MODELING THE EFFECTS OF BREWERY EFFLUENTS ON SURFACE WATER: A CASE STUDY OF *AJALLIOWA* RIVER IN ENUGU STATE.

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CERTIFICATION

We certify that this research work on "Modelling the Effects of Brewery Effluents on Surface Water: A Case Study of Ajalliowa River in Enugu State" was carried out by **Imo, Chimezie Iwunna** with registration number, **20085631968** in partial fulfilment of the requirements for the award of Masters Degree in Agricultural and Bioresources Engineering (Soil and Water Engineering Option)

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DEDICATION

This project work is dedicated to God Almighty, for his protection, love, grace and unfailing faithfulness during the period of this research and also to the less privileged that struggle to acquire education and knowledge, for God to see them through in their good ventures Amen.

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ABSTRACT

This study modelled the effect of brewery effluents on surface water taking Ajalliowa River in Enugu state as a case study. This predictive model, obtained using least square method, was combined with laboratory analysis to determine the changes in the physico-chemical characteristics of the river before and after the pollution, the distribution effects in time and space were also put into consideration. Water samples were collected in duplicate, using 1 litres kegs as sampling bottles and small plastic bottles of 50ml, from several points along the river body, namely: 50m upstream, effluent discharge from the brewery, the discharge point, 50m downstream, 100m downstream and 150m downstream. Prior to sample collection, all the sampling bottles were washed thoroughly, sun-dried and rinsed with the same water to be collected. The sampling bottles were labelled with dates and collection site. Grab samples were collected repeatedly. Until analysis, the collected water samples were kept in a cool container and was preserved for various analysis by addition of 1.0 ml of concentrated nitric acid. The predictive model showed a very high correlation coefficient for some of the important parameters while some are not adequately predicted. The pH model gave the highest correlation coefficient with a very low standard of estimate. Also, for each of the sampling points, high correlation coefficients were observed. With the model showing high correlation coefficient between the experimental and simulated results, this thus indicate clearly that this model is suitable for the prediction and estimation of the major physico-chemical characteristics of the river. There is however room for improvement, which can be achieved by adopting factorial modelling methodology.

Keywords: Modelling, Brewery Effluents, Ajalliowa River, pH Model, Least Square method, Pollution, Nitric Acid.

CHAPTER ONE

INTRODUCTION

1.1 Background of the Study

Pollution can be defined as the direct or indirect alteration of the physical, chemical, thermal, biological or radioactive properties of any part of the environment which creates a hazard to health, safety or welfare of any living species. Pollution may occur naturally but mostly occurs due to changes brought by emission of industrial pollutants by careless discharge of industrial and humans' domestic wastewater or sewage and release of excessive heat from industries (Bell, 1965; Bolin *et al.*,1986). Pollution is destructive and capable of causing harm to both living and non-living organisms in varying degrees depending on the environment to the extent of rendering it useless to man and hence reducing its benefits. As a matter of fact, apart from a few instances of direct pollution on human beings, it is the pollution through degradation of the environment which occurs in many indirect ways as either solid, liquid or gas affecting the air, land or water (APHA, 1965).

Increased industrial activities have led to the pollution of surface water both from industrial, agricultural and domestic sources (Ajayi and Osibanjo, 1981). Untreated wastes from processing factories located near cities are discharged into inland water bodies resulting to stench, discoloration and a greasy oily nature of such water bodies (Mombeshora *et al.*, 1981). These wastes pose serious threat to associated environment including human health risks (Rahman *et al.*, 1997). Thus, there is need to control the pollution of surface and ground water since the public health and wellbeing of the people have a direct link with the availability of adequate quantity of good quality water. Pollution of the aquatic environment could be defined as the introduction by man directly or indirectly of substances or energy into the marine environment which results in such deleterious effects as harm to the living resources, hazards to human health, hindrance of marine activities including fishing and impairment of surface water quality. The major problem associated with waste-loading into rivers is to determine the degree of treatment to be administered on waste water to lessen the size of a concomitant zone of oxygen-sag-curve and also assure that pollution level does not exceed the maximum contaminant level (Igboanugo and Chiejina, 2011).

Industries vary in size, nature of products, characteristics of waste discharged and the receiving environment. The major industrial categories in Nigeria are metals and mining, food, beverages and tobacco; breweries, distilleries, textile, leather products, wood processing and manufacture, furniture, pulp and paper industries and chemical and allied industries. Industrial effluents contain toxic and hazardous materials from the wastes that settle in river water as bottom sediments and constitute health hazards to the urban population that depend on the water as source of supply for domestic uses (Akaniwor et al, 2007). Brewery plants have been known to cause pollution by discharging effluent into receiving stream, ground water and soil. Water consumption for breweries generally ranges 4-8 cubic meters per cubic meter of beer produced (Rahman *et al.,* 1997).

Effluents from individual process steps are variable. For example, bottle washing produces large volume of effluent that, however, contains only a minor part of total organics discharged from brewery (Rahman *et al.,* 1997). Effluents from fermentation and filtering are high in organics and BOD and low in volume, accounting for about 3% of total waste volume but 97% of BOD. Brewery effluent contains organic material such as spent grains, waste yeast, spent hops and grit. Effluent pH averages about 7 for combined effluent but can fluctuate from 3-12 depending on the use of acid or alkaline cleaning agent. (World Bank, 1997). In his study conducted on brewery effluent on Ikpoba River, Eguaoje (1993) observed that the natural quality of the River has been considerably affected by the effluent discharge into it by operating alcoholic beverage companies in the vicinity of the river, and that the pollutant effluent is highly oxygen demanding of 1200mg/l to 1300mg/l; has a high level of suspended matter of 16mg/l to 20mg/l, highly coloured, choking in odour and discharged in high quantities of about 16000 gallons to 20000 gallons per day, depending on the volume of production made.

The study further noted that the total microbial density and aquatic life have been adversely affected. The aquatic organisms that lives in the river struggle to get adequate oxygen any time the brewery effluent is highly concentrated. This poses serious health risks to the residents of the vicinity who rely on the water as an important source of water for domestic and agricultural purposes.

The Ajalliowa River serves the people of Ezeagu and Abonuzu living near it with water for some domestic and agricultural activities.This work will develop a suitable model from several different models to assess the level of hazardousness and the extent of distribution of the effluent in the river.The result of this study would be helpful in finding long term solution to the river pollution problem. Contamination of drinking water supplies from industrial waste is as a result of various types of industrial processes near the water body and disposal practices into it. Industries that use large amounts of water for processing have the potential to pollute waterways through the discharge of their wastes into streams and rivers, or by run-off and seepage of stored wastes into nearby water sources or water bodies. Other disposal practices which cause water contamination include deep well injection and improper disposal of waste in surface impoundments.

Industrial waste consists of both organic and inorganic substances. Organic wastes include spent grain, wort, pesticide residues, solvents and cleaning fluids, dissolved residue from fruits and vegetables, and lignin from pulp and pastes whereas the inorganic wastes include broken bottles, crown corks, synthetic materials and metals. The discharge of the effluents into Ajalliowa River reduces the rate of oxygen that are needed by the aquatic life. This impacts high organic pollutants on receiving waters consequently creating high competition for oxygen within the ecosystem (Osibanjo and Adie, 2007).

Brewery plants have been known to cause pollution by discharging effluent (COD, BOD, SS,) into receiving stream, ground water and soil (Alao*et al.*, 2010). This is because brewery effluents are high in biochemical oxygen demand, chemical oxygen demand, heavy metals, total suspended solids, cations, anions, etc. Discharge of metals and some non-metals into water bodies have serious environmental effects. Brewery effluents contain these heavy metals which are harmful to human health either through direct ingestion or from fish and other animals or plants. Heavy metals particularly arsenic, mercury and lead are environmental pollutants threatening the health of human population and natural ecosystem (Mercier *et al.*, 2009).

Oguzie and Okhagbuzo (2010) carried out studies of brewery effluent discharged in Ajalliowa river and observed that aquatic life in that system is threatened because the level of pollution is alarmingly high with the pH value of above 7 and BOD of 80 mg/L. In their study, they used mere data presentation to examine the problem of aquatic pollution from brewery effluents. This could not actually ascertain the extent of distribution of the effluent in the river. The present study therefore seeks to use statistical models in predicting the distribution of the brewery effluent in the river in order to ascertain the pollutant level.

Modeling is the process of representing a real-world object or phenomenon as a set of mathematical equations. More specifically, the term is often used to describe the process of representing 3-dimensional objects in a computer. All 3-D applications, including CAD/CAM and animation software, perform modeling. Modeling and simulation is getting information about how something will behave without actually testing it in real life. For instance, to determine which type of spoiler would improve traction the most while designing a racecar, a computer simulation of the car could be used to estimate the effect of different spoiler shapes on the coefficient of friction in a turn. Useful insights about different decisions in the design could be gleaned without actually building the car.

1.2 Statement of Problem

The continuous increase in industrial activities have led to the pollution of surface water both from industrial, agricultural and domestic sources; mostly through the introduction of untreated and contaminated wastewater into receiving water bodies.The cumulative effects of these pollutants which eventually enter the food chain could cause severe physiological disorders and a host of other problems to aquatic organisms including fish.This has also posed a greater threat to the present level of ground water either directly or indirectly (Ekhaise and Anyansi, 2005). In most cases, there is presence of heavy metals, cyanides, minerals and organic acids in the underground water systems; rendering it unsuitable for human, recreational and agricultural use. Human is also threatened and the principle of sustainable development is compromised(Oguzie and Okhagbuzo2010).

Ajalliowariveris at the receiving end of highly polluted effluent generated from brewery and other major human activities. The communities like Obelagu-Umana, Abonuzu and Nsude living along the river find Ajalliowariver to be unfit for human consumption and other domestic activities. The high presence of organic compounds in brewery wastewater has direct impact of reducing the dissolved oxygen content of the receiving water body. This makes life difficult for them and thereby make them travel far before they could get portable water for consumption. Also, there has been series of constant ill-health that has not been experienced before the brewery was built. The availability of water which they formally get at their doorstep is no longer obtainable and there is therefore an urgent need to ameliorate this anomaly.

1.3 Objectives of the Study

The main objective of this study is to model the effect of brewery effluents on surface water usingAjalliowa River in Enugu as a case study.

Specific objectives are as follows:

i) Determine the control parameters;
ii) Use laboratory analysis to determine the changes on the properties before and after pollution;
iii) Develop predictive models of the effluent distribution within the definite distance and period of time;
iv) Validate the models with experimental data.

1.4 Justification of the Study

The knowledge of brewery effluent into the Ajalliowariver with the relative understanding of water consumption aids in developing useful information and equation that will stand the test of time in tackling the problems associated with the nature of the river. The water analysis to be carried out are on the physical, chemical and biological parameters. Although the water and brewery effluent analysis is time demanding, but the desired result will be as accurate as possible. These will help to know the level of contamination the brewery effluent has affected ajalliowa river and to know the best approach in tackling the menace. The brewery effluent will be thoroughly examined in order to predict the its effect on Ajalliowa river downstream. The result of this work will serve as a tool in effluent management as it regards to surface water. The knowledge of the effects of effluent discharge on Ajalliowa River will be of immense help towards solving the problem pose on the River that makes it unfit for human consumption and other domestic activities. The danger posed on aquatic animals will be reduced and also for Agricultural purposes.

1.5 Scope of the Study

This project research work would be limited to modelling the effects of brewing effluent discharge on surface water (Ajalliowa River) at 9th mile corner, Ngwo, Enugu State. This study would be based on the physical parameters such as: turbidity, total solid, total suspended solids, and total dissolved solids. The chemical parameters include: pH, electrical conductivity, calcium hardness, chloride, and nitrates. The bacteriological parameters include BOD and COD. The examination of the effect of the industrial effluents on Ajalliowa River will help for predicting the concentration of the brewery effluents on the river in order to know the possible approach to use in controlling the effluents on Ajalliowariver. The parameters will be used to develop predictive models of brewery effluent which will be validated using the actual field data of various parameters.The parameters to be used include the following:pH, temperature, total dissolved solids, biochemical oxygen demand, nitrate, chlorine, chemical oxygen demand, calcium etc.

CHAPTER TWO

LITERATURE REVIEW

2.1 MODELING

The discharge of wastewater and effluent into surface water bodies and the resultant deterring change in water ecology have been reported by several researchers (Ongley, 1994; Brookes, 2002; Ekhaise and Anyansi, 2005; and Alao*et al*., 2010). Moreover, Swayne *et al*. (1980) observed that poorly organized and unregulated disposal of industrial and domestic wastes are regarded as major causes of deterioration of aquatic environment. Odiete (1999) stated that changes brought about by pollution in water bodies may create hazards both to human and animal health and may render water unfit for domestic, industrial and agricultural activities and otherwise.

Previous researchers on brewery effluents discharged in surface water employed statistics to analyze empirical data collected, while some used mere data presentation to examine the problem. Igboanugo and Chiejina (2011) adapted differential calculus and statistical models in the analysis of brewery effluents discharged in Ikpoba stream in Benin City. This study therefore sets out to develop a suitable model which could simulate the effects of brewery effluent discharge on the receiving surface water quality, in order to proffer a long-term pollution control measure for the surface water.

Industries vary in size, nature of products, characteristics of waste discharged and the receiving environment. The major industrial categories in Nigeria are metals and mining, food, beverages and tobacco; breweries, distilleries, textile, leather products, wood processing and manufacture, furniture, pulp and paper industries and chemical and allied industries. Industrial effluents contain toxic and hazardous materials from the wastes that settle in river water as bottom sediments and constitute health hazards to the urban population that depend on the water as source of supply for domestic uses (Akaniwor*et al.*, 2007). Groundwater quality is defined based on a set of health and safety regulations for domestic use.

Ground water used for public domestic supply must adhere to a set of regulatory objectives for health and safety than ground water used strictly for irrigation needs. Groundwater contamination occurs when manmade products such as gasoline, oil, fertilizers, pesticides and other chemicals get into groundwater and cause it to be unsafe and unfit for human use.

Septic systems, hazardous waste sites and landfills are major targets of pollution because rainfall and groundwater leach these highly contaminated substances into rivers, stream and waterways (surface water) which are inadvertently used by people in that area (Asonye*et al*., 2007). Contamination of drinking water supplies from industrial waste is as a result of various types of industrial processes and disposal practices.

Industries that use large amounts of water for processing have the potential to pollute waterways through the discharge of their waste into streams and rivers, or by run-off and seepage of stored wastes into nearby water sources. Other disposal practices which cause water contamination include deep well injection and improper disposal of waste in surface impoundments.

Industrial waste consists of both organic and inorganic substances. Organic wastes include pesticide residues, solvents and cleaning fluids, dissolved residue from fruits and vegetables, and lignin from pulp and paper. This impacts high organic pollutants on receiving waters consequently creating high competition for oxygen within the ecosystem. (Osibanjo and Adie, 2007). Effluents can also contain inorganic wastes such as brine salts and metals. A number of toxic substances human beings encounter regularly may pose serious health risks. Pesticide residues on vegetable crops, mercury in fish and many industrially produced chemicals may cause cancer, birth defects genetic mutations or death.

Lead a prime environmental pollutant, is a multiorgan poison which in addition to well-known toxic effects depresses immune status, causes damage to the central nervous system, kidney and reproductive system. Ingestion leads to a disease known as plumbism. It is also known to produce developmental neurotoxicity in particular infants and children are differentially sensitive to environmental lead exposure (Ademoroti, 1996). Lead is toxic to plants although a few are tolerant. Wastewater from contain these heavy metals which are harmful to human health either through direct ingestion or from fish and other animals or plants. Heavy metals particularly arsenic, mercury and lead are environmental pollutants threatening the health of human population and natural ecosystem (Mercier *etal.,* 2009).

Spatial Multiple Discrete-Continuous Modeling: Land-use change models are used in a variety of fields such as planning, urban science, ecological science, climate science, geography, watershed hydrology, environmental science, political science, and transportation to examine future land-use scenarios as well as to evaluate the potential effects of policies directed towards engendering a socially or economically or ecologically desirable pattern of future land-use that minimizes negative externalities. More recently, there has been substantial attention in the scientific literature on biodiversity loss, deforestation consequences, and carbon emission increases caused by patterns of urban and rural land-use development, and associated climate change impacts. (Fyhn*et al.,* 2004).

This is not surprising, since one of the most important “habitat” elements characterizing Earth’s terrestrial and aquatic ecosystems is the land use pattern. Another is climate pattern, which is increasingly becoming closely related to the land use pattern. In the past decade, there has been increasing interest and attention on recognizing and explicitly accommodating spatial (and social) dependence among decision-makers (or other observation units) in urban and regional modeling, agricultural and natural resource economics, public economics, geography, sociology, political science, and epidemiology. (Lewis et al, 2011).

Dimensional modeling: Dimensional modeling (DM) names a set of techniques and concepts used in data warehouse design. It is considered to be different from entity-relationship modeling (ER). Dimensional Modeling does not necessarily involve a relational database. The same modeling approach, at the logical level, can be used for any physical form, such as multidimensional database or even flat files. According to Kimball and Ross *2002*. Dimensional modeling is oriented around understandability and performance. According to him, although transaction-oriented ER is very useful for the transaction capture, it should be avoided for end-user delivery.

Dimensional modeling always uses the concepts of facts (measures), and dimensions (context). Facts are typically (but not always) numeric values that can be aggregated, and dimensions are groups of hierarchies and descriptors that define the facts. For example, sales amount is a fact; timestamp, product, register, store, etc. are elements of dimensions. Dimensional models are built by business process area, e.g. store sales, inventory, claims, etc. Because the different business process areas share some but not all dimensions, efficiency in design, operation, and consistency, is achieved using conformed dimensions, i.e. using one copy of the shared dimension across subject areas. The term "conformed dimensions" was originated by Kimballand Ross 2002.

