LIQUID WASTE CHARACTERIZATION AND SUSTAINABILITY ASSESSMENT OF A BREWERY FACILITY

IN ONITSHA ANAMBRA STATE, NIGERIA.

BY

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A PROJECT SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENT FOR THE AWARD OF

BACHELOR ENGINEERING (B.Eng.) DEGREE.

IN

THE DEPARTMENT OF CIVIL ENGINEERING

FACULTY OF ENGINEERING,

UNIVERSITY OF BENIN, BENIN CITY, NIGERIA

NOVEMBER, 2025.

PLAGARISM

This work **LIQUID WASTE CHARACTERIZATION AND SUSTAINABILITY ASSESSMENT OF A BREWERY FACILITY** by Utomi, Michael Chukwuka with Matriculation Number ENG2006217 of the Department of Civil Engineering, University of Benin City, Edo State. Nigeria, has PASSED the PLAGIARISM TEST.

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DEDICATION

I dedicate this endeavor primarily to God, who has been my unwavering support throughout my academic journey. A heartfelt tribute to my beloved parents, Mr. and Mrs. Utomi, whose guidance, love, care and financial support have been instrumental in shaping my path. Gratitude extends to my siblings who stood by me in challenging moments. My prayer is that the benevolent forces above continue to safeguard, guide and bestow blessings upon them, Amen.

ACKNOWLEDGEMENT

Firstly, I want to express my heartfelt gratitude to God Almighty for His grace and support throughout my studies and this research journey. I sincerely appreciate everyone who contributed to the successful completion of this project. A special thank you goes to my project supervisor, Engr. Dr. U. Ukeme, whose invaluable guidance, insightful suggestions, and thorough proofreading helped refine my work and ensured the project's success.

I also wish to acknowledge the vital role of the staff in the Department of Civil Engineering, who have consistently gone above and beyond to impart knowledge and foster good conduct, both in and out of the academic environment. I extend my gratitude to the Head of Department, Engr. Prof. (Mrs.) Ngozi Ihimekpen, as well as Prof. O.C. Izinyon, Prof. O.U. Orie, Prof. H.A.P. Audu, Prof. S.O. Osuji, Prof. S.D. Iyeke, Dr. Agbonaye Dr. R.I. Umasabor, Dr (Mrs) K.O.Ngozi, Dr. R.O. Ogirigbo, Dr. R.I. Ilaboya, Dr. (Mrs.) L.O. Bobor, Dr. (Mrs.) A. Rawlings, Engr. Dr. E.S. Okonofua, Engr. Dr U. Ukeme, Engr. Dr (Mrs) Lulu,Engr. E. Oria Usifo, Engr. C.M. Okolie, Engr.Dr P. Ogbeifun, Engr. Dr. S.A. Adegbemileke, Engr. Nosakhare Kent,Engr (Mrs) Agabi Engr. O. Osasu, Engr. B. Omosefe, Engr. O. Oriakhi, Engr.O Janet, Engr.(Mrs) Gloria, and the all the laboratory staff and cleaners.

I express deep appreciation to my parents and siblings, whose immense contributions have been pivotal to my academic journey. To friends who became brothers: Jeremiah, Osemeke, Ugochukwu, Ekenem and my fans from day one, it was never just the journey, it was your company. In case I don’t see you, good afternoon, good evening and goodnight.

ABSTRACT

This project examined the environmental and health hazards from the disposal of liquid waste generated by industries, particularly those involved in beverage production in Nigeria. Increased urbanization and rapid industrialization have occasioned increased volumes of effluent being discharged, usually without proper treatment, into River Niger and other water bodies. This results in various forms of pollution, contaminating the organic and inorganic content, ultimately causing about 25% of all preventable diseases, including waterborne diseases. This research work aimed to study and upgrade the liquid waste disposal methods at the International Breweries Limited Onitsha, Anambra State. Specific objectives included establishing the physical, chemical, and biological characteristics of the effluent and also appraising the sustainability and efficiency of the existing effluent treatment and disposal processes with respect to compliance with WHO standards.

