrogen increased downstream to a peak of 0.867mg/L at site 3 then decreased to 0.798mg/L at site 4 and is accompanied by net gain of channel discharge and extensive surface–subsurface exchange.

Table 4.9: Result of Nitrate Nitrogen

Site	River distance (m)	NO_3-N(mg/L) Replications	NO_3-N(mg/L) Average	Discharge(m^3/s)	NO_3^- uptake rate(μmol s−1)
1	0	0.1-0.8	0.23	0.141	0.0005
2	3500	0.25-0.9	0.575	1.130	0.010
3	7000	0.2-2.1	0.867	1.271	0.017
4	15000	0.5-1.5	0.798	2.217	0.028

The observed increase in [NO_3^-] along the stream is probably due to other water inputs (like effluent discharge from the KRPC plant and increased run-off from farmlands.

Observed increase in NO_3^- and channel discharge along the experimental reach of sampling, indicates that most of the NO_3^- increase occurs at site 4, with an uptake rate of 0.028 μmol s^{-1} where there is the greatest surface–subsurface exchange of water. NO_3^- concentrations and total dissolved P concentrations, suggest that there is no denitrification of NO_3^- along the reach.

DIKE, et al (2009) in Nitrate and Phosphate levels in River Jakara, Kano state, Nigeria saw that the higher wet season mean values in all the sites might be related to surface runoffs from the surrounding farmlands and domestic wastes Denitrification efficiency, as expressed through downstream enrichment in N-NO_3^-, varies comparatively with discharge(see Table 4.8) that when discharge is greater (typically earlier in the water year), denitrification is least efficient and downstream enrichment in N-NO_3^- is greatest. When discharge is lower, denitrification in the streambed appears to occur with greater efficiency, resulting in lower downstream enrichment in N-NO_3^-, due to an inference from test done on well situated by the stream shows that leaching into ground water is low as evidenced by low concentration of 0.294mg/L.

4.2.5 Heavy metals

The results from Table 4.10 show that heavy metal concentration decreased downstream for Pb and Cd from 0.0948ppm and 0.0028ppm respectively at site 1 then increased to 0.1097ppm and .0053ppm respectively at site 4. The Cu concentration took an opposite trajectory increasing from 0.0146ppm at site 1 to 0.0906ppm at site 4 then decreased downstream to 0.0119ppm at site 4.

Table 4.10: Result of Heavy Metals

Site	River distance (m)	Lead (ppm) Replications	Lead (ppm) Average	Copper (ppm) Replications	Copper (ppm) Average	Cadmium (ppm) Replications	Cadmium (ppm) Average
1	0	0.032-0.1811	0.0948	0.0106-0.0188	0.0146	0.0021-0.0079	0.0028
2	3500	0.0107-0.1225	0.0863	0.0038-0.3964	0.0906	0.0021-0..065	0.0042
3	7000	0.0373-0.1331	0.0777	0.003-0.1681	0.0445	0.0003-0.0079	0.0043
4	15000	0.0533-0.1757	0.1097	0.0023-0.0188	0.0119	0.0021-0.0076	0.00528

Also the results show that the concentrations of the metals at each site are in the order of Pb>Cu>Cd.

As the pH decreases certain metals such as aluminium, copper and lead are more easily dissolved and are leached from soil and sediments into runoff and ground water entering surface water (Strap, 1995)

The result obtained when compared to pH obtained strongly validates that a relationship exists between the pH of the stream and the solubility of metals contained in the bottom sediments or as suspended material, because the heavy metals concentration increased downstream as the p^H decreased downstream

4.3 BIOLOGICAL PARAMETERS

4.3.1 Biochemical Oxygen Demand

The biochemical oxygen demand shown in Table 4.11 decreased downstream from 0.15mg/L at site 1 to 0.06mg/L at site 2 until 0.03mg/L at site 3 then slightly to 0.02 mg/L at site 4.