Analytical Models: Analytical models are mathematical models that have a closed form solution, i.e. the solution to the equations used to describe changes in a system can be expressed as a mathematical analytic function. (This example is also used to describe numerical models so that numerical and analytical models can be compared and contrasted more easily). Although the solution to equations describing more complex systems can often become fairly complicated. However, for those comfortable with mathematics, an analytical solution does provide a concise preview of a model's behavior that is not as readily available with a numerical solution. Also implicit in the argument of an analytical model's superiority to numerical models is that graphing is tedious (Erkut and Neuman,1989).

This may have been the case 30 years ago but is certainly not true now. Regardless of whether one obtains an analytical solution or a numerical solution to a mathematical model, graphs showing the system's behavior over time and its sensitivity to variations in key model parameters are essential for student understanding. One disadvantage of analytical solutions is that they are often very mathematically challenging to obtain. (Erkut and Verter, 1998).

Mathematical Model: A mathematical model is a description of a system using mathematical concepts and language. The process of developing a mathematical model is termed mathematical modeling. Mathematical models are used in the natural sciences (such as physics, biology, earth science, meteorology) and engineering disciplines (such as computer science, artificial intelligence), as well as in the social sciences (such as economics, psychology, sociology, political science). Physicists, engineers, statisticians, operations research analysts, and economists use mathematical models most extensively. A model may help to explain a system and to study the effects of different components, and to make predictions about behaviour (Aris, 1978).

Mathematical models can take many forms, including but not limited to dynamical systems, statistical models, differential equations, or game theoretic models. These and other types of models can overlap, with a given model involving a variety of abstract structures. In general, mathematical models may include logical models. In many cases, the quality of a scientific field depends on how well the mathematical models developed on the theoretical side agree with results of repeatable experiments. Lack of agreement between theoretical mathematical models and experimental measurements often leads to important advances as better theories are developed.

A major source of pollution in developing countries is industrial activities and this has gradually increased the problem of waste disposal. Water pollution occurs when some substance or condition so degrades the quality of a body of water that the water fails to meet quality standards and such polluted water is capable of posing harmful effect on individual organisms, population, biological communities and ecosystem. This poses serious threat to associated environment including human health risks (Rahman *et al.*, 1997). Thus, there is need to control the pollution of surface and ground water since the public health and wellbeing of the people have a direct link with the availability of adequate quantity of good quality water.

Pollution of the aquatic environment has been defined by UNESCO /WHO/UNEP (1996), as the introduction by man directly or indirectly of substances or energy into the marine environment which results in such deleterious effects as harm to the living resources, hazards to human health, hindrance of marine activities including fishing and impairment of quality for use of sea water.

Industrial activities and urbanization in developing countries including Nigeria has gradually led to increased problem of waste disposal. Increase in crude oil exploration, refining and activities of other industrial establishments in the Niger Delta has resulted in the wide-scale contamination of most of its creeks, swamps and rivers with hydrocarbon and dispersant products (Kobayashi and Rittman, 1982). Man-made pollution of water is divided into two kinds: point source is caused by discharge of pollutants from specific location for example discharge from factories, sewage treatment plants and oil tankers into rivers, and non-point source occurs from rainfall or melting of snow and the run-off washes away pollutants into lakes, rivers and coastal waters.

2.2 Brewery Industry

Brewery, the alcohol producing industry, is one of the major polluting industries. It involves the making of fermented alcoholic beverages, such as beer and ale from cereal grains. There are two major steps involved in the process of malting and brewing. Brewery wastes are composed mainly of liquor pressed from the wet grain and wash water from the various departments. After the distillation of the alcohol process, the residue remains are referred to as "distillery slops", or "still bottoms". The brewing industry consumes much water about 10 gallons of processed water / gallon of product. The biochemical oxygen demand levels are quite high, as are the total solids, typically about half the BOD and over 90% of the suspended solids are generated in the brewing operation.

There are also solid wastes, spent grains, hops and sludges that are formed in this and the malting steps that must be disposed. Disposal of such effluent without any prior treatment into water courses causes serious pollution problems. Such wastes when discharged into open drain undergo aerobic decompositions and create obnoxious odourous conditions. The indiscriminate disposal of untreated waste water into water courses or into land invariably pollutes the ecosystem (Mala andBabu, 2006). It also poses adverse effects to the aquatic fauna and flora and also to the ground water. Hence treatment of brewery effluent is a very important consideration before its disposal.

2.3 Composition, characteristics and effects of Brewery Effluent on Surface Water:

Brewery plants have been known to cause pollution by discharging effluent into receiving stream, ground water and soil. Water consumption for breweries generally ranges 4-8 cubic meters per cubic meter of beer produced. Production steps include malt production, wort production and beer production. According to the World Bank (1997) report, untreated effluent typically contains suspended solids in the range of 10-60 mg/l, BOD in the range of 1000- 1500 mg/l, COD in the range of 1800-3000 mg/l and nitrogen in the range of 30-100 mg/l. Effluents from individual process steps are variable. For example, bottle washing produces large volume of effluent that, however, contains only a minor part of total organics discharged from brewery. Effluents from fermentation and filtering are high in organics and BOD and low in volume, accounting for about 3% of total waste volume but 97% of BOD.

Brewery effluent contains organic material such as spent grains, waste yeast, spent hops and grit. Effluent pH averages about 7 for combined effluent but can fluctuate from 3-12 depending on the use of acid or alkaline cleaning agent. Drinking water should be odourless, tasteless, colourless and devoid of particulate matter. Chemical investigation of the water quality of some Nigerian rivers (Bassey*et al.*, 1999) reveals that water that was once an abundant natural resource is rapidly becoming scarce in quantity (high demand) and the quality is deteriorating in many places, owing to activities of manufacturing companies. There is little knowledge about the effects of effluent discharge on surface water in Nigeria (Alao*et al.*, 2010). This study is aimed at developing a suitable model that could be used to assess the effects of brewery effluents on the quality of surface water especially on Ajalliowa River considering pH, COD, BOD, TDS, N, CL, T and Ca.

Brewery effluents from Nigerian brewery generates too many effluents that are discharged into Ajalliowa River. Thus, for some time now, the brewing industry has shown increasing awareness for environmental protection and the need for sustainable production processes (Driessen and Vereijken, 2003). Implementation of ISO 14001 (2015) certification and more stringent environmental legislation have been important factors for raising awareness in the brewing industry towards effluent fluid control. Brewing effluent fluid in mostly water by weight, other materials make up only a small portion of the wastewater which has high strength of organic matter with moderately high quantity of Total Suspended Solids (TSS) concentration generated from a number of plant operations. The main constituents include COD, BOD, TSS, Nitrogen and Phosphorous. The constituents of the brewery effluent are present in large quantities and may require some pre-treatment before discharging the effluent fluid into a sewage system. The hazards posed by these contaminants and due to the growing environmental awareness, the brewing industry has significantly increased investments in environmental protection measures (Driessen and Vereijken, 2003).

Important internal drivers for the brewing industry are implementation of environmental management systems (EMS) like ISO 14001(2015), as well as the need for establishing benchmarks for brewing process optimization.The major organic matters in wastewater are protein, carbohydrates, fats and oil. They are however composed of carbon, oxygen, hydrogen, nitrogen and sulphur. Untreated brewery effluents, typically contain suspended solids in the ranges of 10 – 60 mg/l, BOD in the range of 1000 – 1500 mg/l, COD in the range of 1800 – 300 mg/l and nitrogen in the range of 30 – 100 mg/l (Alao, 2010). Musa and Okonkwo(2017) investigated the impact of the effluents of a brewing industry located in Kaduna on RafinGiya stream and its self-purification potential. The brewery wastewater effluents were collected and analyzed for some physicochemical parameters for a period of 27 days to determine the level of constituents, toxicity level and suitability for its discharge into receiving water body. Physicochemical parameters were found to be higher than the limits set by the National Environmental Standards and Regulations Enforcement Agency (NESREA) in Nigeria for industrial wastewater discharge into receiving water bodies. NESREA was established by the section 34 of the 2007 establishment actNESREA (2009). The physicochemical parameters determined for the stream waterinclude: pH, Temperature, Total suspended solids (TSS), Turbidity, Chlorides, Biological Oxygen Demand (BOD_5), Dissolved oxygen (DO), Electrical conductivity (EC), Total dissolved solids (TDS) and coliform. Their studyrevealed that with the exception of temperature, total dissolved solids and total coliform, all other physicochemical parameters of the brewery wastewater measured were very high than the NESREA limits for industrial wastewater discharge and thus have caused high pollution effects on the stream. The typical compositions of brewery effluents are shown in Table 2.1.

Table 2.1: Typical Characteristics of Brewery Effluent and Indicative Discharge Standards (Limits) in the EU.

Parameter	**Unit**	**Brewery Effluent Composition**	**Typical Brewery Benchmark**
Flow	m/s		2 - 8 effluent/ beer
COD	mg/l	2 – 6kg	0.5 - 3 kg COD/ beer
BOD	mg/l	1.2 – 3.6kg	0.2 - 2 kg BOD/ beer
TSS	mg/l	0.2 – 1kg	0.1 - 0.5 kg TSS/ beer
T	^oC	18 - 40	
pH		4.5 - 12	
Nitrogen	mg/l	25 - 80	
Phosphorus	mg/l	10 - 50	

Source: Driessen and Vereijken (2003)

The characteristics of brewery effluents that are of special concern are pH, Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), suspended solids, dissolved solids, nitrogen and phosphate.

2.3.1.pH

The hydrogen-ion concentration is an important quality parameter of both natural and wastewaters. It is used to describe the acid or base properties of wastewater. A pH less than 7 in wastewater influent is an indication of septic conditions while values less than 5 and greater than 10 indicate the presence of industrial wastes and non-compatibility with biological treatment. The pH concentration range for the existence of biological life is quite narrow (typically 6-9). An indication of extreme pH is known to damage biological processes in biological treatment units (EPA, 1996; Gray, 2002).

2.3.2 Biochemical Oxygen Demand (BOD)

Biochemical oxygen demand is the amount of oxygen used by microorganisms as they feed upon the organic solids in wastewater (Water Environmental Federation, 1996; Gray, 2002; FAO, 2007). The 5-day BOD (BOD_5) is the most widely organic pollution parameter applied to wastewater. It involves the measurement of dissolved oxygen used by microorganisms in the biochemical oxidation of organic matter for a period of 5-days at incubation temperature of 20°C. The presence of sufficient oxygen promotes the aerobic biological decomposition of an organic waste (Metcalf and Eddy, 2003). Although BOD test is widely used, it has a number of limitations, which include the requirement of a high concentration of active acclimated microorganisms and the need for treatment when dealing with toxic wastes, thus reducing the effects of nitrifying organisms. The BOD measures only the biodegradable organics and requires a relatively long time to obtain test results (Gray, 2002; Metcalf and Eddy, 2003). Increased level of BOD implies a low DO which means an increased pollution load of a water body.

2.3.3. Chemical Oxygen Demand (COD)

Chemical oxygen demand measures the oxygen equivalent of the organic material in wastewater that can be oxidized chemically to carbon (IV) oxide and water.According to Barnes*et al.*(1998); COD is higher than that of BOD but it varies based on the industrial process and nature of the raw materials used. The COD measures substances that are both chemically and biologically oxidized. The ratio of COD: BOD up to 3:1 provides a useful guide to the proportion of organic material present in wastewaters, although some polysaccharides, such as cellulose, can only be degraded anaerobically and so will not be included in the BOD estimation. One of the main advantages of the COD test is that it can be completed in about 2.5 h, compared to the 5-day BOD test (Eckenfelder and Grau, 1992; Gray, 2002; Metcalf and Eddy, 2003).

2.3.4. Suspended Solids

Although wastewater is normally 99.9 % water, 0.1 % of it comprises of solids. Discharges from industrial and domestic sources also add solids to the plant influent. Although there are different ways of classifying solids in wastewater, the most common types are total dissolved solids (TDS), total suspended solids (TSS), settleable, floatable and colloidal solids, and organic and inorganic solids (EPA, 1996). Normally, wastewater processes using settling or flotation are designed to remove solids but cannot remove dissolved solids. Biological treatment units such as trickling filters and activated sludge plants convert some of these dissolved solids into settleable solids that are removed by sedimentation tanks (Eckenfelder and Grau, 1992).

2.3.5. Phosphorus

Surface waters contain levels of phosphorus in various compounds, which are essential constituents of living organisms. In natural conditions, the phosphorus concentration in waters is balanced. However, when phosphorus input to waters is higher than that which a population of living organisms can assimilate, the problem of excess phosphorus content occurs (Rybicki, 1997). An excess content of phosphorus (> 0.025 mg/l) in receiving waters usually leads to extensive algal growth (eutrophication). Although phosphate itself does not have notable adverse health effects, phosphate levels greater than 1.0mg/L may interfere with coagulation in water treatment plants (McCasland*et al.*, 2008). Controlling phosphorus discharge from municipal and industrial wastewater treatment plants is a key factor in preventing eutrophication of surface waters. The following groups of phosphorus compounds are of great importance in wastewater: organic phosphates, condensed phosphates and inorganic phosphates.

2.3.6. Nitrogen

Nitrogen is important in wastewater management. It can have adverse effects on the environment, since its discharge above the required limit of 10 mg/L can be undesirable due to its ecological and health impacts Nitrogen is required by all organisms for the basic processes of life to make proteins, grow and reproduce. It is recycled continually by plants and animals. Most organisms cannot use nitrogen in the gaseous form (N_2) for their nutrition, so they are dependent on other organisms to convert it into other forms. The principal forms of nitrogen are organic nitrogen, ammonia, nitrate and nitrite. Ammonia, nitrate and nitrite make up the inorganic forms (Kurosu, 2001). Organic and inorganic forms of nitrogen may cause eutrophication problems in nitrogen-limited freshwater lakes and in estuarine and coastal waters. In the environment, ammonia is oxidized to nitrate, creating an oxygen demand and low dissolved oxygen in surface waters (Kurosu, 2001; Sabalowsky, 1999). Despite the fact that nitrate levels that affect infants do not pose a direct threat to older children and adults, they indicate the presence of other serious residential or agricultural contaminants, such as bacteria and pesticides (McCasland*et al.*, 2008). Methemoglobinemia is the most significant health problem associated with nitrate in water. Usually, blood contains an iron-based compound (haemoglobin) that carries oxygen, but when nitrite is present, haemoglobin can be converted to methaemoglobin, which cannot carry oxygen. Similarly, nitrogen in the form of ammonia is toxic to fish and exerts an oxygen demand on receiving water by nitrifies (CDC, 2002).

2.4 Effluent Discharge Requirements

The effluent discharge limits a brewery has to comply with depends on local environmental legislation. It is obvious that in case of discharging to a municipal sewer, discharge limits are less stringent than when the effluent is to be discharged into a sensitive receiving surface water body (river, lake, sea, etc). According to Driessen and Vereijken (2003), removal of organic compounds (COD chemical oxygen demand) from the wastewater is important to avoid anaerobic conditions in the receiving waters. Nutrients like nitrogen (N) and phosphorous (P) should be removed to avoid algae bloom disturbing the receiving waters ecosystem (Metcalf and Eddy, 2003). Table 2.2 presents some indicative discharge limits as are generally applied in the European Union for receiving surface water bodies. Actual discharge limits might vary for each location, region and country.

Table 2.2: Indicative discharge standards in the EU

Parameter	Unit	Limits
COD	mg/l	125
BOD	mg/l	25
TSS	mg/l	35
NP	mg/l	10 - 15
P	mg/l	1 - 2

Source: Driessen and Vereijken (2003)

2.5 Modeling of Brewery Effluents

Models involve mathematical equations that have been derived not from the physical processes in the catchments but from an analysis of the concurrent input and output time series and they are valid only within the boundaries of the domain where data is given. The different models for brewery effluents include the ANOVA model, Latin square model, partial differential equation, etc (Igboanugo and Chiejina, 2011).

Some researchers on similar studies had employed different models to study the effects of brewery effluent loading on the receiving surface water. For instance, Oguzie and Okhagbuzo (2010), Ekhaise and Anyansi (2005) carried out studies of brewery effluent discharged in similar rivers and observed that aquatic life in that system is threatened because the level of pollution is alarmingly high. Whereas the former used statistical models to analyze empirical data collected, the latter used Differential Equations to examine the problem. Again, Igboanugo and Chiejina (2011) adopted the latin square model for the analysis of brewery effluent distribution in Ikpoba river in Benin City, and these models proved to be successful in predicting the contaminant distribution in the rivers studied. However, this project research work would adopt the ANOVA model and the Partial Differential Equation (PDE) to establish a quantitative relationship on the effects of brewery effluents on the receiving surface water.

2.6 Water Pollution:

Water pollution is the contamination of water bodies (e.g. lakes, rivers, oceans, aquifers and groundwater). This form of environmental degradation occurs when pollutants are directly or indirectly discharged into water bodies without adequate treatment to remove harmful compounds. Water pollution affects the entire biosphere – plants and organisms living in these bodies of water. In almost all cases the effect is damaging not only to individual species and population, but also to the natural biological communities. Water pollution is a major global problem which requires ongoing evaluation and revision of water resource policy at all levels (international down to individual aquifers and wells). It has been suggested that water pollution is the leading worldwide cause of deaths and diseases, and that it accounts for the deaths of more people daily. In addition to the acute problems of water pollution in developing countries, developed countries also continue to struggle with pollution problems (Laws, 2000).