The methodology used in this research involves a case study approach at the brewery plant. Effluent samples were collected from pre-treatment and post-treatment points during the month of August, at morning periods to capture peak production waste. Each sample size was 2 liters, preserved at 4°C, and conveyed to the laboratory within 4 hours. Physical parameters such as pH, temperature, turbidity, total suspended solids, and color were analyzed using calibrated instruments like pH meters and spectrophotometers. Chemical parameters for biochemical oxygen demand, chemical oxygen demand, heavy metals, and nutrients were analyzed by digestion followed by atomic absorption spectrophotometry. Biological parameters-total heterotrophic bacteria, coliform counts, and E. coli-were determined by membrane filtration and incubation on selective media. Data analysis involved the use of descriptive statistics and comparison with WHO benchmarks. These results portrayed partial efficacy of the treatment. Physical parameters were improved, with turbidity falling from 1.0 NTU to 0.5 NTU; however, pH and total dissolved solids were still above WHO limits at 5.0 and 2829 mg/L, respectively. The chemical parameters were reduced-for instance, COD was reduced from 80.1 mg/L to 56.3 mg/L-but remained high, as were heavy metals (e.g., lead, 0.74 mg/L> 0.01 mg/L) and nutrients (ammonia, 8.74 mg/L> 0.5 mg/L); thus, offering a high risk for eutrophication and toxicity. Biological parameters were fully met, as coliform and E. coli counts were nil after treatment.

The study concluded that the brewery's treatment system was inefficient to achieve full compliance, with the need to invest in effective treatment technologies such as reverse osmosis and nutrient removal. Individuals should advocate for clean water practices, corporate organizations should invest in advanced treatment technologies, and government agencies should establish stricter monitoring and incentives for sustainable waste management.

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ACRONYMS

APHA: American Public Health Association

BNR: Biological Nutrient Removal

BOD: Biochemical Oxygen Demand

COD: Chemical Oxygen Demand

Ca: Calcium

Cd: Cadmium

Cl: Chloride

Col: Colour (in Platinum-Cobalt units, Pt.Co)

Cr: Chromium

Cu: Copper

EC: Electrical Conductivity

Fe: Iron

HCO3: Bicarbonate

K: Potassium

MPN: Most Probable Number

Mg: Magnesium

Mn: Manganese

ND: Not Detected

NESREA: National Environmental Standards and Regulations Enforcement Agency

NH4N: Ammonium Nitrogen

NO2: Nitrite

NO3: Nitrate

NTU: Nephelometric Turbidity Units

Na: Sodium

Ni: Nickel

P: Phosphorus

Pb: Lead

Pt.Co: Platinum-Cobalt Units

RO: Reverse Osmosis

SDGs: Sustainable Development Goals

SO4: Sulfate

Sal: Salinity

TDS: Total Dissolved Solids

THC: Total Hydrocarbon Content

TSS: Total Suspended Solids

UV: Ultraviolet

V: Vanadium

WHO: World Health Organization

WSPs: Water Safety Plans

XLD: Xylose Lysine Deoxycholate

Zn: Zinc

CHAPTER ONE

INTRODUCTION

1.1 Background of the Study

Waste creation has been a natural phenomenon in human activity since the earliest hunting and gathering periods (Insaidoo, 2008). Waste in those early days was mostly organic and comprised food wastes and vegetable matter and animal excreta, and its limited quantities were consumed by the environment due to low population levels and minimal industrial processes. However, the current age, marked by rapid population growth, urbanization, and industrial development, has altered this process, particularly in developing countries like Nigeria. The increase in human activities has produced a wide range and abundant waste products, such as liquid waste from industry, which are serious environmental and health issues unless they are properly managed.

Waste can be broadly defined as any material or product that is no longer needed by its creator (Woodward, 2001). It is usually categorized under domestic, commercial, municipal, industrial, and agricultural wastes. Domestic and municipal wastes are typically treated by local government authorities, and agricultural wastes are normally recycled as compost. Industrial wastes present unique challenges due to their complicated composition, comprising both organic and inorganic matter. The nature of the industrial waste further depends on the industry, if it is an industry of beer production, iron production, or textile processing and is dependent upon the technological prowess and the governing laws of the nation where the industry is operating. In Nigeria, the soft drink manufacturing industry, courtesy of the International Breweries Limited in Onitsha, generates high volumes of liquid waste that require proper disposal to prevent environmental pollution, particularly to very important water bodies like the River Niger.

Handling industrial waste was an international issue during the eighteenth and nineteenth-century Industrial Revolution (Huzeima, 2014). This period saw the spectacular growth of factories, with workers living in close proximity to industrial zones, leading to unprecedented sanitation issues in the cities. Cities like London saw clogged drains, leaking sewage, and extremely polluted water bodies, with the Thames River being utilized as a dumping ground for untreated industrial effluents (Stanbury, 1995). This environmental degradation led to serious public health issues, including the transmission of cholera, typhus, and influenza epidemics. In reaction, Edwin Chadwick contended in 1839 that proper waste management was cheaper than the treatment of the resulting illnesses, prompting the House of Lords to tackle London's sanitation problem (Haight, 1999). This sets the background for realizing the long history of needing strong waste management measures, a fact very pertinent to contemporary industrial centers such as Onitsha.