The BOD of the stream before entrance of KRPC Wastewater load was 0.05mg/L and the KRPC wastewater had a BOD of 0.08mg/L.

Table 4.11: Result of Biochemical Oxygen Demand

Site	River distance (m)	BOD(mg/l)
1	0	0.15
2	3500	0.06
3	7000	0.03
4	15000	0.02

Biological oxygen demand (BOD) is the consumption (or decrease) of DO, caused either by microorganisms as they decompose organic material or by chemical oxidation. BOD measures the potential of certain materials to decrease DO concentrations as these materials are converted to other substances. Rivers with low BOD have low nutrient levels (Delzer et al 2003). The average value of BOD in the River Romi indicates the presence of organic pollution sources in 15Km stretch selected area.

Residence time is the amount of time that water remains in a water body. Generally, increasing flow volume decreases residence time by increasing flow velocity in the

channel. Channel geometry (i.e., width, depth) determines residence time by affecting the velocity with which a given volume of water passes through a channel segment.

(a) Relationship between Residence Time and BOD

Residence time affects BOD concentrations (and DO concentrations) by controlling the period over which BOD substances can exert an oxygen demand in a river reach. The longer the residence time, the more BOD is created by decay and the more DO concentration declines.

Table 4.12 shows that as discharge (which is the inverse of residence time) increased, the BOD was reducing along the river.

Table 4.12: Comparison of Biochemical Oxygen Demand vs Discharge

Site	River distance (m)	**BOD(mg/l)**	Cumulative Discharge(m^3/s)
1	0	0.15	0.141
2	3500	0.06	1.130
3	7000	0.03	1.271
4	15000	0.02	2.217

4.3.2 Chemical Oxygen Demand

Table 4.13 shows COD was 480mg/L at site 1 then decreased to 360mg/L at site 2 then increased to 410mg/L at site 3 and decreased at site 4 to 370mg/L. The COD of the stream before inflow of KRPC waste water was 370mg/L and the waste water had a COD of 370mg/L.

Table 4.13: Result of Chemical Oxygen Demand

Site	River distance (m)	COD(mg/l)
1	0	480
2	3500	360
3	7000	410
4	15000	370

Chemical oxygen demand test determines the oxygen required for chemical oxidation of organic matter with the help of strong chemical oxidant. The COD value was highest at site 1 due to the effluent discharge from KRPC plant. It then dropped to at sites 2 and 3 and increased at site 4 due to side inflow from NNPC housing estate.

4.3.3 Correlation between BOD and COD values obtained

There is no reliable conversion that allows BOD to be converted to COD. The relationship between BOD & COD will vary significantly from wastewater stream to wastewater stream, depending on the processes that give rise to the wastewater and even that will often not be valid from day to day if the composition of your wastewater is highly variable(Wastewater.com Help Forums Jun 17th, 2011, 11:45am)

4.3.4: Fecal Coliform Testing

The E-coli colonies count from Table 4.14 shows a decrease per 10ml as you go downstream (from 392 at site 1 to 372 at site 2,then 241 at site 3 and finally 115 at site 4).

Table 4.14: Result of Fecal coliform count showing dates

River Dist(m)	12/12/2009	16/01/2010	23/01/2010	06/02/2010	Average of 4 data
0	17	318	470	761	392
3500	24	352	425	688	372
7000	24	175	362	401	241
15000	33	141	115	170	115

The E-coli colonies count suggests that there is a die off rate along the river course.

E. coli are washed into the water from nearby manure-fertilized agricultural fields and in storm water runoff or are introduced from improperly maintained septic tanks or by livestock with unhindered access to the water.

4.4 SELF PURIFICATION

Oxygen deficit at any time in the stream is given by the Streeter Phelps equation.

$$D_t = \frac{K_1 L_0}{K_2 - K_r}(e^{-K_r t} - e^{-K_2 t}) + D_0 e^{-K_2 t} \qquad (4.1)$$

where L_0 and D_0 are the initial biochemical oxygen demand and the initial dissolved oxygen deficit, respectively, and D_t is the deficit at time t. The proportionality constants K_1 and K_2 represent the coefficients of deaeration and reaeration, respectively, and K_r the coefficient of BOD removal in the stream.