Interactions between groundwater and surface water are complex. Consequently, groundwater pollution, also referred to as groundwater contamination, is not as easily classified as surface water pollution. By its very nature, groundwater aquifers are susceptible to contamination from sources that may not directly affect surface water bodies, and the distinction of point vs. non-point source may be irrelevant. A spill or ongoing release of chemical or radionuclide contaminants into soil (located away from a surface water body) may not create point or non-point source pollution but can contaminate the aquifer below, creating a toxic plume. The movement of the plume, called a plume front, may be analyzed through a hydrological transport model or groundwater model. Analysis of groundwater contamination may focus on soil characteristics and site geology, hydrogeology, hydrology, and the nature of the contaminants. (Michael,2010).

2.7 Previous studies on the effluent pollution of water bodies

With the growing competition for water and declining freshwater resources, the utilization of marginal quality water for agriculture has posed a new challenge for environmental management. In water scarce areas there are competing demands from different sectors for the limited available water resources (Tiwari and Mahapatra, 1999). Though the industrial use of water is very low when compared to agricultural use, the disposal of industrial effluents on land and/or on surface water bodies make water resources unsuitable for other uses. A water accounting study conducted for the Lower Bhavani River

Basin shows that industrial water use (45 million cubic meters (Mm^3)) is almost 2 percent of the total water use in the basin (2,341 Mm^3) and agriculture has the highest share, more than 67 percent or 1,575 Mm^3. Industry is a small user of water in terms of quantity but has a significant impact on quality (Bashera *et al;* 2002). Over three-quarter of freshwater drawn by the domestic and industrial sector, return as domestic sewage and industrial effluents which inevitably end up in surface water bodies or in the groundwater, thereby affecting water quality. The 'marginal quality water' could potentially be used for other uses like irrigation (Ghosh and Chaudhuri 2005). Hence, the reuse of wastewater for irrigation using domestic sewage or treated industrial effluents has been widely advocated by experts and is practiced in many parts of India, particularly in water scarce regions. However, the environmental and socioeconomic impact of reuse is not well documented, at least for industrial effluents, particularly for a developing country like India where the irrigation requirements are large (Tiwari and Mahapatra, 1999).

The reuse of industrial effluents for irrigation has become more widespread in the State of Tamil Nadu after a High Court order in the early 1990s, which restricted industries from locating within one kilometer (1km) from the embankments of a list of rivers, streams, reservoirs, etc (Sharma, 2005). The intention of this order was to stop industries from contaminating surface water sources. Apart from the High Court order, industrial effluent discharge standards for disposal on inland surface water bodies are stringent when compared to disposal on land for irrigation, specifically for biological oxygen demand (BOD), chemical oxygen demand (COD), total suspended solids (TSS), total residual chlorine (TRC) and heavy metals. Therefore, industries prefer to discharge their effluents on land (Ghoshand Chaudhuri2005). Continuous irrigation using even treated effluents may lead to groundwater and soil degradation through the accumulation of pollutants. Currently, industries are practicing effluent irrigation without giving adequate consideration to the assimilation capacity of the land. As a result, the hydraulic and pollution load often exceeds the assimilative capacity of the land and pollutes groundwater and the soil. Apart from the disposal of industrial effluents on land, untreated effluents and hazardous wastes are also injected into groundwater through infiltration ditches and injection wells in some industrial locations in India to avoid pollution abatement costs (Reddy et al; 2002). As a result, groundwater resources of surrounding areas become unsuitable for agriculture and/or drinking purposes. Continuous application of polluted groundwater for irrigation can also increase the soil salinity or alkalinity problems in farmlands.

According to Aina et al; (1992), waste treatment in majority of the industries is virtually non-existent. Only a few industries have installed the simplest pollution control equipment such as sedimentation, sand filtration or oil and grease traps for effluents scrubbers and particulate traps or precipitators for gaseous emissions. Regrettably, most of the treatment facilities where they exist are grossly inadequate to cope with the volume and type of waste generated. Others are poorly maintained or have broken down completely. In short, what we have today, as treatment facilities are environmentally unacceptable (Aina et al; 1992).

The Lagos Lagoon complex is the largest lagoon systems of the Gulf of Guinea coast in West Africa (Webb and Hill, 1958). This lagoon system borders the rain forest belt and receives a number of major rivers and streams. In Nigeria over 85% of all industries are situated in Lagos metropolitan area (Portman *et al*., 1997) and their effluents ultimately get into the Lagos Lagoon complex directly or indirectly via drainages or streams and pollute the nursery grounds of both fishes and shrimps (Oyewo, 1998; Solarin, 1998). In Nigeria, measures for scheming pollution of coastal waters are relatively recent and there is inadequate baseline data on which to base appropriate management practices. The aim of this study therefore was to determine the heavy metals in some industrial effluents that discharge into Lagos Lagoon.

Lagos Lagoon lies between longitudes 3° 22’ E and 3° 40’ E and Latitude 6° 17’N and 6° 28’ N. The lagoon is generally shallow with a depth of between 0.3 and 3.2 m in most parts with the exception of some dredged parts, notably in the Lagos Harbour, where depth is greater than 10 m. The tidal range is 0.3-1.3 m.The colors of the effluents at the points of entry into the drainage channels varied. The physico-chemical parameters such as temperature, pH etc. differs.

That most Nigeria industries discharge their untreated effluent through drain or canals into the nearest water body e.g., streams, rivers, estuaries, lagoon and sea as observed by Adebayo *et al*. (2007) and Aina et al; (1992) was confirmed in this study as all the effluent used for the tests was collected from the drainage channels.According to Ekhaiseand Anyansi(2005), the bacteriological and physico-chemical qualities of the Ikpoba River, Benin city was investigated to assessed the extent of pollution of the water due to effluent discharge from the two brewery industries in Benin City.

The water resources of our planet, a basic and most important of our existence, are the most threatened aspect in life existence. In 1978, the UN reported consumable water levels at 2.7% of earth’s water, with ground water being a major contributor. Present estimates quantify consumable water levels at 1%, ground water levels also being threatened by pollution either directly or indirectly (Davis and Cornwell, 1991). The bacteriological parameters analyzed were total microbial population counts, which had values ranging from 1.0 x 10^3 to 4.8 x 10^3 cfu/ml and 1.3 x 10^7 to 5.7 x 10^7 cfu/ml for the fungal and bacterial isolates respectively. Total coliform counts ranged from 4.3 x 10 MPN/100 ml to 38.0 x 10 MPN/100 ml. Microorganisms isolated include acchromycescereviceae, Aspergillusniger, Penicillium sp., Geotrichumsp.Candida sp., Proteus sp Staphylococcus sp, Escherichia coli, Streptococcus faecalis and Bacillus sp. Physicochemical parameter studies revealed that Ikpoba river though show some parameters whose values are higher than the WHO tolerant levels. Others fall within the WHO acceptable limits. There is therefore, contamination of the surface water due to the brewery effluent discharged, which could probably be hazardous to human health.

However, sustainable utilization of the earth's water is therefore being defined as the use of water resources which imposes no cost whatsoever on future generations, which might arise through depletion of the resource or through a reduction in its quality (Kehinde, 1996). Ikpoba River, a fourth order stream, is located in Benin City, Edo State in South Western Nigeria (Lat 6.5^0N, Long $5\text{-}8^0$E). Its headwater originates from North West of Benin City and flows north to south through the city (Benka-Coker and Ojior, 1995). The river flows through a dense rain forest where the allochtonous input of organic matter from the surrounding vegetation is derived through run-off from the surface of the soil. Ikpoba River empties into the Benin River system, the third largest in Nigeria. The river serves as a source of water for domestic purpose including drinking and cooking. Fishing activities also take place in the river. The water body receives a variety of wastes ranging from industrial, agricultural, domestic and natural sources. These wastes introduce foreign microorganisms, organic and inorganic matter, in addition to indigenous microflora.

The Oregbeni community flanks the river on one side behind Guinness Nigeria Plc and Bendel Breweries. The products of the brewery operations include large volumes of wastewater, conveyed over a distance of 2.5 km by an underground tunnel and discharged into the receiving river. Increase industrial activities have led to pollutional stress on surface water both from industrial, agricultural and domestic sources (Ajayi and Osibanjo, 1981). Major streams in industrial areas of some Nigerian cities are already seriously polluted by waste from industries while streams flowing through densely polluted areas of Ibadan.

According to the review on impact of brewery effluents on surface water quality in Nigeria published in chemistry research journal 2017, Effluent from Nigeria Breweries Plc. that discharge into Lagos Lagoon were collected at different drainage channels and analysed forphysico-chemical parameters and heavy metals. The level of thephysico-chemical parameters considered such as pH, alkalinity, biological oxygen demand, chemical oxygen demand, dissolve oxygen and alkalinity were very high. Nigeria breweries effluent had the highest values of most of these parameters**.** Heavy metals like Mn, Pb, Cd, Cr, Fe and Cu were present in all the effluents from the companies. Cu, Zn, Mn, Pb and Fe were the most common heavy metals in all the effluents while Cr was found consistently in textile effluents. The Fe in Brewery's effluent doubles that of textile's effluent. There was decreasing concentration of some metals (Fe, Cu, Cd, Mn, Cr, Zn, Mn, Pb, Cr, Cu and Hg) from their source towards the Lagoon.

Heavy Metals are vital source of pollution not just because they are toxic above a relatively low concentration but also because they are persistent, remaining in the environment long after the source of pollution has been removed (Voutsinou-Taliadouri, 1981). Lori (1991) identified effluents from textile industries in Nigeria as one of those introducing heavy metals along with other pollutants into the environment. The rate of heavy metal pollutants into natural waters in Nigeria is therefore still largely unknown (Oyewo, 1998).

According to Aina et al, (1992), waste treatment in majority of the industries is virtually non-existent. Only a few industries have installed the simplest pollution control equipment such as sedimentation, sand filtration or oil and grease traps for effluents scrubbers and particulate traps or precipitators for gaseous emissions. Regrettably, most of the treatment facilities where they exist are grossly inadequate to cope with the volume and type of waste generated. Others are poorly maintained or have broken down completely. In short, what we have today, as treatment facilities are environmentally unacceptable (Aina et al; 1992).

The Lagos Lagoon complex is the largest lagoon systems of the Gulf of Guinea coast in West Africa (Webb and Hill, 1958). This lagoon system borders the rain forest belt and receives a number of major rivers and streams. In Nigeria over 85% of all industries are situated in Lagos metropolitan area (Portman *et al*., 1997) and their effluents ultimately get into the Lagos Lagoon complex directly or indirectly via drainages or streams and pollute the nursery grounds of both fishes and shrimps (Oyewo, 1998; Solarin, 1998). In Nigeria, measures for scheming pollution of coastal waters are relatively recent and there is inadequate baseline data on which to base appropriate management practices. The aim of this study therefore was to determine the heavy metals in some industrial effluents that discharge into Lagos Lagoon. Lagos Lagoon lies between longitudes 3° 22' E and 3° 40' E and Latitude 6° 17'N and 6° 28' N. The lagoon is generally shallow with a depth of between 0.3 and 3.2 m in most parts with the exception of some dredged parts, notably in the Lagos Harbour, where depth is greater than 10 m. The tidal range is 0.3-1.3 m.

Effluent Collection

Twenty-five liters containers were used for the collection of the effluent sample. The effluents were collected in 2005 from Nigerian breweries into Lagos Lagoon. The Nigeria Brewery PLC is located at Iganmu Industrial area of Lagos.

The collection sites were designated A, B and C

A : Point of outlet from the company into the Lagos Lagoon

B : Five hundred meters away from A along the drainage channel

C : One thousand meters away from A along the same drainage channel.

Control-water from Badore-Aja end of the Lagos Lagoon was taken as the zone was reported (Oyewo, 1998) to be free of effluent entry.

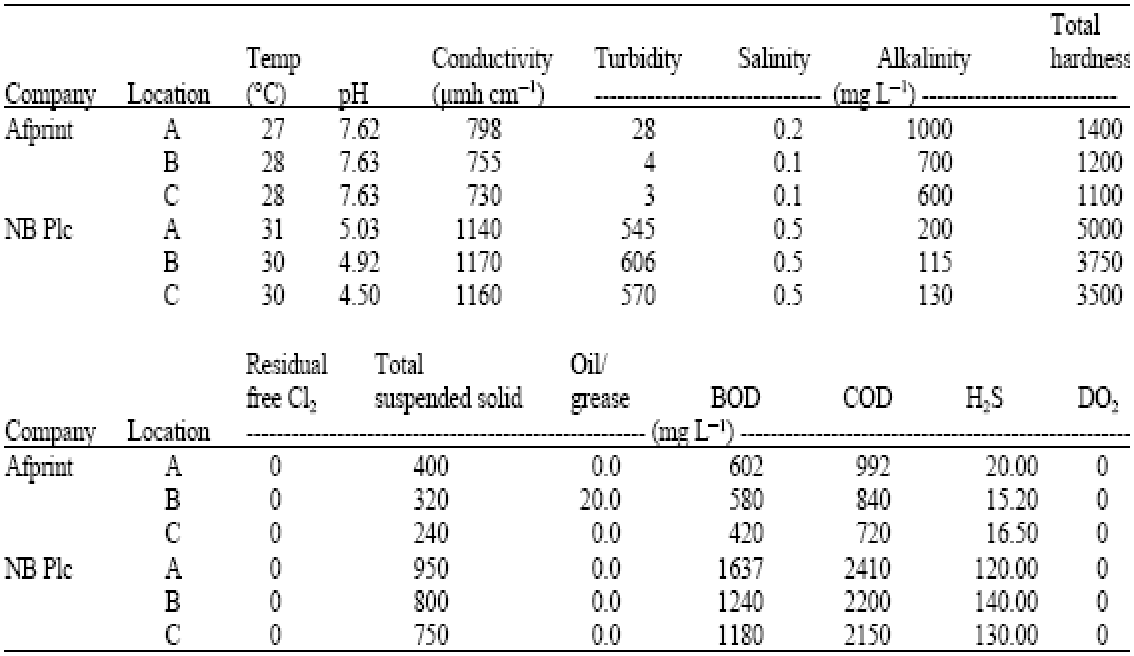
Chemical Analysis of Effluents

Temperature of the effluents were taken by immersing a mercury in-glass thermometer directly in the 25 L container used in collecting the effluent immediately after collection before leaving the site Alkalinity was estimated titrimetrically using 0.02 NH_2SO_4 with phenolphthalein and methyl orange as indicator.pH, conductivity, turbidity and salinity of the effluent samples were determined using Horiba water checker model U-10.Dissolve Oxygen (DO), Biological Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Total Suspended Solid (TSS), total hardness, hydrogen sulphide, oil/grease and residual/free chlorine were determined using standard methods as described in Global Environmental Monitoring System of WHO (1987).

Cadmium (Cd), Iron (Fe), Chromium (Cr), Copper (Cu), lead (Pd) and manganese (Mn) in the effluent samples were assayed using Atomic Absorption Spectrophotometer (AAS) model Unicam Solar Spectrometer 969V5.24. Fifty milliliters of each sample were used for the analysis. Standards were prepared from 1000 mg L^{-1} stock solution of the different metals of interest. Serial dilutions were made to obtain 1.0, 2.0 and 3.0 mg L^{-1}. The equipment was calibrated using deionized water as blank.

The colors of the effluents at the points of entry into the drainage channels varied. The physico-chemicalparameters such as temperature, pH etc. differs (Table 2.1).That most Nigeria industries discharge their untreated effluent through drain or canals into the nearest water body e.g., streams, rivers, estuaries, lagoon and sea as observed by Portman *et al*. (1989) and Aina et al; (1992) was confirmed in this study as all the effluent used for the tests was collected from the drainage channels.

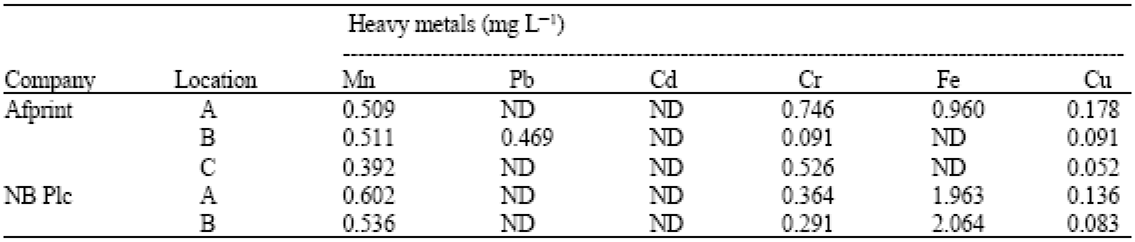
Table 2.3: Physico-chemical parameter of the effluents



Company	Location	Temp (°C)	pH	Conductivity (μmh cm^{-1})	Turbidity	Salinity	Alkalinity	Total hardness
					(mg L^{-1})			
Afprint	A	27	7.62	798	28	0.2	1000	1400
	B	28	7.63	755	4	0.1	700	1200
	C	28	7.63	730	3	0.1	600	1100
NB Plc	A	31	5.03	1140	545	0.5	200	5000
	B	30	4.92	1170	606	0.5	115	3750
	C	30	4.50	1160	570	0.5	130	3500

Company	Location	Residual free Cl_2	Total suspended solid	Oil/ grease	BOD	COD	H_2S	DO_2
				(mg L^{-1})				
Afprint	A	0	400	0.0	602	992	20.00	0
	B	0	320	20.0	580	840	15.20	0
	C	0	240	0.0	420	720	16.50	0
NB Plc	A	0	950	0.0	1637	2410	120.00	0
	B	0	800	0.0	1240	2200	140.00	0
	C	0	750	0.0	1180	2150	130.00	0

Table 2.4: Level of heavy metals in the effluents



		Heavy metals (mg L^{-1})					
Company	Location	Mn	Pb	Cd	Cr	Fe	Cu
Afprint	A	0.509	ND	ND	0.746	0.960	0.178
	B	0.511	0.469	ND	0.091	ND	0.091
	C	0.392	ND	ND	0.526	ND	0.052
NB Plc	A	0.602	ND	ND	0.364	1.963	0.136
	B	0.536	ND	ND	0.291	2.064	0.083

ND = Not Detected

2.8 National standards for wastewater

Textile industries produce wastewater, otherwise known as effluent, as a bi-product of their production. The effluent contains several pollutants, which can be removed with the help of an effluent treatment plant (ETP). The “clean” water can then be safely discharged into the environment.