In Onitsha, a business city in Anambra State, Nigeria, with a population of more than 1.5 million (PopulationStat, 2025), industrial liquid waste management is a pertinent issue. Strategically located on the banks of the River Niger, Onitsha is an industrial and commercial hub, thus forming an essential case study to understanding the nexus between industrial pursuits and environmental sustainability. The International Breweries Limited, one of the biggest beverage bottling factories in the city, generates huge volumes of liquid waste as a result of its production. The waste, if not controlled, poses a direct danger to the River Niger, which is a vital source of potable water, fishing, and irrigation for people in the region. The environmental and health impacts of such pollution are of great concern, necessitating a particular study to investigate and improve the waste management process in the International Breweries Limited.

1.2 Statement of the Problem

Poor environmental conditions, particularly those that result from ineffective waste management, have a direct and indirect impact on human health, responsible for approximately 25% of avoidable diseases worldwide (Insaidoo, 2008). Water-borne illnesses such as diarrhea and respiratory diseases are the most prevalent, having a significant effect on public health systems, especially in developing countries such as Nigeria. Nigeria, whose daily waste generation rate is an average of 0.45 kg per person, produces around 4 million tonnes of domestic waste annually (Insaidoo, 2008). While municipal waste management is a state concern, with proper disposal of merely about 20% (Boadi and Kuitunen, 2003), industrial wastes are left to the industries to manage. However, most industries, profit-making in nature, seek to produce maximally at the cost of environmental and public health issues, leading to inferior waste management practices.

In Onitsha, the International Breweries Limited is also a principal producer of industrial liquid waste, generating large amounts of effluent daily in its beverage production processes. This effluent includes organic and inorganic contaminants such as cleaning agent residues, sugar, and reverse osmosis reject water, which is typically discharged into the River Niger after negligible treatment. The World Health Organization (WHO), which is the regulating body charged with regulating discharge of effluent, has implemented stringent standards to protect aquatic organisms and human health. Some of these standards involve limits on Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), pH, and other characteristics to ensure that discharged effluent will not decrease oxygen levels in water bodies or introduce toxic substances (Amoah and Kosoe, 2014). Initial findings suggest that the current methods of disposal within the International

Breweries Limited are probably not completely compatible with such WHO standards, which can lead to oxygen deficiency in the River Niger and become harmful to aquatic organisms. Such a situation also risks the health of downstream communities that utilize the river for household and agricultural purposes, increasing their susceptibility to waterborne disease. This study aims to investigate such practices and provide environmentally friendly solutions that ensure WHO standards and regional environmental sustainability.

1.3 Aim and Objectives

The aim of this study is to investigate and improve the industrial liquid waste disposal practices of the Onitsha International Breweries factory with the aim of ensuring environmental sustainability and WHO standards. To achieve this aim, the study adopts the following specific objectives:

1. To determine physical properties of liquid waste produced by the International Breweries Limited.
2. To determine chemical properties of liquid waste produced by the International Breweries Limited.
3. To determine biological properties of liquid waste produced by the International Breweries Limited.
4. To assess sustainability and efficiency of existing liquid waste disposal processes by the company.

1.4 Scope of Study

This study is geographically limited to Onitsha, Anambra State, Nigeria, a rapidly developing commercial center with over 1.5 million population (PopulationStat, 2025). That Onitsha has its location along the River Niger makes it a site of study of the impact of industrial wastes on water resources. Contextually, the study has its focus on International Breweries Limited that is one of the leading industries within the local beverage sector. The research will entail sampling of the effluent for one month, carrying out a survey of the waste management culture of the company, factory personnel, and the public at large in general in an attempt to gain a proper understanding of the stakes involved.

1.5 Justification of Study

Industrial liquid waste management is crucial to the environment and human existence, particularly in an area like Onitsha, where the River Niger is the source of livelihood for millions of people. The WHO's SDGs Target 6 has embarked on providing access to clean water and sanitation to all human beings by the year 2030, with special emphasis on water bodies being free from industrial pollution. Waste management in total is the responsibility of the Nigerian Ministry of the Environment, and WHO provides standards for regulatory effluent discharge of grades to provide for protection of the environment and the public (Environmental Sanitation Policy of Nigeria, 1999).

The Niger River is polluted with raw or inadequately treated industrial effluent that is harmful to freshwater aquatic biodiversity and connected fishery stocks, which form a major protein source for the local people. The river is also harmful to the livelihood of the farmers and fishermen who make their livelihood out of agriculture dependent on the river for irrigation. According to WHO reports, exposure to water pollution is a major cause of waterborne illness in Nigeria, with riverine communities in Onitsha being the most affected. The study coincides with Nigeria's Environmental Sanitation Policy whose goal is to provide an environment that is clean, safe, and acceptable for the maintenance of social, economic, and physical well-being of the people. Second, the work of this study may be in the area of a good policy report for policymakers, industry players, and future researchers who would be interested in studying sustainable practice in waste management for Nigeria's industrialization. In preventing such a problem, the study is part of the greater vision of providing environmental sustainability in Onitsha and adding Nigeria's input towards achieving global development goals.