Table 4.15: Results of experiments at sites 1 and 4

Site	Date	Temp	DO	BOD	Flow
1	09/10/2009	22.9	6.8	0.15	0.25
4		22.8	6.8	0.02	2.33
1	21/10/2009	30.7	7	0.15	
4		30.2	6.7	0.02	
1	05/11/2009	29.7	6.2	0.11	0.120
4		31.9	7	0.02	0.298
1	07/12/2009	25.4	7.5	0.18	0.118
4		25.3	7.4	0.02	0.084
1	16/12/2009	26.8	8	0.16	
4		26.7	6.5	0.02	
1	18/01/2010	24.7	5.5	0.15	0.075
4		24.2	6.3	0.02	0.140

For utilizing the data, the averages was computed and are given in Table 4.16

Table 4.16: Result of Averages of data

site	Temp	DO	BOD	Flow
1	26.7	6.83	0.15	0.141
4	26.85	6.78	0.02	2.217

Table 4.17: Result of Converted data for calculating the Streeter-Phelps model

site	DO (mg/L) deficit	DO (mg/L exist	DO(mg/L) saturation	DO (lb/day)	BOD_5 (mg/L)	flow (mgd)	flow (m^3/s)
1	1.18	6.83	8.01	633.568	0.15	3.22	0.141
4	1.21	6.78	7.99	1047.355	0.02	50.63	2.217

The saturation limit of DO was determined by involving altitude and average of temperature in the region for each station. From Table 4.16, we can calculate Streeter-Phelps parameters.

Velocity of stream between the station: *V=0.909m/s=78.53Km/d*

Distance between the station: *X*= 15Km

Residence Time between the stations: Δt =0.191day

After converting BOD_5 to BOD_t we can calculate L and K_1 as follows:

K_1= ——— ——— =1.143 d^{-1} (Nazari –Alavi *et al,* 2007)

L =$(1047.36 + 633.57) \times$ — = 1176.65 lb.d (Nazari –Alavi *et al,* 2007)

The average of dissolved oxygen deficit between the stations:

D=$\{(1.18 \times 8.345 \times 3.22) + (1.21 \times 8.345 \times 50.63)\} \div 2$

= ——— =271.50 lb.d (A. Nazari –Alavi et al 2007)

The variation of dissolved oxygen deficit at the stations:

ΔD= 31.77-511.23= 479.46lb.d

K_2=1.143 ——— ——— (A. Nazari –Alavi *et al.*, 2007)

= 4.954-4.020 =0.934 d^{-1}

The FAIR equation and his table permit to determinate that the river belongs to which category: f = — = 0.934/1.143 =0.817

According to Fair`s classification (Chapra, 1997; WHF. 2004) Romi River has the slow stream.

The above shows that de-oxygenation rate (K_1), = 1.143 d^{-1} with a re-aeration rate (K_2) of 0.934d^{-1}.

This shows that there is appreciable self purification going on within the selected range due of the short distance covered by the study.

Using the Streeter-Phelps model, we can do error analysis with the values above as below ;

$$D_t = \frac{(\quad\cdot\quad)(\quad:\quad)}{(\quad\cdot\quad\quad\cdot\quad)}[(e^{-(1.143)(0.191)} - e^{-(0.934)(0.191)}] + 1.181[e^{-(0.934)(0.191)}]$$

=1.01mg/L

*Note here we assumed that $K_2 = K_r$

4.4.1 Relationship between Residence Time and Re-aeration

Residence time affects re-aeration by controlling the amount of time that re-aeration is allowed to act on the water moving through the water course. The greater the residence time, the greater amount of re-aeration that occurs, until saturation is reached.

4.4.2 Relationship between Residence BOD and Distance

The BOD decreased along the measured river course.