Effluent from textile dyeing industries must meet the national effluent discharge quality standards set by World Health Organization (WHO), including the “Quality Standards for Classified Industries” (Tables 2.3), and may also need to meet additional standards set by international textile buyers. Consequently, any ETP must be designed and operated in such a way that it treats the wastewater to these standards.

The regulations state that these quality standards must be ensured from the moment of going into trial production for industrial units. They also state that the Department of Environment can undertake spot checks at any time and the pollution levels must not exceed these quality standards.

Furthermore, the quality standards may be enforced in a more stringent manner if considered necessary in view of the environmental conditions of a particular situation.

The waste discharge quality standards differ according to the point of disposal. So, the standards are different for inland surface water (ponds, tanks, water bodies, water holes, canals, river, springs or estuaries); public sewers (any sewer connected with fully combined processing plant including primary and secondary treatment); and irrigated land defined as an appropriately irrigated plantation area of specified crops based on quantity and quality of wastewater.

Table 2.5: National Standards - Waste Discharge Quality Standards for Industrial Units and Projects (quality standard at discharge point)

Parameter	WHO				NESREA
	Unit	Inland Surface Water	Public Sewer secondary treatment plant	Irrigated Land	
Ammoniacal Nitrogen (N molecule)	mg/l	50	75	75	-
Ammonia (free ammonia)	mg/l	5	5	15	-
Arsenic	mg/l	0.2	0.5	0.2	-
BOD_5 20^0C	mg/l	50	250	100	-
Boron (B)	mg/l	2	2	2	-
Cadmium (Cd)	mg/l	0.05	0.5	0.5	1.0
Chloride (Cl—)	mg/l	600	600	600	250
Chromium (total Cr)	mg/l	0.5	1.0	1.0	1.0
COD	mg/l	200	400	400	60:90
Chromium (hexavalent Cr)	mg/l	0.1	1.0	1.0	-
Copper (Cu)	mg/l	0.5	3.0	3.0	-
Dissolved Oxygen (DO)	mg/l	4.5-8	4.5-8	4.5-8	30:50
Electrical Conductivity	micro mho/cm	1200	1200	1200	-
Total Dissolved Solids (TDS)	mg/l	2100	2100	2100	500
Fluoride (F)	mg/l	7	15	10	-

Sulfide (S)	mg/l	1	2	2	-
Iron (Fe)	mg/l	2	2	2	-
Total Kjeldahl Nitrogen (N)	mg/l	100	100	100	100
Lead (Pb)	mg/l	0.1	0.1	0.1	0.05
Manganese (Mn)	mg/l	5	5	5	0.2
Mercury (Hg)	mg/l	0.01	0.01	0.01	
Nickel (Ni)	mg/l	1.0	1.0	1.0	0.05
Nitrate (N molecule)	mg/l	10.0	Undetermined	10.0	-
Oil & grease	mg/l	10	20	10	10
Phenol compounds (C_6H_5OH)	mg/l	1.0	5	1	0.5
Dissolved Phosphorus (P)	mg/l	8	8	10	-
Radioactive materials:	As determine d by Bangladesh Atomic Energy Commission				-
pH		6-9	6-9	6-9	6.5-8;8; 6-9
Selenium (Se)	mg/l	0.05	0.05	0.05	-
Zn (Zn)	mg/l	5.0	10.0	10.0	-
Temperature	Centigrade				
Summer	0C	40	40	40	40
Winter	0C	45	45	45	-
Total Suspended Solid	mg/l	150	500	200	25
Cyanide (CN)	mg/l	0.1	2.0	0.2	-

Source: Water Environment Federation (1996). Operation of Municipal Wastewater Treatment Plant: Manual of Practice, 5th edition vol. 2. Alexandria.

Under the Environmental Conservation Rules 1997, industrial units and projects are classified into four categories (Green, Orange A, Orange B, and Red) based on their environmental impact and location. Fabric dyeing and chemical treatment industries fall under the Red category.

This means that when they are applying for site clearance they must submit an ETP plan to the Department of Environment, including the layout and location. When the design has been approved by the Department of Environment and the ETP has been constructed, then Red category industries can apply for an environmental clearance certificate.

CHAPTER THREE

MATERIALS AND METHODS

3.1 Study Area

The study was conducted at Ama–Eke, 9th Mile corner, Ngwo, in Udi Local Government Area of Enugu State, and lies on the latitude $6^0$25' North and longitude 7^o24' East. The area is 9 miles (14.4 km) from Enugu metropolis and is bound by Ngwo in the North, Nsude in the south, Enugu in the East and ObeleaguUmana in the West as shown in the map (Plates 3.1 and 3.2). The Ajalliowa River lies within the humid tropical zone of latitude 6^o27'N and longitude 7^o73'S and has an undulating land surface structure, comprising hills and valleys. It is in the rainforest zone but has a derived savanna vegetation area. The soil type is sandy and not sandstone as generally seen in Enugu (Asonye*et al.,* 2007).

Nigerian Breweries whose activities and effluent discharge to Ajalliowa River pose great concern to both the aquatic organisms and residents of the area under study. The features of industrial waste disposal facilities and outlets are presented in Plates 3.3 and 3.4 Plate 3.5 shows where spent grain is being dumped and will during rainfall be washed into the Ajalliowa River thereby contaminating the river.

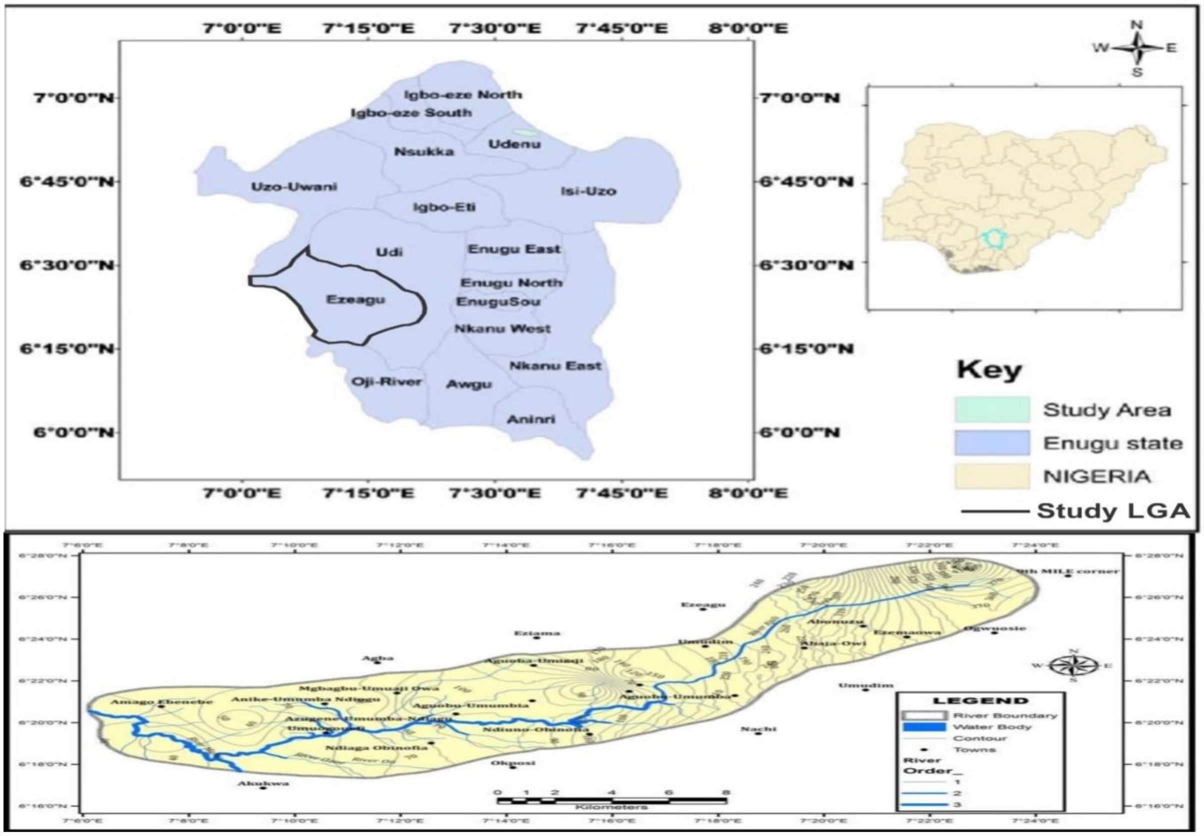


PLATE 3.1: Map showing Nigeria and Enugu Placement of Ajali River

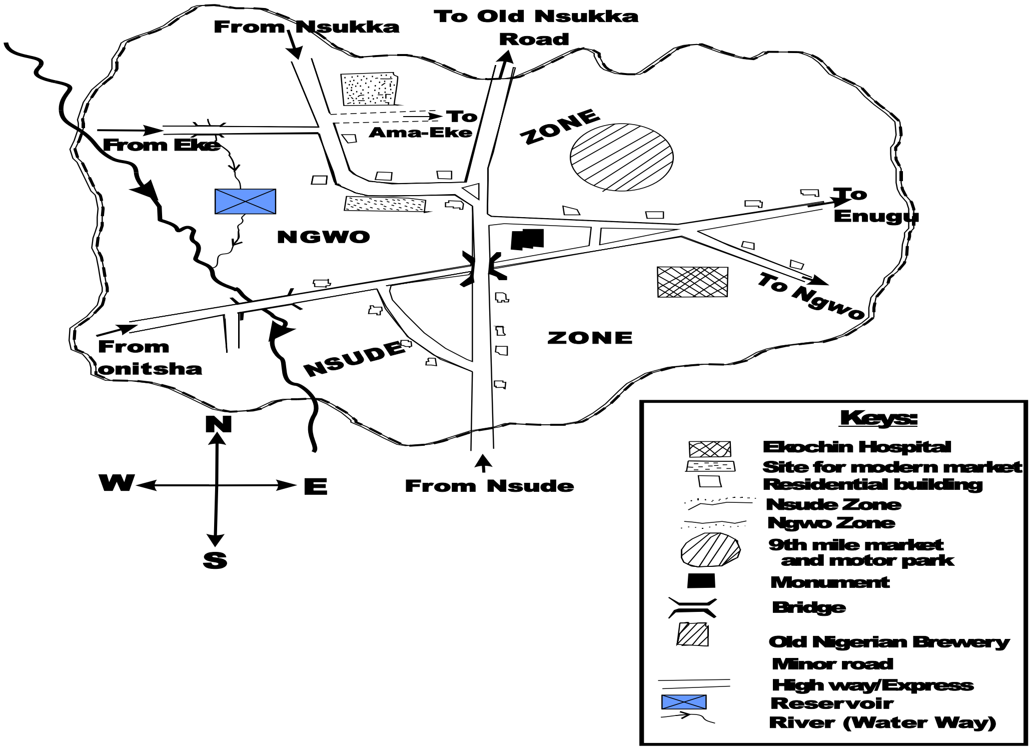
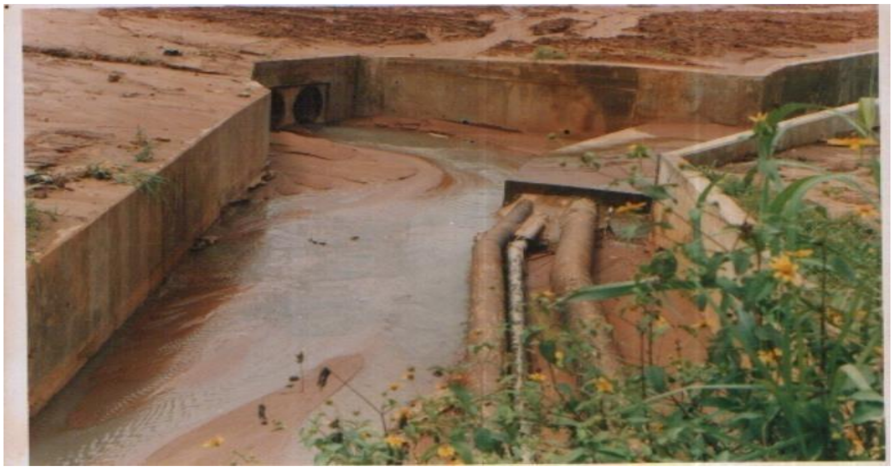


PLATE 3.2: Map showing Ngwo and Ajaliowa River

Source: Enugu State Water Cooperation Oct.2011



Plates 3.3: The wastewater that flows out of the Nigerian Brewery on open channel.

Plates 3.4: The point of discharge of the wastewater into Ajalliowa River.

Plates 3.5 Dumped spent grain

3.2 Sampling:

The samples were taken four different times at the interval of ten minutes after each sample is collected. Samples of the brewery effluents were collected with whirl pack of 1 litre, at 50m up stream, sample from brewery effluent, sample at the point of discharge into Ajalliowa River, then from 50m, 100m and 150m downstream of effluent discharge point. Surface water was collected from the run-off of effluent and samples were collected 1litre whirl pack from brewery effluent. The physico-chemical characteristics analysed were biological oxygen demand, chemical oxygen demand, dissolved oxygen, pH and electrical conductivity.

3.2.1 Sample Analysis

The standard analytical methods that were used for determination of physicochemical parameters of the brewery effluent were from American Public Health Association series of Standard Methods of Examination of Water and Wastewater (APHA, 1998).

3.2.2 Analysis of parameters:

Total dissolved solids.

Procedure: This was based on calculation using the relation.

$$TDS = EC \times 0.56\, mg/l. \qquad \text{Equation 1}$$

Where: EC = Electrical conductivity value of the sample.

Electrical conductivity (EC):

Apparatus: conductivity meter, electrode and glass and glass wares

Procedure: The electrode was wetted thoroughly with the sample collected from Ajalliowa River and then plugged into the conductivity meter before it was inserted into a 250ml beaker containing distilled water. The conductivity meter was switched on and zero error was corrected. The distilled water was replaced with raw water samples and the electrode was inserted in each case. This was allowed to stabilize and the reading was noted.

Determination of pH:

Apparatus: pH-meter (Electrometric), glass wares, glass electrode, buffer solution with pH value 4.0

*Procedure:*The glass electrode was thoroughly wetted using deionised water. pH meter was switched on and the buffer solution was used to standardize it. This was done by connecting glass electrode to the pH meter and inserting electrode into the buffer solution. This was allowed to stabilize and pH meter reading indicated 4.0, which was equal to its known value.

The beaker containing buffer solution was then replaced consecutively with ones containing raw water samples and the electrode was inserted into it. This was allowed to stabilize and the reading was taken.

Determination of calcium hardness (titrimetric method):

Apparatus / reagents:Titration apparatus, muroxide indictor solution, lm NaOH solution, 0.0lm EDTA.

Procedure: 10ml of each of the water sample was made up to 100ml in a rinsed 250ml conical flask. 2ml of 1 mNaOH solution and 3- drops of muroxide indicator were added to each sample.

It was swirled thoroughly to mix, giving a pink color. Each of the sample solution was carefully titrated against 0.0lm EDTA solution until the colour changed from pink to purple. The volume of 0.0lm EDTA solution used for each sample was recorded.

Determination of chloride (argentometric method):

Apparatus / reagents: Titration apparatus, potassium chromate indicator solution, 0.02M Ag NO_3 solution.

Procedure: 10ml each of the raw water sample was made up to 100ml with deionised water (chlorine free water) in a rinsed 250ml conical flask. 1ml of potassium chromate indicator solution was then carefully titrated against 0.02M $AgNO_3$ solution to obtain Reddish brown color. The volume of 0.02M $AgNO_3$ solution used was noted at each end-point.

Determination of nitrates (phenoldisulphonic acid method):

Apparatus/ reagents:Nesslerizer, phenoldisulphonic acid reagent, 10% ammonia solution, crucible, water bath, nessler tube, nitrate disc.

Procedure: 50ml each of the water sample was poured into a rinsed crucible and evaporated in a water bath to dryness. This was allowed to cool and 15 drops of phenol disulphonic acid was added to each sample making sure that it touches all the areas formerly covered by the raw water sample in the crucible. It was allowed for about two minutes to enable re-dissolution of caked nitrate compounds in the crucible. After re-dissolution, each solution was washed with distilled water into a nessler tube. 10ml of 10% ammonia solution was added to each sample solution for colour development. This was made up to 50ml mark with distilled water. The nessler tube containing the respective sample solution was consecutively placed at the right side of nessleriser while another nessler tube containing distilled water as blank sample was placed at the left side of the nessleriser. The color was then matched using nitrate disc. The value at which the two nessler tubes match in color in each case was noted.

3.3 Modelling the Physico-chemical Characteristics of Ajalliowa River.

Model development for the prediction and estimation of the physico-chemical characteristics of Ajalliowariver was achieved using the least square method. In a similar study carried out by Igboanugo and Chiejina (2011), Latin square method was adopted for the analysis of brewery effluent distribution in Ikpoba river in Benin City and only four parameters (biochemical oxygen demand (BOD), chemical oxygen demand (COD), dissolved oxygen (DO) and pH) were considered to develop the model which proved successful in predicting the effluent distribution along the river.However, to account for variation in pollution levels of water bodies, eight parameters of interest were considered for modelling the physico-chemical characteristics of Ajalliowariver. The parameters of interest include; biochemical oxygen demand (BOD), chemical oxygen demand (COD), pH, temperature (T), total dissolve solids (TDS), nitrite (N), chlorine (Cl) and calcium (Ca).

3.3.1 pHModeling using least square method

The pH of water is a reflection of the resultant effect of temperature (T), total dissolved solid (TDS), biochemical oxygen demand (BOD), nitrite (N), chloride (Cl), chemical oxygen demand (COD), and calcium (Ca). This is expressed mathematically in equations 2 and 3 below.

$pH = f\ (T, TDS, BOD, N, Cl, COD, Ca)$ Equation 2

$pH = f\ (a.T + b.TDS + c.BOD + d.N + e.Cl + f.COD + g.Ca)$ Equation 3

where pH is the dependent variable; a, b, c, d, e, f and g are the model coefficients to be determined respectively and T, TDS, BOD, N, Cl, COD and Ca are the independent measured variables for the desired pH.

TakingI as the square of error between the observed (P) and predicted values of pH, the numerical representation of the square errorcan be presented mathematically as shown in equation 4.

$I = (P - pH)^2$ Equation 4

Substituting equation 3 in equation 4, we have:

$I = \{P - f\ (a.T + b.TDS\ c.BOD + d.N + e.Cl + f.COD + g.Ca)\}^2$Equation 5

For n number of experiment, equation 5 becomes:

$nI = \Sigma n\, \{P - f(a.T + b.TDS + c.BOD + d.N + e.Cl + f.COD + g.Ca)\}^2$Equation 6

MathCAD software was used to generate values for the model coefficients, which are substituted intoEquation 3. Equations 7 - 12 are modeled equations that are obtained for samples taken at the distances of 50m upstream, brewing effluent, point of discharge, 50m downstream, 100m downstream, and 150m downstream.

$pH_{50Up} = 0.20.T + 0.02.TDS + 0.04.BOD – 0.24.N + 0.09.Cl – 0.04.COD + 0.06.Ca$

Equation 7

$pH_{ed} = 0.25.T + 0.06.TDS + 0.12.BOD – 0.82.N + 0.10.Cl + 0.03.COD – 1 .73.Ca$

Equation 8

$pH_{dp} = 0.25.T + 0.06.TDS + 0.12.BOD – 0.82.N + 0.10.Cl + 0.03.COD – 1 .73.Ca$

Equation 9

$pH_{50ds} = 0.38.T – 0.02.TDS + 0.19.BOD – 1.57.N + 0.02.Cl + 0.05.COD – 1.75.C$

Equation 10

$pH_{100ds} = 0.51.T + 0.01.TDS + 0.07.BOD – 0.47.N – 0.25.Cl + 0.04.COD – 0.16.Ca$

Equation 11

$pH_{150ds} = 0.56.T + 0.05.TDS + 0.15.BOD – 1.59.N – 0.18.Cl + 0.05.COD – 1.79.Ca$

Equation 12

3.3.2 BOD Modeling using least square method

Similarly, the BOD of a water body is a reflection of the resultant effect of temperature (T), total dissolved solid (TDS), pH, nitrite (N), chloride (Cl), chemical oxygen demand (COD), and calcium (Ca). This is expressed mathematically in equations 13 and 14 below.

$BOD = f\ (T, TDS, pH, N, Cl, COD, Ca)$ Equation 13

$BOD = f\ (a.T + b.TDS + c.pH + d.N + e.Cl + f.COD + g.Ca)$ Equation 14

where BOD is the dependent variable; a, b, c, d, e, f and g are the model coefficients to be determined respectively and T, TDS, pH, N, Cl, COD and Ca are the independent measured variables for the desired BOD.

TakingI as the square of error between the observed (P) and predicted values of BOD, the numerical representation of the square error can be presented mathematically as shown in equation 15.

$I = (P – BOD)^2$ Equation 15

Substituting equation 14 in equation 15, we have:

$I = \{P – f\ (a.T + b.TDS\ c.pH + d.N + e.Cl + f.COD + g.Ca)\}^2$Equation 16

For n number of experiment, equation 16 becomes:

$nI = \Sigma n\ \{P – f(a.T + b.TDS + c.pH + d.N + e.Cl + f.COD + g.Ca)\}^2$ Equation 17

MathCAD software was used to generate values for the model coefficients, which are substituted intoEquation 14. Equations 18 - 23 are modeled equations that are obtained for samples taken at the distances of 50m upstream, brewing effluent, point of discharge, 50m downstream, 100m downstream, and 150m downstream.

$$BOD_{50Up} = 0.90.T - 0.28.TDS - 0.72.pH - 0.01.N + 0.22.Cl + 0.31.COD + 0.90.Ca$$

Equation 18

$$BOD_{ed} = -1.60.T - 0.42.TDS - 0.92.pH - 0.11.N + 0.52.Cl + 0.53.COD + 0.74.Ca$$

Equation 19

$$BOD_{dp} = -1.50.T + 0.65.TDS - 0.89.pH - 0.10.N + 0.90.Cl + 0.72.COD + 0.83.Ca$$

Equation 20

$$BOD_{50ds} = -1.78.T + 0.42.TDS - 0.49.pH - 0.05.N + 0.96.Cl + 0.78.COD + 0.65.Ca$$

Equation 21

$$BOD_{100ds} = 0.90.T + 0.72.TDS - 0.68.pH - 0.05.N + 0.58.Cl + 0.69.COD + 0.62.C$$

Equation 22

$$BOD_{150ds} = 0.70.T + 0.94.TDS - 0.66.pH - 0.11.N + 0.85.Cl + 0.86.COD + 0.69.C$$

Equation 23

3.3.3 COD Modeling using least square method

Similarly, the COD of a water body is a reflection of the resultant effect of temperature (T), total dissolved solid (TDS), pH, nitrite (N), chloride (Cl), biochemical oxygen demand (BOD), and calcium (Ca). This is expressed mathematically in equations 24 and 25 below.

$COD = f\ (T, TDS, pH, N, Cl, BOD, Ca)$ Equation 24

$COD = f\ (a.T + b.TDS + c.pH + d.N + e.Cl + f.BOD + g.Ca)$ Equation 25

where COD is the dependent variable; a, b, c, d, e, f and g are the model coefficients to be determined respectively and T, TDS, pH, N, Cl, BOD and Ca are the independent measured variables for the desired COD.

TakingI as the square of error between the observed (P) and predicted values of COD, the numerical representation of the square error can be presented mathematically as shown in equation 26.

$I = (P - COD)^2$ Equation 26

Substituting equation 25 in equation 26, we have:

$I = \{P - f\ (a.T + b.TDS\ c.pH + d.N + e.Cl + f.BOD + g.Ca)\}^2$Equation 27

For n number of experiment, equation 27 becomes:

$nI = \Sigma n\ \{P - f(a.T + b.TDS + c.pH + d.N + e.Cl + f.BOD + g.Ca)\}^2$ Equation 28

MathCAD software was used to generate values for the model coefficients, which are substituted intoEquation 25. Equations 29 - 34 are modeled equations that are obtained for samples taken at the distances of 50m upstream, brewing effluent, point of discharge, 50m downstream, 100m downstream, and 150m downstream.

$$COD_{50Up} = 0.95.T - 0.47.TDS - 0.72.pH - 0.01.N + 0.26.Cl + 0.35.BOD - 0.22.Ca$$

Equation 29

$$COD_{ed} = -2.15.T - 0.48.TDS - 0.95.pH - 0.12.N + 0.48.Cl + 0.45.BOD + 0.42.Ca$$

Equation 30

$$COD_{dp} = -1.50.T + 0.69.TDS - 0.80.pH - 0.12.N + 0.95.Cl + 0.70.BOD + 0.68.Ca$$

Equation 31

$$COD_{50ds} = -1.55.T + 0.48.TDS - 0.55.pH - 0.05.N + 0.92.Cl + 0.75.BOD + 0.65.Ca$$

Equation 32

$$COD_{100ds} = 1.05.T + 0.75.TDS - 0.65.pH - 0.08.N + 0.61.Cl + 0.66.BOD + 0.68.Ca$$

Equation 33

$$COD_{150ds} = 0.89.T + 0.76.TDS - 0.68.pH - 0.11.N + 0.88.Cl + 0.85.BOD + 0.62.Ca$$

Equation 34

3.3.4 TDSModeling using least square method

Similarly, the TDS of a water body is a reflection of the resultant effect of temperature (T), chemical oxygen demand (COD), pH, nitrite (N), chloride (Cl), biochemical oxygen demand (BOD), and calcium (Ca). This is expressed mathematically in equations 35 and 36 below.

$$TDS = f\,(T, COD, pH, N, Cl, BOD, Ca)$$ Equation 35

$$TDS = f\,(a.T + b.COD + c.pH + d.N + e.Cl + f.BOD + g.Ca)$$ Equation 36

where TDS is the dependent variable; a, b, c, d, e, f and g are the model coefficients to be determined respectively and T, COD, pH, N, Cl, BOD and Ca are the independent measured variables for the desired TDS.

TakingI as the square of error between the observed (P) and predicted values of TDS, the numerical representation of the square error can be presented mathematically as shown in equation 37.

$I = (P - TDS)^2$ Equation 37

Substituting equation 36 in equation 37, we have:

$I = \{P - f\,(a.T + b.COD + c.pH + d.N + e.Cl + f.BOD + g.Ca)\}^2$Equation 38

For n number of experiment, equation 38 becomes:

$nI = \Sigma n\,\{P - f(a.T + b.COD + c.pH + d.N + e.Cl + f.BOD + g.Ca)\}^2$ Equation 39

MathCAD software was used to generate values for the model coefficients, which are substituted intoEquation 36. Equations 40 - 45 are modeled equations that are obtained for samples taken at the distances of 50m upstream, brewing effluent, point of discharge, 50m downstream, 100m downstream, and 150m downstream.

$TDS_{50Up} = 0.65.T - 0.44.COD - 0.52.pH - 0.04.N + 0.52.Cl + 0.45.BOD - 0.42.Ca$

Equation 40

$TDS_{ed} = -1.35.T - 0.45.COD - 0.93.pH - 0.12.N + 0.46.Cl + 0.49.BOD + 0.52.Ca$

Equation 41

$TDS_{dp} = -1.08.T + 0.69.COD - 0.82.pH - 0.14.N + 0.93.Cl + 0.72.BOD + 0.48.Ca$

Equation 42

$TDS_{50ds} = -1.32.T + 0.54.COD - 0.57.pH - 0.06.N + 0.95.Cl + 0.62.BOD + 0.35.Ca$

Equation 43

$TDS_{100ds} = 1.52.T + 0.70.COD - 0.68.pH - 0.09.N + 0.67.Cl + 0.58.BOD + 0.38.Ca$

Equation 44

$TDS_{150ds} = 0.79.T + 0.71.COD - 0.64.pH - 0.10.N + 0.84.Cl + 0.62.BOD + 0.52.Ca$

Equation 45

3.3.5 ClModeling using least square method

Similarly, the Cl content of a water body is a reflection of the resultant effect of temperature (T), chemical oxygen demand (COD), pH, nitrite (N), total dissolve solids (TDS), biochemical oxygen demand (BOD), and calcium (Ca). This is expressed mathematically in equations 46 and 47 below.

$Cl = f\,(T, COD, pH, N, Cl, BOD, Ca)$ Equation 46

$Cl = f\,(a.T + b.TDS + c.pH + d.N + e.COD + f.BOD + g.Ca)$ Equation 47

where Cl is the dependent variable; a, b, c, d, e, f and g are the model coefficients to be determined respectively and T, COD, pH, N, TDS, BOD and Ca are the independent measured variables for the desired Cl.

TakingI as the square of error between the observed (P) and predicted values ofCl, the numerical representation of the square error can be presented mathematically as shown in equation 48.

$I = (P - Cl)^2$ Equation 48

Substituting equation 47 in equation 48, we have:

$I = \{P - f\,(a.T + b.TDS + c.pH + d.N + e.COD + f.BOD + g.Ca)\}^2$Equation 49

For n number of experiment, equation 38 becomes:

$nI = \Sigma n\,\{P - f(a.T + b.TDS + c.pH + d.N + e.COD + f.BOD + g.Ca)\}^2$Equation 50

MathCAD software was used to generate values for the model coefficients, which are substituted intoEquation 47. Equations 51 - 56 are modeled equations that are obtained for samples taken at the distances of 50m upstream, brewing effluent, point of discharge, 50m downstream, 100m downstream, and 150m downstream.

$$Cl_{50Up} = 0.93.T - 0.45.TDS - 0.70.pH - 0.04.N + 0.35.COD + 0.39.BOD - 0.12.Ca$$

Equation 51

$$Cl_{ed} = 2.25.T - 0.57.TDS - 0.72.pH - 0.12.N + 0.47.COD + 0.45.BOD + 0.23.Ca$$

Equation 52

$$Cl_{dp} = 1.60.T + 0.64.TDS - 0.62.pH - 0.14.N + 0.74.COD + 0.75.BOD + 0.42.Ca$$

Equation 53

$$Cl_{50ds} = 1.75.T + 0.49.TDS + 0.53.pH - 0.08.N + 0.64.COD + 0.72.BOD + 0.48.Ca$$

Equation 54

$$Cl_{100ds} = 1.05.T + 0.78.TDS - 0.69.pH - 0.06.N + 0.67.COD + 0.64.BOD + 0.51.Ca$$

Equation 55

$$Cl_{100ds} = 0.89.T + 0.76.TDS - 0.68.pH - 0.11.N + 0.88.COD + 0.85.BOD + 0.62.Ca$$

Equation 56

3.3.6 Ca Modeling using least square method

Similarly, the Ca content of a water body is a reflection of the resultant effect of temperature (T), chemical oxygen demand (COD), pH, nitrite (N), total dissolve solids (TDS), biochemical oxygen demand (BOD), and chlorine (Cl). This is expressed mathematically in equations 57 and 58 below.

$Ca = f\ (T, COD, pH, N, Cl, BOD, Cl)$ Equation 57

$Ca = f\ (a.T + b.TDS + c.pH + d.N + e.COD + f.BOD + g.Cl)$ Equation 58

where Ca is the dependent variable; a, b, c, d, e, f and g are the model coefficients to be determined respectively and T, COD, pH, N, TDS, BOD and Cl are the independent measured variables for the desired Ca.

Taking I as the square of error between the observed (P) and predicted values ofCa, the numerical representation of the square error can be presented mathematically as shown in equation 59.

$I = (P - Ca)^2$ Equation 59

Substituting equation 58 in equation 59, we have:

$I = \{P - f\ (a.T + b.TDS + c.pH + d.N + e.COD + f.BOD + g.Cl)\}^2$Equation 60

For n number of experiment, equation 60 becomes:

$nI = \Sigma n\, \{P - f(a.T + b.TDS + c.pH + d.N + e.COD + f.BOD + g.Cl)\}^2$Equation 61

MathCAD software was used to generate values for the model coefficients, which are substituted into Equation 58. Equations 62 - 67 are modeled equations that are obtained for samples taken at the distances of 50m upstream, brewing effluent, point of discharge, 50m downstream, 100m downstream, and 150m downstream.

$$Ca_{50Up} = 0.75.T - 0.54.TDS - 0.76.pH + 0.01.N + 0.32.COD + 0.55.BOD - 0.32.Cl$$

Equation 62

$$Ca_{ed} = 1.55.T - 0.78.TDS - 0.89.pH + 0.12.N + 0.28.COD + 0.65.BOD + 0.22.Cl$$

Equation 63

$$Ca_{dp} = 1.54.T + 0.58.TDS - 0.85.pH + 0.12.N + 0.45.COD + 0.81.BOD + 0.62.Cl$$

Equation 64

$$Ca_{50ds} = 1.85.T + 0.45.TDS - 0.58.pH + 0.05.N + 0.65.COD + 0.85.BOD + 0.64.Cl$$

Equation 65

$$Ca_{100ds} = 1.65.T + 0.64.TDS - 0.73.pH + 0.08.N + 0.68.COD + 0.46.BOD + 0.64.Cl$$

Equation 66

$$Ca_{150ds} = 0.73.T + 0.71.TDS - 0.68.pH + 0.11.N + 0.56.COD + 0.83.BOD + 0.66.Cl$$

Equation 67

3.3.7 TemperatureModeling using least square method

Similarly, the temperature of a water body is a reflection of the resultant effect biochemical oxygen demand (BOD), total dissolved solid (TDS), pH, nitrite (N), chloride (Cl), chemical oxygen demand (COD), and calcium (Ca). This is expressed mathematically in equations 68 and 69 below.

$T = f\ (BOD, TDS, pH, N, Cl, COD, Ca)$ Equation 68

$T = f\ (a.BOD + b.TDS + c.pH + d.N + e.Cl + f.COD + g.Ca)$ Equation 69

where T is the dependent variable; a, b, c, d, e, f and g are the model coefficients to be determined respectively and BOD, TDS, pH, N, Cl, COD and Ca are the independent measured variables for the desired T.

Taking I as the square of error between the observed (P) and predicted values of T, the numerical representation of the square error can be presented mathematically as shown in equation 70.