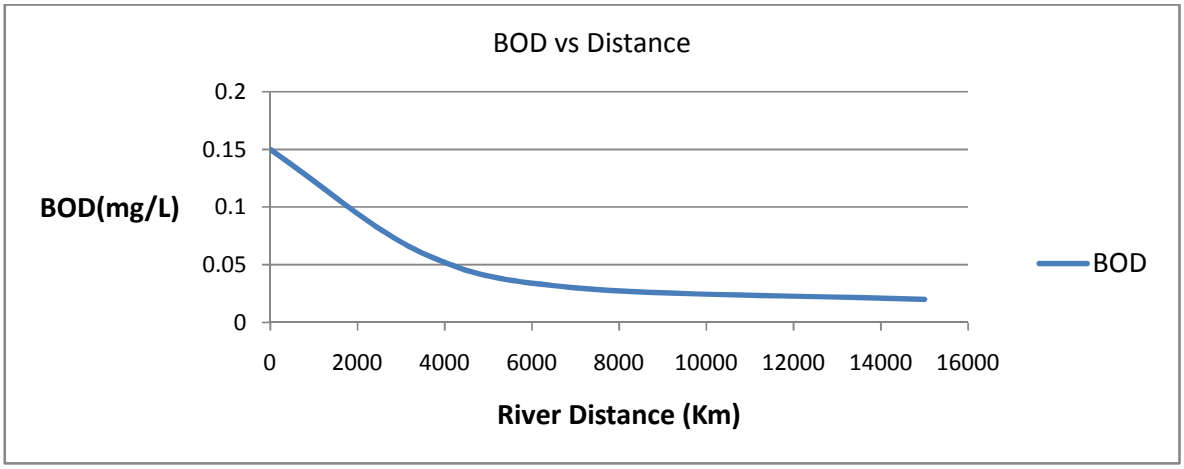


Figure 5.1: BOD against River Distance

From the results obtained ,a model of BOD against Distance was developed as shown below;

$$B_t = B_o - D^n \qquad (4.2)$$

Where B_t = BOD along the stream at any time,t.
B_o = initial BOD
D = distance in meters
n = any integer between -0.2 and -0.3

We now carry out error analysis to validate the model

Now applying equation 5 of the error analysis methods we calculate the error in the model thus

$$n = (\log B_t - \log B_o) / \log D = (0.434)^2 . (S_{Bt} / B_t) . (B_o / S_{Bo}) . (S_D / D)$$

Assuming the $S_{Bo} = 0.001mg/L$

$S_{Bt} = 0.001mg/L$

$S_D = 10m$

Therefore $S_N = (0.434)^2 .(0.001/0.06).(0.15/0.001)(10/3500)$

$= 0.00135$

Hence $n = -0.3 \pm 0.00135$ *or* -0.2 ± 0.00135

4.4.3 Relationship between Residence DO and Distance

The dissolved oxygen was depleted and recovers slightly along the river course.