$I = (P - T)^2$ Equation 70

Substituting equation 69 in equation 70, we have:

$I = \{P - f\ (a.BOD + b.TDS\ c.pH + d.N +\ e.Cl\ +\ f.COD\ +\ g.Ca)\}^2$Equation 71

For n number of experiment, equation 71 becomes:

$nI = \Sigma n\,\{P - f(a.BOD + b.TDS + c.pH + d.N + e.Cl + f.COD + g.Ca)\}^2$ Equation 72

MathCAD software was used to generate values for the model coefficients, which are substituted into Equation 69. Equations 73 - 78 are modeled equations that are obtained for samples taken at the distances of 50m upstream, brewing effluent, point of discharge, 50m downstream, 100m downstream, and 150m downstream.

$$T_{50Up} = 0.95.BOD - 0.84.TDS - 0.75.pH - 0.04.N + 0.25.Cl + 0.35.COD - 0.93.Ca$$

Equation 73

$$T_{ed} = -1.52.BOD - 0.70.TDS - 0.94.pH - 0.10.N + 0.55.Cl + 0.56.COD + 0.78.Ca$$

Equation 74

$$T_{dp} = -1.38.BOD + 0.68.TDS - 0.79.pH - 0.11.N + 0.70.Cl + 0.70.COD + 0.81.Ca$$

Equation 75

$$T_{50ds} = -1.25.BOD + 0.45.TDS - 0.55.pH - 0.05.N + 0.86.Cl + 0.74.COD + 0.64.Ca$$

Equation 76

$$T_{100ds} = 0.86.BOD + 0.75.TDS - 0.65.pH - 0.15.N + 0.65.Cl + 0.65.COD + 0.65.Ca$$

Equation 77

$$T_{150ds} = 0.75.BOD + 0.88.TDS - 0.65.pH - 0.21.N + 0.80.Cl + 0.80.COD + 0.66.Ca$$

Equation 78

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 Experimental and Simulated Results

The result obtained from the experimental stage is presented in table 4.1. The simulated result was obtained by combining the experimental results and the model equations developed for predicting the physico-chemical characteristics of Ajalliowa river at50 m Upstream, effective discharge, discharge point, 50 m downstream, 100 m downstream, and 150 m downstream. The simulated result is presented in table 4.2.

Table 4.1: Mean Experimental values

Table 4.1: Mean Experimental values

Sample	pH	Temp. ^{0}C	TDS (mg/L)	BOD (mg/L)	N (mg/L)	Cl (mg/L)	COD (mg/L)	Ca (mg/L)
50m UPStr.	6.35	32.0533	65.7533	28.5	0.13833	12.9133	116.5	21.6667
Eff. Dis.	8.3	28.6117	69.56	244.333	0.02833	161.193	222.5	27.3333
Dis. Pt.	7.65	26.5883	156.547	243.333	0.11167	92.0067	232.5	53.3333
50m DStr.	7.54167	28.235	134.413	236.667	0.11333	61.7067	323	40.1667
100m DStr.	7.53333	21.795	92	140.833	0.11333	68.2283	163.333	41
150m DStr.	7.51667	26.51	138	349	0.11667	83.7283	329.333	46

Table 4.2: Mean Simulated values using the Least square method

Table 4.2: Mean Simulated values

Sample	pH	Temp. ^{0}C	TDS (mg/L)	BOD (mg/L)	N (mg/L)	Cl (mg/L)	COD (mg/L)	Ca (mg/L)
50m UPStr.	6.405	6.14608	9.4492	2.23167	0.10225	1.67081	21.4167	18.6067
Eff. Dis.	7.89	33.465	75.5667	177.012	0.03933	13.4744	141.725	16.8467
Dis. Pt.	7.65667	29.4658	77.4423	83.7717	0.15417	48.3034	44.9642	45.983
50m DStr.	7.16458	35.3087	234.647	173.162	0.03383	37.0635	186.515	44.75

100m DStr.	7.006	18.1932	53.595	76.69	0.171	113.591	104.658	24.0533
150m DStr.	6.91533	20.823	80.47	201.79	0.12675	48.8442	197.803	182.952

4.2 Description and analysis of pH model for AjalliowaRiver

The model showed that pH of the effluent is a reflection of the resultant effect of Temperature (*T*), Total Dissolved Solid (TDS), Biochemical Oxygen Demand (BOD), Chloride (Cl), Chemical Oxygen Demand (COD), and Calcium (Ca). Observing the model equations, it can be noticed that some coefficients have positive signs while others have negative signs. The positive sign indicates direct proportionality between the parameters and the pH, while the negative sign indicates inverse proportionality between them. In other words, an increase in any of the parameters having positive coefficient will lead to an increase in pH, that is, the pH will become more acidic. On the contrary, an increase in any of the parameters having negative coefficients will lead to decrease in the pH, hence, the water will become more basic.

Table 4.3: Mean pH values

Sample	Experimental	Simulated
50m UPStr.	6.35	6.405
Eff. Dis.	8.3	7.89
Dis. Pt.	7.65	7.65667
50m DStr.	7.54167	7.16458
100m DStr.	7.53333	7.006
150m DStr.	7.51667	6.91533

In this study, the mean pH values obtained, ranged from 6.35 – 8.3 for experiment and 6.405 – 7.89 for simulation as shown in table 4.3. The pH was slightly higher than the neutral 7 - pH of water as shown in fig. 1. This could be due to detergents used for washing that constituted part of the brewery wastewater. However, the values were within the permissible standards of NESREA and WHO of 6 – 9 and 6.5 – 8.5, respectively. Hence the pH of the sampling points poses no threat to the aquatic organisms and the people using the water for other purpose. Similar results were recorded by Otokuneforand Obiukwu (2005);Alao*et al.*, (2010); Egwuonwu*et al.* (2012) and Dimowo (2013) among others.

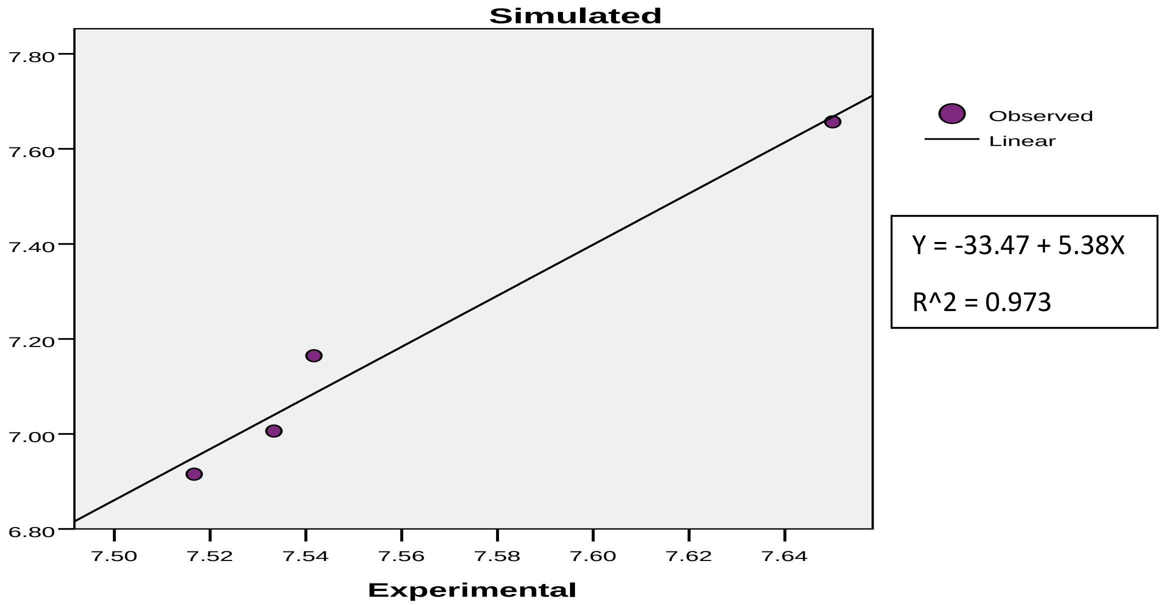


Figure 1: Mean pH for experiment and simulation at different sampling point

Table 4.4: Relationship between simulation and experimental mean pH

Model Summary and Parameter Estimates

Dependent Variable: Simulated

	Model Summary					Parameter Estimates	
Equation	R Square	F	df1	df2	Sig.	Constant	b1
Linear	.973	71.972	1	2	.014	-33.471	5.378

The independent variable is Experimental.

From the model summary above, the relationship between the mean simulated and experimental pH showed that the model at each sampling point have a strong relationship with results obtained from the experiment, with coefficient of determination R^2 value of 0.81.

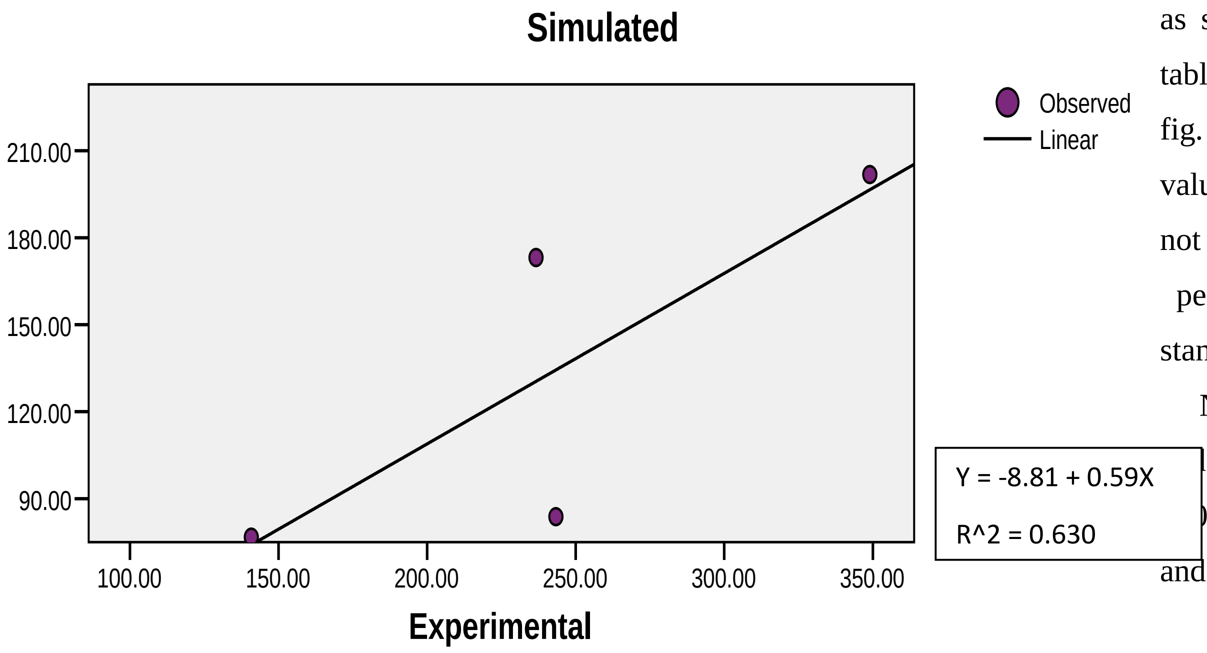
4.3 Description and analysis of BOD model for AjalliowaRiver

The model showed that BOD of the effluent is a reflection of the resultant effect of Temperature (*T*), Total Dissolved Solid (TDS), pH, Nitrogen (N), Chlorine (Cl), Chemical Oxygen Demand (COD), and Calcium (Ca). Observing the model equations, it can be noticed that some coefficients have positive signs while others have negative signs. The positive sign indicates direct proportionality between the parameters and the BOD, while the negative sign indicates inverse proportionality between them. In other words, an increase in any of the parameters having positive coefficient will lead to an increase in BOD, that is, there will be low DO available for aquatic lives to breathe. On the contrary, an increase in any of the parameters having negative coefficients will lead to decrease in the BOD.

Table 4.5: Mean BOD values

Sample	Experimental (mg/L)	Simulated (mg/L)
50m UPStr.	28.5	2.23167
Eff. Dis.	244.333	177.012
Dis. Pt.	243.333	83.7717
50m DStr.	236.667	173.162
100m DStr.	140.833	76.69
150m DStr.	349	201.79

In this study, the mean BOD values obtained, ranged from 28.5 mg/L – 349 mg/L for both experiment and simulation as shown in table 4.4 and fig. 3. This values do not meet the permissible standards of NESREA WHO of mg/L and 120 mg/L



respectively. Hence the BOD of the sampling points poses threat to the aquatic organisms and the people using the water for other purpose.Similar results were recorded by Otokuneforand Obiukwu (2005);Alao*et al.*, (2010); Egwuonwu*et al.* (2012) and Dimowo (2013) among others.

Figure 2: Mean BOD for experiment and simulation at different sampling point

Table 4.6: Relationship between simulation and experimental mean BOD

Model Summary and Parameter Estimates

Dependent Variable: Simulated

	Model Summary					Parameter Estimates	
Equation	R Square	F	df1	df2	Sig.	Constant	b1
Linear	.630	3.402	1	2	.206	-8.807	.588

The independent variable is Experimental.

From model summary above, the relationship between the mean simulated and experimental BOD showed that the model at each sampling point have a strong relationship with results gotten from the experiment, with coefficient of determination R^2 value of 0.80.

4.4 Description and analysis of COD model for AjalliowaRiver

The model showed that COD of the effluent is a reflection of the resultant effect of Temperature (*T*), Total Dissolved Solid (TDS), Biochemical Oxygen Demand (BOD), Chloride (Cl), pH, Nitrogen (N), and Calcium (Ca). Observing the model equations, it can be noticed that some coefficients have positive signs while others have negative signs. The positive sign indicates direct proportionality between the parameters and the COD, while the negative sign indicates inverse proportionality between them. In other words, an increase in any of the parameters having positive coefficient will lead to an increase in COD.On the contrary, an increase in any of the parameters having negative coefficients will lead to decrease in the COD.

Table 4.7: Mean COD Values

Sample	Experimental (mg/L)	Simulated (mg/L)
50m UPStr.	116.5	21.4167
Eff. Dis.	222.5	141.725
Dis. Pt.	232.5	44.9642
50m DStr.	323	186.515

100m DStr.	163.333	104.658
150m DStr.	329.333	197.803

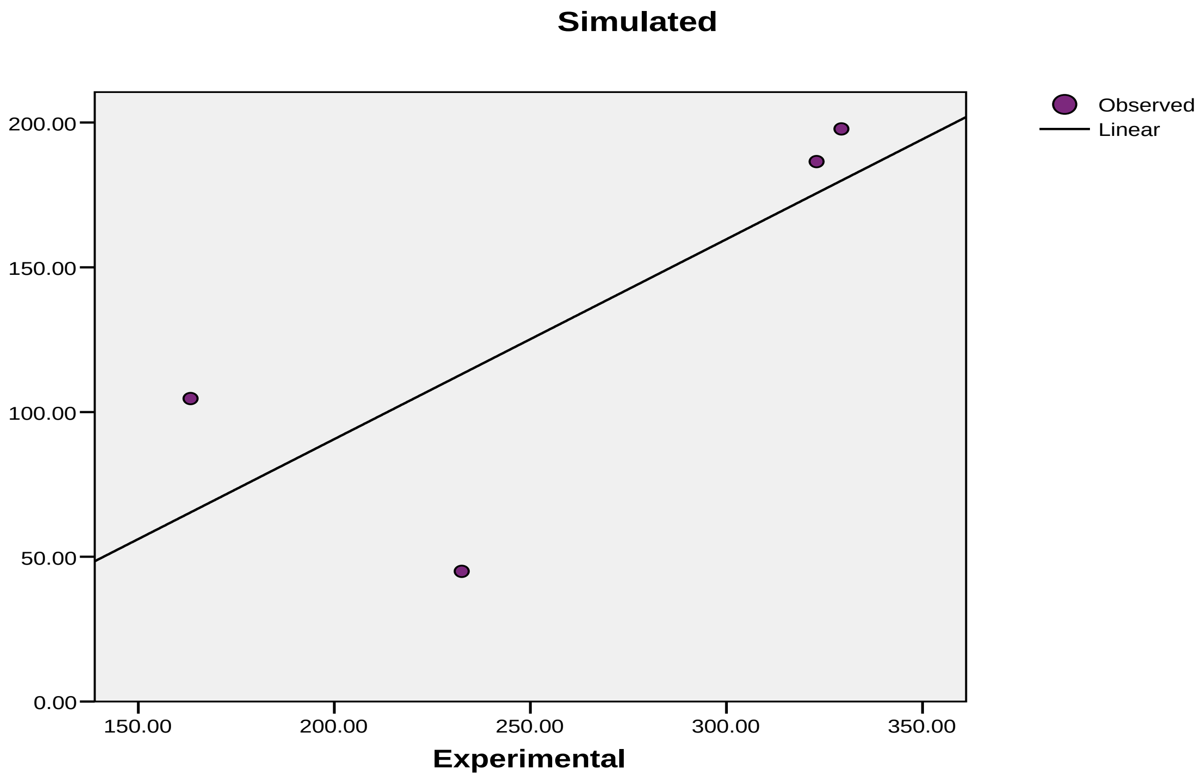
In this study, the mean COD values obtained, ranged from 116.5 mg/L – 329.333 mg/L for experiment and 21.4167 mg/L – 197.803 mg/L for simulation as shown in table 4.5. This could be due to detergents used for washing that constituted part of the brewery wastewater. However, the values are higher than the permissible limits of NESREA and WHO. Hence the COD of the sampling points poses threat to the aquatic organisms and the people using the water for other purpose. Similar results were recorded by Otokunefor and Obiukwu (2005) while evaluating the impact of refinery effluent on the physicochemical properties of a water body in the Niger Delta, Ekhaise and Anyasi (2005) on the influence of breweries effluent discharges on the microbiological and physicochemical quality of Ikpoba River Nigeria, Alao*et al.,* (2010) on the impact of brewery effluent on water quality in Majawe River, Ibadan, Southwestern Nigeria, Egwuonwu*et al.* (2012) on the effects of Nigeria Breweries PLC, Enugu industrial wastewater discharge on surface water, Olorode and Fagade (2012) on the effects of brewery effluent on the physical, chemical and microbiological characteristics of its receiving stream, and Dimowo (2013) on the comparison of physicochemical parameters of River Ogun with national and international standards.

Figure 3: Mean COD for experiment and simulation at different sampling point

Table 4.8: Relationship between simulation and experimental mean COD

Y = -47.43 + 0.69X

R^2 = 0.576



Model Summary and Parameter Estimates

Dependent Variable: Simulated

Equation	Model Summary					Parameter Estimates	
	R Square	F	df1	df2	Sig.	Constant	b1
Linear	.576	2.714	1	2	.241	-47.430	.690

The independent variable is Experimental.

However, from the model summary above as shown in table 4.8, the relationship between the mean simulated and experimental COD showed that the model at each sampling point have a weak relationship with results gotten from the experiment, with coefficient of determination R^2 value of 0.70.

4.5 Description and analysis of TDS model for AjalliowaRiver

The model showed that TDS of the effluent is a reflection of the resultant effect of Temperature (*T*), Biochemical Oxygen Demand (BOD), Chloride (Cl), Chemical Oxygen Demand (COD), Nitrogen (N), pH, and Calcium (Ca). Observing the model equations, it can be noticed that some coefficients have positive signs while others have negative signs. The positive sign indicates direct proportionality between the parameters and the TDS, while the negative sign indicates inverse proportionality between them. In other words, an increase in any of the parameters having positive coefficient will lead to an increase in TDS.On the contrary, an increase in any of the parameters having negative coefficients will lead to decrease in the TDS.

Table 4.9: Mean TDS values

Sample	Experimental (mg/L)	Simulated (mg/L)
50m UPStr.	65.7533	9.4492
Eff. Dis.	69.56	75.5667
Dis. Pt.	156.547	77.4423
50m DStr.	134.413	234.647
100m DStr.	92	53.595
150m DStr.	138	80.47

In this study, the mean TDS values obtained, ranged from 65.75 mg/L – 156.55 mg/L for experiment and 9.45 mg/L – 234.65 mg/L for simulation which falls within the permissible standards of NESREA. Hence the TDS of the sampling points poses no threat to the aquatic organisms and the people using the water for other purpose. Similar results were recorded by Otokunefor and Obiukwu (2005) while evaluating the impact of refinery effluent on the physicochemical properties of a water body in the Niger Delta, Ekhaise and Anyasi (2005) on the influence of breweries effluent discharges on the microbiological and physicochemical quality of Ikpoba River Nigeria, Alao*et al.*, (2010) on the impact of brewery effluent on water quality in Majawe River, Ibadan, Southwestern Nigeria, Egwuonwu*et al.* (2012) on the effects of Nigeria Breweries PLC, Enugu industrial wastewater discharge on surface water, Olorode and Fagade (2012) on the effects of brewery effluent on the physical, chemical and microbiological characteristics of its receiving stream, and Dimowo (2013) on the comparison of physicochemical parameters of River Ogun with national and international standards. As the level of TDS rises, the conductivity will also increase. Discharges to water could change the conductivity depending on the discharge type.

Figure 4: Mean TDS for experiment and simulation at different sampling point

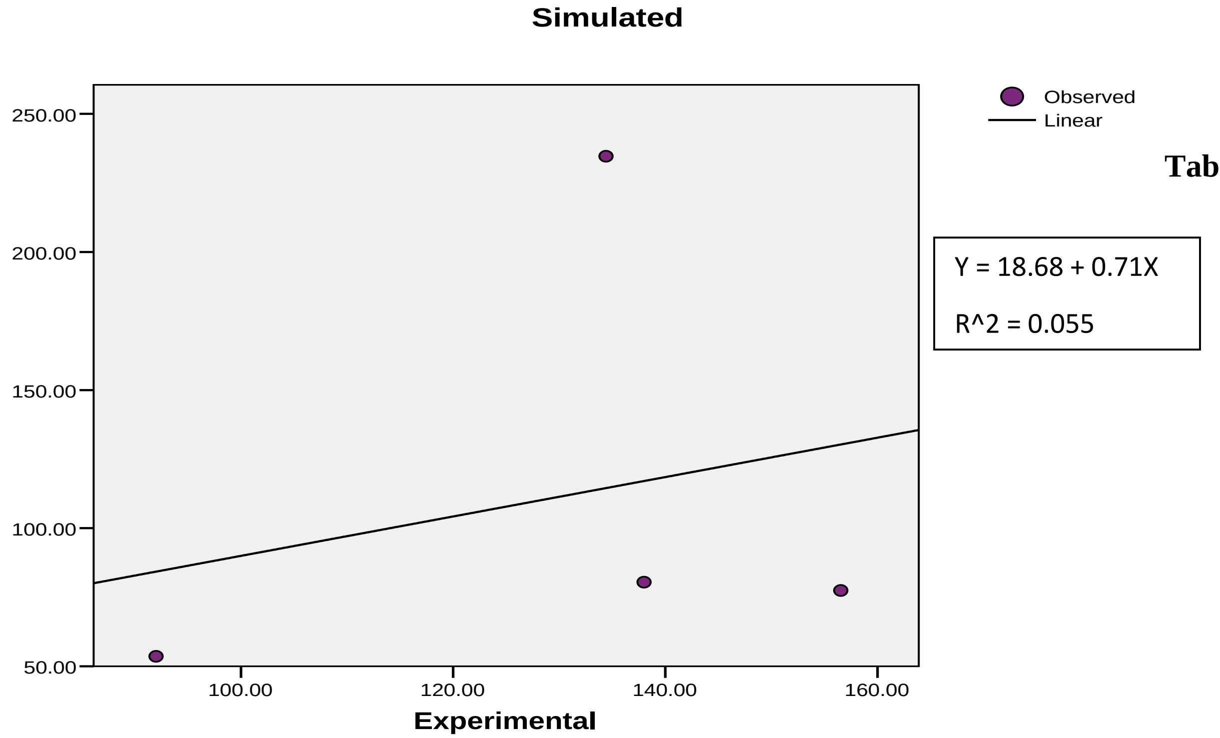


Table 4.10:

Relationship between simulation and experimental mean TDS

Model Summary and Parameter Estimates

Dependent Variable: Simulated

	Model Summary					Parameter Estimates	
Equation	R Square	F	df1	df2	Sig.	Constant	b1
Linear	.055	.116	1	2	.766	18.676	.713

The independent variable is Experimental.

Also, from table 4.10, the relationship between the simulated and experimental mean TDS showed that the model at each sampling point have a strong relationship with results gotten from the experiment, with coefficient of determination R^2 value of 0.26.

4.6 Description and analysis of Cl model for AjalliowaRiver

The model showed that Clof the effluent is a reflection of the resultant effect of Temperature (*T*), Total Dissolved Solid (TDS), Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Nitrogen (N), pH, and Calcium (Ca). Observing the model equations, it can be noticed that some coefficients have positive signs while others have negative signs. The positive sign indicates direct proportionality between the parameters and the Cl, while the negative sign indicates inverse proportionality between them. In other words, an increase in any of the parameters having positive coefficient will lead to an increase in Cl.On the contrary, an increase in any of the parameters having negative coefficients will lead to decrease in the Cl.

Table 4.11: Mean Chlorine values

Sample	Experimental (mg/L)	Simulated (mg/L)
50m UPStr.	12.9133	1.67081
Eff. Dis.	161.193	13.4744
Dis. Pt.	92.0067	48.3034
50m DStr.	61.7067	37.0635
100m DStr.	68.2283	113.591
150m DStr.	83.7283	48.8442

In this study, the mean Cl values obtained, ranged from 12.91 – 161.19 mg/L for experiment and 48.30 – 113.59 mg/L for simulation.

The chloride content is a good indicator of electrical conductivity of the wastewater since it depends on the dissolved chemical compounds present in water. The higher the chloride content, the higher the conductivity in the water samples. The measured chloride content also exceeded the NESREA limit for industrial wastewater discharge into receiving water bodies.

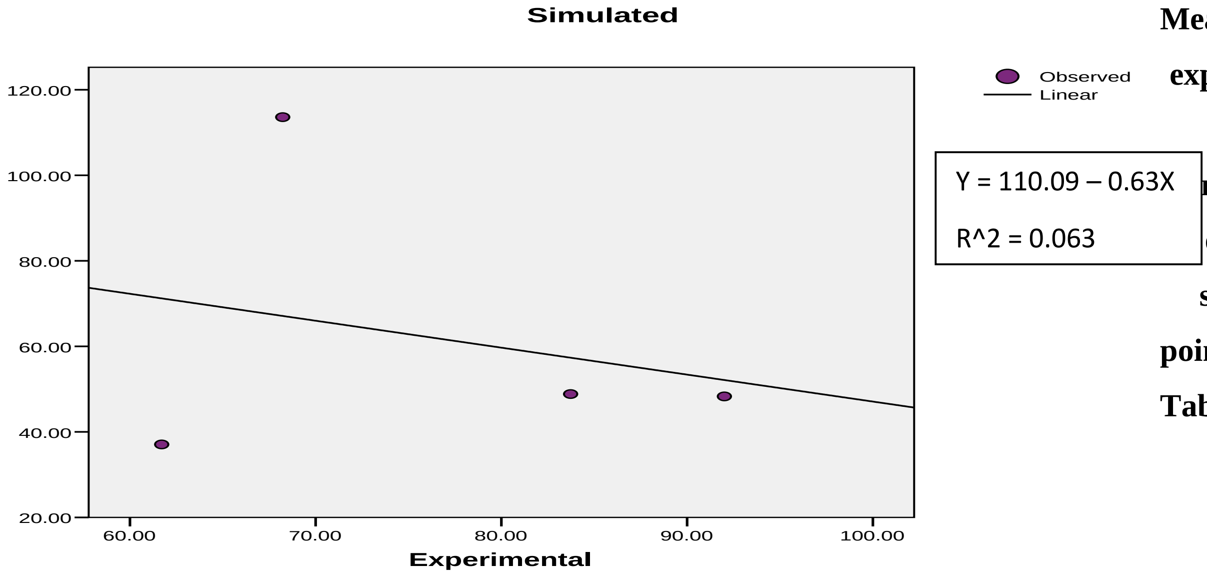


Figure 5: Mean Cl for experiment and mulation different sampling point

Table 4.12: Relationship between simulation and experimental mean Cl

Model Summary and Parameter Estimates

Dependent Variable: Simulated

Equation	Model Summary					Parameter Estimates	
	R Square	F	df1	df2	Sig.	Constant	b1
Linear	.063	.135	1	2	.749	110.092	-.630

The independent variable is Experimental.

Table 4.12 also showed that the relationship between the model of the simulated mean chlorine at each sampling point has a very weak relationship with results gotten from the experiment, with coefficient of determination R^2 value 0.001.

4.7 Description and analysis of Ca model for AjalliowaRiver

The model showed that Ca of the effluent is a reflection of the resultant effect of Temperature (*T*), Total Dissolved Solid (TDS), Biochemical Oxygen Demand (BOD), Chloride (Cl), Chemical Oxygen Demand (COD), Nitrogen (N), and pH. Observing the model equations, it can be noticed that some coefficients have positive signs while others have negative signs. The positive sign indicates direct proportionality between the parameters and the Ca, while the negative sign indicates inverse proportionality between them. In other words, an increase in any of the parameters having positive coefficient will lead to an increase in Ca. On the contrary, an increase in any of the parameters having negative coefficients will lead to decrease in the Ca.

Table 4.13: Mean Calcium values

Sample	Experimental (mg/L)	Simulated (mg/L)
50m UPStr.	21.6667	18.6067
Eff. Dis.	27.3333	16.8467
Dis. Pt.	53.3333	45.983
50m DStr.	40.1667	44.75
100m DStr.	41	24.0533
150m DStr.	46	182.952

In this study, the mean Ca values obtained, ranged from 21.67 – 53.33 mg/L for experiment and 24.05 – 182.95 mg/L for simulation as shown in table 4.13. The presence of calcium indicates hardness of water. Total hardness is defined as the sum of calcium and magnesium both expressed as CaCO3 in /l. People h kidney and bladder stones should avoid high content of calcium and magnesium in water. However, the result gotten from the experiment were still within permissible limits of NESREA and WHO.

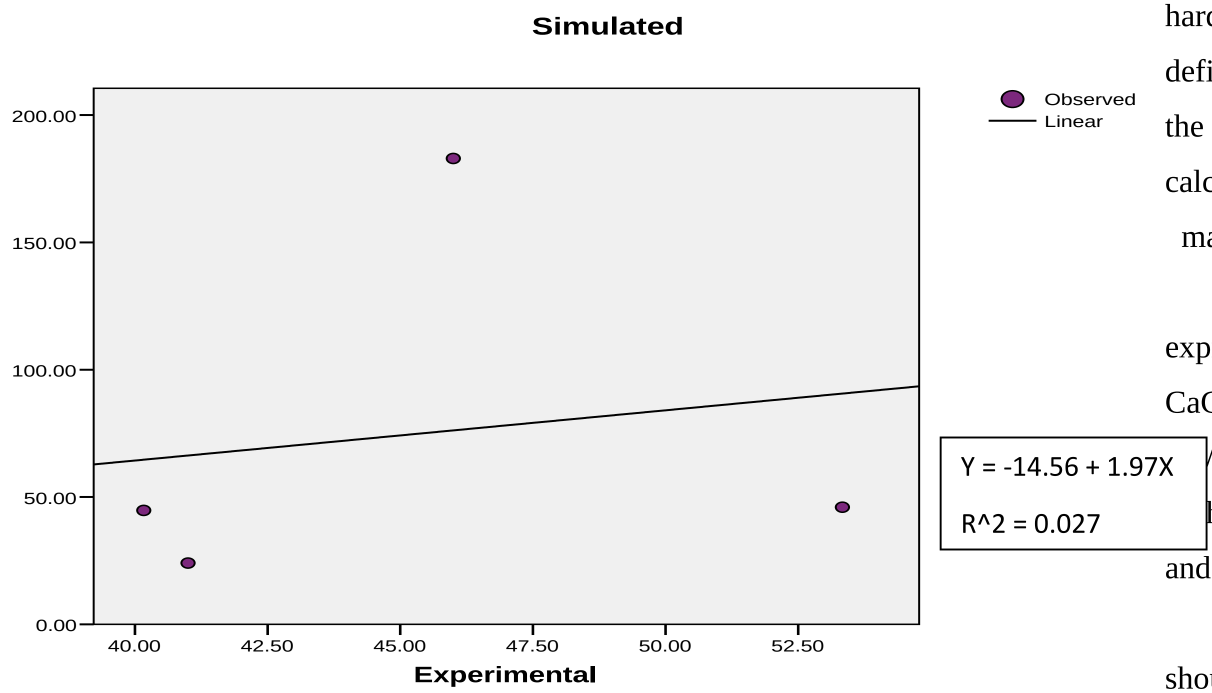


Figure 6: Mean Ca for experiment and simulation at different sampling point

Table 4.14: Relationship between simulation and experimental mean Ca

Model Summary and Parameter Estimates

Dependent Variable: Simulated

Equation	Model Summary					Parameter Estimates	
	R Square	F	df1	df2	Sig.	Constant	b1
Linear	.027	.055	1	2	.837	-14.556	1.972

The independent variable is Experimental.

Table 4.14 also showed that the relationship between the model of the simulated mean calcium at each sampling point has a weak relationship with results gotten from the experiment, with coefficient of determination R^2 value 0.22.

4.8 Description and analysis of T model for AjalliowaRiver

The model showed that T of the effluent is a reflection of the resultant effect of Total Dissolved Solid (TDS), Biochemical Oxygen Demand (BOD), Chloride (Cl), Chemical Oxygen Demand (COD), Nitrogen (N), pH, and Calcium (Ca). Observing the model equations, it can be noticed that some coefficients have positive signs while others have negative signs. The positive sign indicates direct proportionality between the parameters and the T, while the negative sign indicates inverse proportionality between them. In other words, an increase in any of the parameters having positive coefficient will lead to an increase in T. On the contrary, an increase in any of the parameters having negative coefficients will lead to decrease in the T.