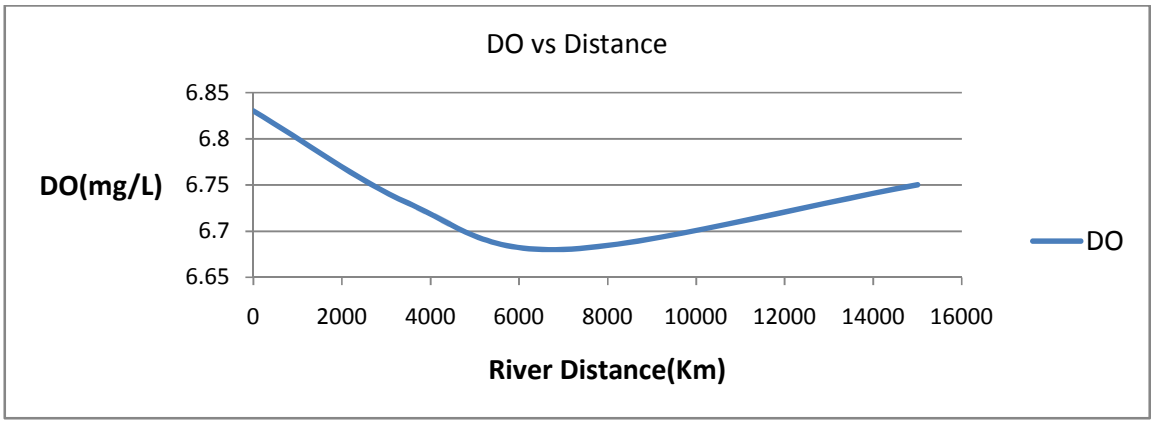


Figure 5.2: DO against River Distance

4.4.4 Relationship between Residence COD and Distance

The COD decreased from site 1 to site 2 and then increased again at site 3.

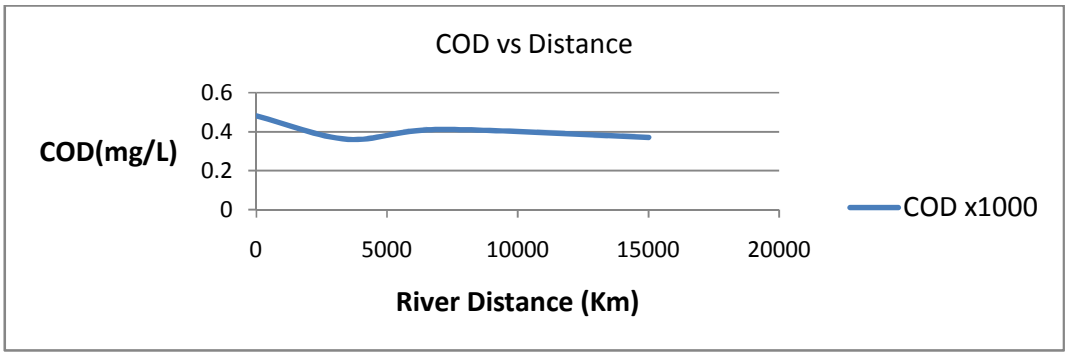


Figure 5.3: COD against River Distance

4.4.5 Relationship between Residence Bacteria colony and Distance

The bacteria colony died off along the river course.