Table 4.15: Mean Temp.values

Sample	Experimental (^{0}C)	Simulated (^{0}C)
50m UPStr.	32.0533	6.14608
Eff. Dis.	28.6117	33.465
Dis. Pt.	26.5883	29.4658
50m DStr.	28.235	35.3087
100m DStr.	21.795	18.1932
150m DStr.	26.51	20.823

All the mean temperature values obtained in the study did not meet NESREA (2009) standards for effluent discharges to surface water and WHO guideline values (12 – 25^{0}C). High temperatures recorded could contribute to oxygen depletion in 2 ways. First, relatively small increase in temperature kills certain species of fish and increases the rate of decay. In addition to this, high temperatures raise the metabolic rate of surviving fish, leading to increase in oxygen consumption which will invariably lead to oxygen depletion (Sharda *et al.*, 2013)

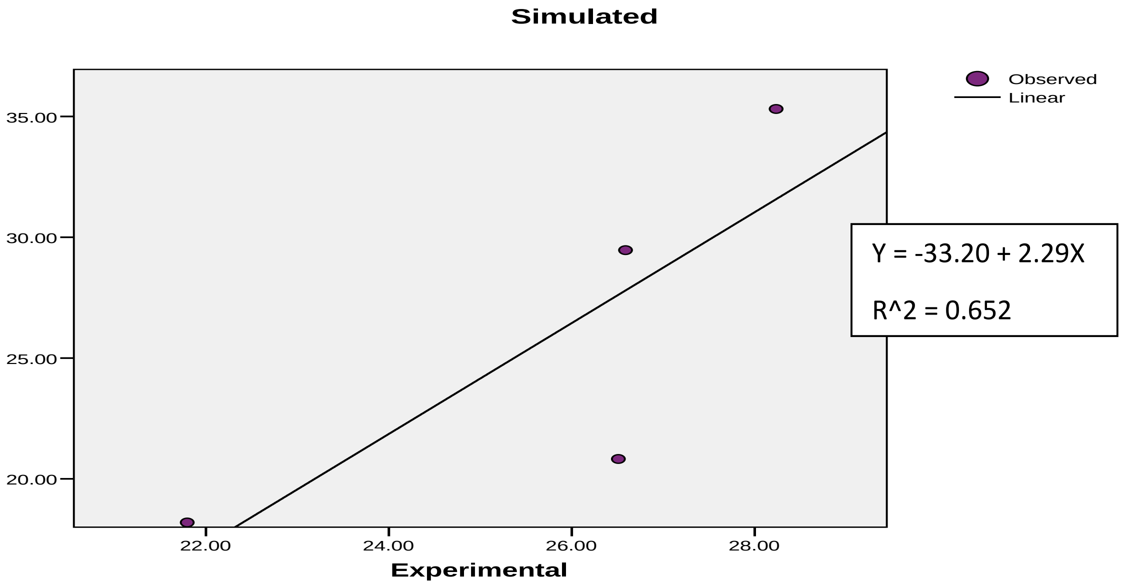


Figure 7: Mean Temp.for experiment and simulation at different sampling point

Table4.16: Relationship between simulation and experimental mean Temp.

Model Summary and Parameter Estimates

Dependent Variable: Simulated

Equation	Model Summary					Parameter Estimates	
	R Square	F	df1	df2	Sig.	Constant	b1
Linear	.652	3.750	1	2	.192	-33.207	2.294

The independent variable is Experimental.

Also, from table 4.16, the relationship between the mean simulated and experimental mean temperatures showed that the model at each sampling point have a very weak relationship with results gotten from the experiment, with coefficient of determination R^2 value of 0.028.

4.9 Description and analysis of N model for AjalliowaRiver

The model showed that N of the effluent is a reflection of the resultant effect of Temperature (*T*), Biochemical Oxygen Demand (BOD), Chloride (Cl), Chemical Oxygen Demand (COD), Total dissolve solids (TDS), pH, and Calcium (Ca). Observing the model equations, it can be noticed that some coefficients have positive signs while others have negative signs. The positive sign indicates direct proportionality between the parameters and the N, while the negative sign indicates inverse proportionality between them. In other words, an increase in any of the parameters having positive coefficient will lead to an increase in N. On the contrary, an increase in any of the parameters having negative coefficients will lead to decrease in the N.

Table 4.17: Mean Nitrogen values

Sample	Experimental (mg/L)	Simulated (mg/L)
50m UPStr.	0.13833	0.10225
Eff. Dis.	0.02833	0.03933
Dis. Pt.	0.11167	0.15417
50m DStr.	0.11333	0.03383
100m DStr.	0.11333	0.171
150m DStr.	0.11667	0.12675

In this study, the mean nitrogen values obtained, ranged from 0.03 mg/L – 0.15 mg/L for both experiment and simulation as shown in table 4.17. The presence of nitrogen is probably due to the use of preservatives containing nitrogenous compound and presence of organic pollutants rich in nitrogen content in the effluent.

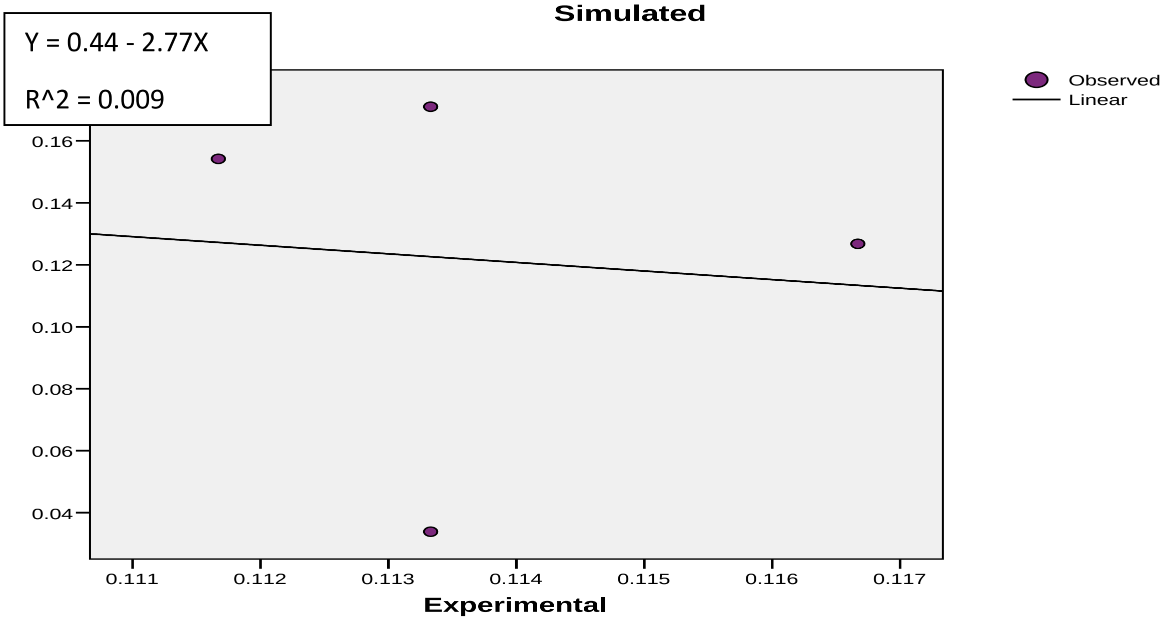
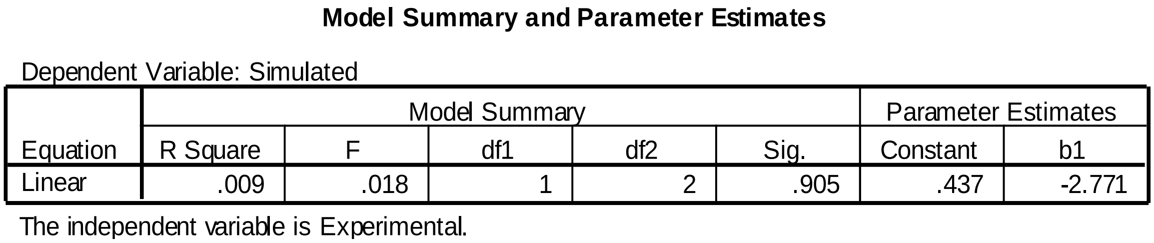


Figure 8: Mean Nitrogen for experiment and simulation at different sampling point

Table 4.18: Relationship between simulation and experimental mean Nitrogen



Model Summary and Parameter Estimates

Dependent Variable: Simulated

	Model Summary					Parameter Estimates	
Equation	R Square	F	df1	df2	Sig.	Constant	b1
Linear	.009	.018	1	2	.905	.437	-2.771

The independent variable is Experimental.

Table 4.18 shows that the relationship between the model of the simulated mean nitrogen at each sampling point has a very strong relationship with results gotten from the experiment, with coefficient of determination R^2 value 0.5.

CHAPTER FIVE

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion:

Modeling of brewery effluent on Ajalliowa River was undertaken. The model equations have high correlation coefficients for most of the considered physico-chemical characteristics of the river at all the sampling points; 50m upstream, brewery effluent, point of discharge, 50m downstream, 100m downstream and 150m downstream, respectively. It can be seen that the empirical equations developed are in agreement and perfectly correlated with the experimental results. This is because the correlation coefficients tend toward unity. It can be concluded that the model equations developed using the empirical method of the least squares can be used to investigate the effect of effluent from brewery effluent on the quality of Ajalliowariver. It can be concluded that the Ajalliowariver in the vicinity of Enugu city is under pollution stress, mainly from effluent from industries. The downstream analyses, away from the disposal site, indicated improvement in water quality, with respect to chemical but not microbiological parameters. It is of interest to note the increased level of indicators of pollution compared closely well to the international permissible limits. In addition, fluctuations are dynamic and exist not only among seasons but between years. In addition, chemicals and bio-treatments should be imposed prior to disposal of effluents into the river.

5.2 Contribution to Knowledge

The following contributions to knowledge are hereby given from this study:

i.) The prediction models for ascertaining the level of contamination of Ajalliowariver were provided.

ii.) The study provided an approach to modelling the brewery effluent on the studied river.

iii.) The extent of pollution by brewery effluent was studied.

iv.) Using the Simulated values, the prediction of pollution on Ajalliowa River can be made in future.

5.3 Recommendations:

The following recommendations are considered for further studies:

i.) Modeling of the impact of the brewery effluents on surface water in major rivers in Abia, Anambra and Edo states as well as assessing the extent of pollution by the effluents.

ii.) Studies of the impact of brewery effluent on surface and ground water of rivers in the above-mentioned states for different seasons in Nigeria are of considerable interest.

iii.) Breweries in other places such as Lagos and Port Harcourt should be studied and then compared.

iv.) Also, alternative methods of modeling such as factorial design method of modeling should be used as well.

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APPENDIX

Table 4.1: Experimental results at the distance of 50m upstream

	Sample	pH	Temp	TDS	BOD	N	Cl	COD	Ca
	1	6	29.11	57.76	20	0.09	10.49	100	17
	2	6.8	34.84	76.36	38	0.19	14.99	129	28
	3	6.6	33.45	70.68	33	0.16	14.01	125	26
	4	6.4	32.94	66.96	30	0.15	13.49	120	22
	5	6.2	31.48	62.64	27	0.13	12.99	115	19
	6	6.1	30.5	60.12	23	0.11	11.51	110	18
MEAN		6.35	32.053	65.753	28.5	0.1383	12.913	116.5	21.667

Table 4.2: Simulated results at the distance of 50m upstream

	Sample	pH	Temp	TDS	BOD	N	Cl	COD	Ca
	1	6	4.3665	5.776	0.8	0.0414	0.9441	3	1.02
	2	6.77	8.71	12.981	4.18	0.1577	2.6982	64.5	50.4
	3	6.51	6.69	11.309	2.97	0.1296	2.1015	25	31.2
	4	6.48	6.2586	10.044	2.4	0.114	1.8886	16.8	19.8
	5	6.39	5.6664	8.7696	1.89	0.0949	1.299	11.5	7.6
	6	6.28	5.185	7.8156	1.15	0.0759	1.09345	7.7	1.62
MEAN		6.405	6.1461	9.4492	2.2317	0.1023	1.6708	21.417	18.607

Table 4.3: Experimental results of the brewery effluent.

	Sample	pH	Temp	TDS	BOD	N	Cl	COD	Ca
	1	7.8	26.07	67.76	240	0.01	154.95	210	22
	2	8.8	29.98	71.64	250	0.05	165.45	235	33
	3	8.6	29.54	70.64	247	0.04	164.95	230	31
	4	8.4	29.01	69.52	245	0.03	162.95	225	28
	5	8.2	28.82	69.76	243	0.02	160.91	220	26
	6	8	28.25	68.04	241	0.02	157.95	215	24
MEAN		8.3	28.612	69.56	244.33	0.0283	161.19	222.5	27.333

Table 4.4: Simulated results of the brewery effluent

	Sample	pH	Temp	TDS	BOD	N	Cl	COD	Ca
	1	7.02	26.07	33.88	45.466	0.012	7.7475	96.6	5.94
	2	8.448	35.976	85.968	208.6	0.07	14.8905	157.45	22.11
	3	8.256	35.448	84.768	205.7	0.056	14.8455	154.1	20.77
	4	8.064	34.812	83.424	203.29	0.042	14.6655	150.75	18.76
	5	7.872	34.584	83.712	201.43	0.028	14.4819	147.4	17.42
	6	7.68	33.9	81.648	197.59	0.028	14.2155	144.05	16.08
MEAN		7.89	33.465	75.567	177.01	0.0393	13.474	141.73	16.847

Table 4.5: Experimental result at the point of discharge

	Sample	pH	Temp	TDS	BOD	N	Cl	COD	Ca
	1	7.4	22.54	140.56	237	0.07	84.97	208	50
	2	7.9	29.1	167.52	251	0.15	97.97	248	57
	3	7.8	28.96	163.88	248	0.13	95.97	243	55
	4	7.7	27.87	160.92	244	0.12	93.64	239	54
	5	7.6	26.49	158.64	241	0.11	90.52	231	53
	6	7.5	24.57	147.76	239	0.09	88.97	226	51
MEAN		7.65	26.588	156.55	243.33	0.1117	92.007	232.5	53.333

Table 4.6: Simulated result at the point of discharge

	Sample	pH	Temp	TDS	BOD	N	Cl	COD	Ca
	1	7.6	20.286	35.14	28.44	0.07	27.1904	8.6336	15
	2	7.74	37.83	113.9136	163.15	0.27	89.1527	66.4388	91.1121
	3	7.7	31.856	81.94	79.36	0.169	45.1059	47.7229	44.1462
	4	7.65	30.657	80.46	78.08	0.156	44.0108	48.2918	43.0744
	5	7.63	29.139	79.32	77.12	0.143	42.5444	50.6044	41.6392
	6	7.62	27.027	73.88	76.48	0.117	41.8159	48.0939	40.9262
MEAN		7.6567	29.466	77.442	83.772	0.1542	48.303	44.964	45.983

Table 4.7: Experimental result at the 50m downstream

	Sample	pH	Temp	TDS	BOD	N	Cl	COD	Ca
	1	7.2	27.53	130.36	227	0.08	50.2	246	21
	2	7.9	28.95	139.16	246	0.15	71.98	399	55
	3	7.75	28.56	136.76	242	0.13	67.51	359	51
	4	7.55	28.37	135.52	239	0.12	63.95	338	45
	5	7.45	28.11	133.56	236	0.11	60.62	308	39
	6	7.4	27.89	131.12	230	0.09	55.98	288	30
MEAN		7.5417	28.235	134.41	236.67	0.1133	61.707	323	40.167

Table 4.8: Simulated result at the 50m downstream

	Sample	pH	Temp	TDS	BOD	N	Cl	COD	Ca
	1	6.84	24.2264	21.1316	72.64	0.008	6.526	83.64	21
	2	7.505	52.11	346.705	199.26	0.06	71.98	363.09	99
	3	7.3625	34.272	270.6957	196.02	0.039	39.1558	186.68	45.9
	4	7.1725	34.044	264.8515	193.59	0.036	37.091	175.76	40.5
	5	7.0775	33.732	254.3729	191.16	0.033	35.1596	160.16	35.1
	6	7.03	33.468	250.1266	186.3	0.027	32.4684	149.76	27
MEAN		7.1646	35.309	234.65	173.16	0.0338	37.063	186.52	44.75

Table 4.9: Experimental result at the 100m downstream

	Sample	pH	Temp	TDS	BOD	N	Cl	COD	Ca
	1	6.7	16.42	75	81	0.07	50.52	121	25
	2	7.9	29.79	115	200	0.17	84.21	192	55
	3	7.8	25.37	100	178	0.14	81.34	185	50
	4	7.7	21.95	94	153	0.12	75.18	179	43
	5	7.6	19.28	89	128	0.1	62.37	158	39
	6	7.5	17.96	79	105	0.08	55.75	145	34
MEAN		7.5333	21.795	92	140.83	0.1133	68.228	163.33	41

Table 4.10: Simulated result at the 100m downstream

	Sample	pH	Temp	TDS	BOD	N	Cl	COD	Ca
	1	6.231	5.2544	16.5	21.06	0.077	14.8436	12.1	6.25
	2	7.347	29.4921	102.35	174	0.289	177.8881	168.96	43.45
	3	7.254	22.3256	56	83.66	0.21	165.2484	123.95	28.5
	4	7.161	19.316	52.64	71.91	0.18	112.835	119.93	24.51
	5	7.068	16.9664	49.84	60.16	0.15	108.0216	105.86	22.23
	6	6.975	15.8048	44.24	49.35	0.12	102.7102	97.15	19.38
MEAN		7.006	18.193	53.595	76.69	0.171	113.59	104.66	24.053

Table 4.11: Experimental result at the 150m downstream

	Sample	pH	Temp	TDS	BOD	N	Cl	COD	Ca
	1	7	19.31	120	324	0.07	72.45	300	39
	2	8	32.43	156	372	0.18	96.51	352	55
	3	7.8	30.58	150	367	0.15	89.23	347	51
	4	7.6	28.42	145	350	0.12	84.62	335	47
	5	7.4	25.89	130	346	0.1	80.65	328	43
	6	7.3	22.43	127	335	0.08	78.91	314	41
MEAN		7.5167	26.51	138	349	0.1167	83.728	329.33	46

Table 4.12: Simulated result at the 150m downstream

	Sample	pH	Temp	TDS	BOD	N	Cl	COD	Ca
	1	6.44	11.3929	42	81	0.063	16.6635	135	156.07
	2	7.36	29.8356	135.72	331.08	0.27	84.9288	316.8	207.9
	3	7.176	23.8524	84	227.54	0.1425	59.7841	194.32	196.3
	4	6.992	22.1676	79.75	217	0.114	56.6954	187.6	193.68
	5	6.808	20.1942	71.5	179.92	0.095	37.9055	180.4	174.06
	6	6.716	17.4954	69.85	174.2	0.076	37.0877	172.7	169.7
MEAN		6.9153	20.823	80.47	201.79	0.1268	48.844	197.8	182.95