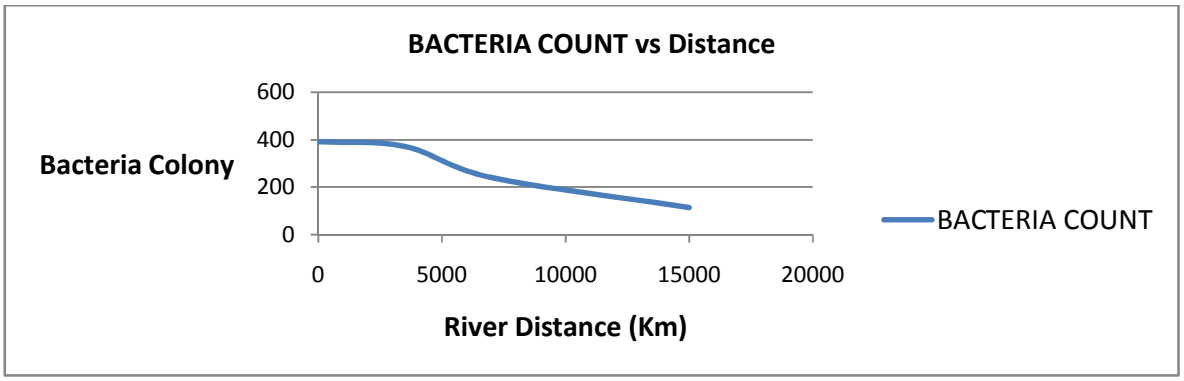


Figure 5.4: Bacteria Count against River Distance

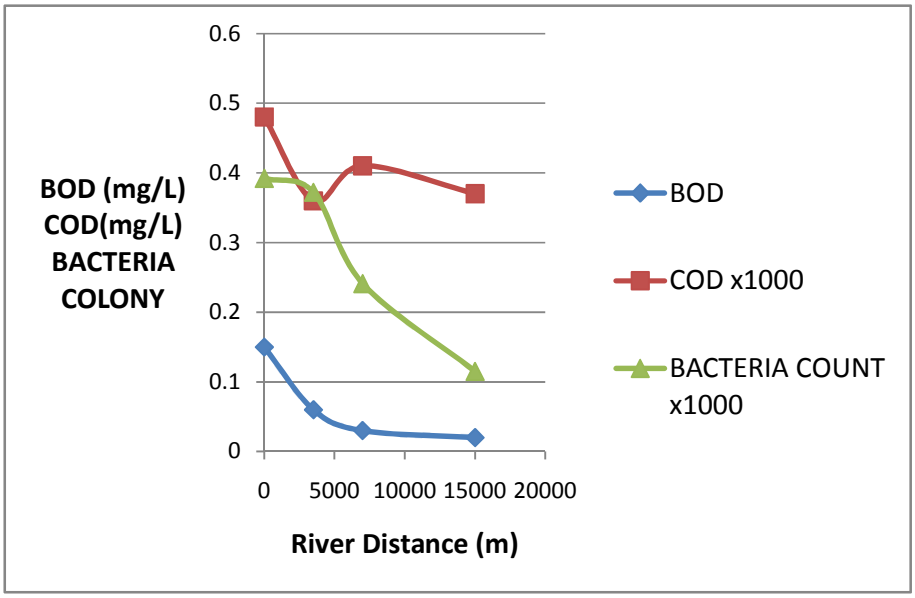


Figure 5.5: BOD,COD and Bacteria Count against River Distance

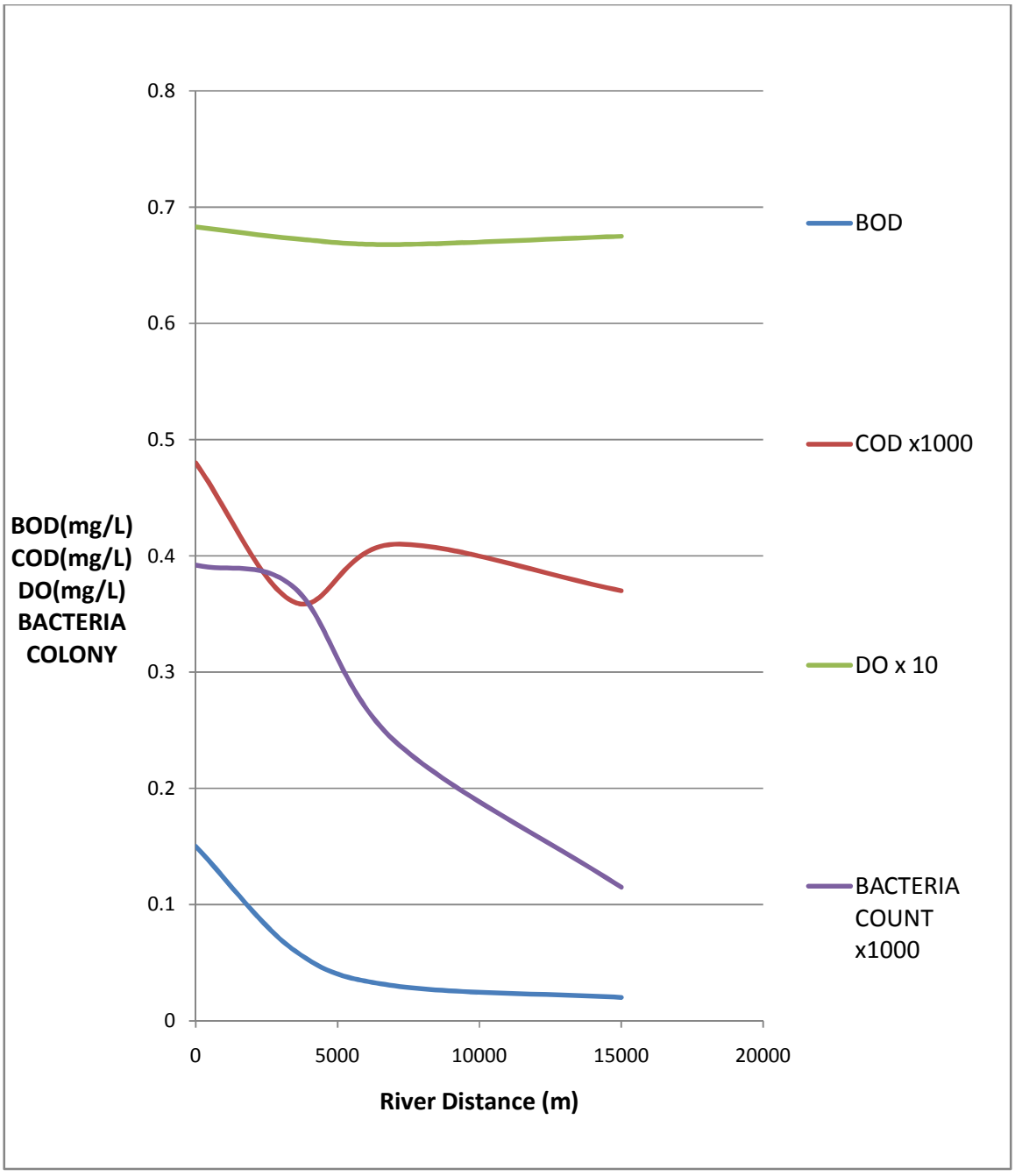


Figure 5.6: DO, BOD,COD and Bacteria Count against River Distance

CHAPTER FIVE

CONCLUSION AND RECOMMENDATIONS

5.1 CONCLUSION

The results of the study led to the following conclusions:

1. All the parameters monitored indicate serious water quality impairment along the 15km stretch studied. The deterioration is due to discharges from KRPC Plant and NNPC housing estate.
2. The DO values encountered in the river have marked time dependence due to the relationship between photosynthesis and solar radiation. For these sites the variations have a cycle with a dip as low as zero in the morning and a maximum in the late afternoons.
3. The river discharge was lowest at site 1 and maximum at site 4 and the ratio of flow of waste water into the river to the river discharge varied at the different dates measured.
4. The BOD is as a result of more bacteria activity as evidenced by the higher bacteria colony count of the in-coming flow.
5. The De-oxygenation rate K_1 was found to be $1.143d^{-1}$ and the Re-aeration rate $K_2 = 0.934d^{-1}$ for the self purification observed.
6. The dissolved oxygen deficit at site 1 and 4 was 1.18mg/L and 1.21mg/L respectively deducted the saturation concentration. At saturation DO increases as Temperature decreases.
7. For Most of the parameters monitored in the stretch there is an reduction in its concentration after site 3 but the COD and Total Dissolved Solids increased

thereafter. The accompanying increase in DO here at site 4 suggests recovery or better water quality further down.

8. For most of parameters monitored, the water quality deteriorated from site 1 to site 3 and but Pb, Cu and the bacteria count decreased along these sites. Clearly these three sites determine the pollution level in this 15km stretch of the river at this time.

9. From the results obtained ,a model of BOD against Distance was developed as shown below;

$$B_t = B_o - D^n \qquad (4.2)$$

Where B_t = BOD along the stream at any time,t.

B_o = initial BOD

D = distance in meters

n = any integer between -0.2 and -0.3

5.2 RECOMMENDATIONS

The results that emerge from this study is that the River Romi in Kaduna State is already polluted in the stretch studied . Therefore, the relevant government authority should establish a waste treatment facility that will reduce the amount of stench being experienced and, domestic and chemical pollutants being discharged into the river like the COD, Ammonia Nitrate and total solid pollutions and improve the portability of the water according to WHO (2000) standards.

The use of chemical fertilizers for farming along the river should be controlled or an alternative farmlands for the farmers within the catchment area of the river should be provided in order to reduce the phosphates and nitrates contents of the river.

The flow conveyed by the river in this section is dominated by the discharge from NNPC Refinery; an improved housekeeping with respect to effluent treatment will reduce the pollution level of the river especially the heavy metal content.

Parameters like heavy metals etc which gained more materials downstream probably from land use activities like farming, hence purification efforts along the river should be directed to the control of these parameters, for instance Cd, NH_4-NO_3 in the study area was found to exceed the WHO (2000) drinking water standard.

Without control the situation will further deteriorate and may lead to the breakout of epidemics. Government will then be forced to take fast, precipitate and usually costly action. Even where epidemics are not imminent, a healthy environment, especially as it affects water supply sources, will lead to significant reductions in the cost of health care delivery in Nigeria as 70% of diseases here are water borne.

A Portion of the river, say site 1 could be widened to act as a detention basin. The basin should be capable of detaining the flow for 24 hours. By so doing the river should be able to recover from all pollution before flowing on.

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APPENDIX I



APPENDIX II

A: STREAM PROFILE

Date	Site	Temperature (^{o}C)	pH	DO (mg/L)
09/10/2009				
	1	22.9	6.81	6.8
	2	22.7	6.92	6.5
	3	22.8	7.13	6.7
	4	22.8	7.02	6.8
21/10/2009				
	1	30.7	7.19	7
	2	29.7	6.86	6.8
	3	29.6	7.05	6.6
	4	30.2	6.87	6.7
05/11/2009				
	1	29.7	6.67	6.2
	2	29.9	6.63	6.5
	3	31.2	6.65	6.3
	4	31.9	7.5	7
07/12/2009				
	1	25.4	9.22	7.5
	2	25.2	7.45	7.2
	3	25.3	7.19	7
	4	25.3	6.97	7.4
	WELL	25.3	7.14	7.6
16/12/2009				
	1	26.8	8.1	8
	2	26.8	7.29	7.4
	3	26.7	7.12	7
	4	26.7	7.13	6.5
	WELL	26.5	5.9	8.8
18/01/2010				
	1	24.7	6.5	5.5
	2	24.7	6.69	6
	3	24.5	6.49	6.5
	4	24.2	6.44	6.3
	WELL	24.8	5.84	5

APPENDIX III



Satellite Imagery of KRPC and Environ

APPENDIX IV

The following techniques are used to determine how error propagates through an experimental procedure. This method is based upon combining the uncertainty for each step.
Symbols used:

A. **x; result of calculation**
B. **a, b & c; numbers used for calculation**
C. **s_x; uncertainty in result**
D. **s_a, s_b & s_c; uncertainty in numbers used for calculation**

Operations

1. **Addition and Subtraction**
   x = a + b – c…..

$$s_x = \sqrt{s_a^2 + s_b^2 + s_c^2 + \ldots}$$

2. **Multiplication and Division**
   x = a * b/c

$$s_x = x \cdot \sqrt{\left(\frac{s_a}{a}\right)^2 + \left(\frac{s_b}{b}\right)^2 + \left(\frac{s_c}{c}\right)^2 + \ldots}$$

3. **Exponentiation (assuming no uncertainty in b)**
   $x = a^b$

$$s_x = x \cdot b \cdot \left(\frac{s_a}{a}\right)$$

4. ***Logarithm***
   1. **Base 10 $x = \log_{10} a$**

$$s_x = 0.434 \cdot \left(\frac{s_a}{a}\right)$$

   2. **Base e x = ln a**

$$s_x = \frac{s_a}{a}$$

5. ***Antilog***
    1. **Base 10 $x = 10^a$ a**

$$s_x = 2.303 \cdot x \cdot s_a$$

    2. **Base e $x = e^a$**

$$s_x = x \cdot s_a$$