CHAPTER TWO

LITERATURE REVIEW

Theoretical Framework

2.1 Definition of Industrial Liquid Waste

Waste is any substance which on initial use is worthless or discarded, defective and useless. Liquid waste, conversely, is any waste product which in form is liquid. Individually, industrial liquid waste, also referred to as effluent, is wastewater produced from an industrial process and comprises a mixture of impurities characteristic to the industry. It encompasses water used in manufacturing, cleaning, cooling, or any other process that gets contaminated with organic, inorganic, or biological substances (Ranade and Bhandari, 2014). Lagos state Environmental Sanitation Edict, 1985 has categorized waste to encompass:

a. Waste of all types.
b. Any substance which is waste material or an effluent or other unwanted excess substance resulting from the application of any process.

United Kingdom Environmental Protection Act 1990, subsequently further clarifying this statutory definition, did so in section 75(2) wastes are:

a. Any substance that is a scrap material or an effluent or other unwanted surplus material resulting from the application of any process and
b. Any substance that will be required to be disposed of as being broken, worn out, contaminated or otherwise spoiled.

Aside from that, one may refer to waste as the property of one voluntarily discarded at a specific point and time which is not of any perceived immediate or economic value to him or her. The thought that it is unwanted and of perceived value is a misconception because these concepts are relative and opinion- and situation-based. It is not easy to define waste in the terms of such assumptions as that which is waste for one may be the treasure for another. The judicial doctrine has learned that in definition cases involving concepts of "unwanted" or "value," the following holds:

i. The condition of the dumped waste must be as perceived from the dumping party's viewpoint.

ii. Trash is discarded stuff and remains so unless reprocessed in some useful manner and thereby reformed as something valuable. That a sorting process has occurred is not enough.

iii. Byproducts of a production process which still retain value or worth from the producer's perspective are not trash.

To dump factory waste at the same sites residential wastes are dumped is often inadmissible on the above grounds.

The principle behind it is very crucial in civil engineering, wherein focus is laid on designing systems of collection, treatment, and disposal of wastes in a manner that no damage is inflicted on the environment.

Treatment operations are typically divided to remove the impurities like suspended solids, organic wastes, and toxic chemicals and render the effluent disposable or reusable (Ranade and Bhandari, 2014). A broader definition of liquid industrial waste is its classification on the basis of the nature of the contaminants, i.e., biodegradable organic waste or non-biodegradable inorganic waste, and therefore the treatment mechanism (Metcalf et al., 1991). For instance, in the case of food processing, for instance, in Onitsha-based International Breweries factory, wastewater is largely due to cleaning and filtration processes, which can include biological treatment to account for organic composition (Dada, 2011). Industrial liquid waste treatment is not only for environmental protection but also for good industrial practice because untreated effluent has the potential for causing severe ecological and public health problems (Metcalf et al., 1991).

2.2 Sources and Types of Industrial Liquid Waste

Industrial liquid waste sources differ depending on the industry, but in the food beverage sector at the International Breweries Limited, the main sources are water used in washing bottles, machine cleaning, and reject water for filter processes such as reverse osmosis (Dada, 2011). The rest of the manufacturing industries except the chemical industry generate effluent from chemicals released during cooling or undergoing chemical reactions, and the majority of it is loaded with toxic chemicals like heavy metals (Ranade and Bhandari, 2014).

Still another research study on wastewater treatment in developing countries announces textile factories prevalent in West Africa discharge effluent containing dyes and salts that present some treatment difficulty (Pareek, 1992). Industrial liquid wastes can be categorized as follows based on the character of waste:

i. **Organic Waste:** Made up of biodegradable components like proteins and sugars, it is prevalent in the beverages sector owing to organic content. High Biochemical Oxygen Demand (BOD) and Chemical Oxygen Demand (COD) levels indicate oxygen required for biodegradation of such compounds, which is a prevalent problem in treatment of effluent (Ranade and Bhandari, 2014).

ii. **Inorganic Waste:** Includes salts, minerals, and heavy metals, usually found in reverse osmosis reject water at bottling plants (Dada, 2011). An industrial effluent study in Ghana is reflective of the presence of inorganic contaminants like sodium and chloride in soft drink wastewater (Amoah and Kosoe, 2014).

iii. **Biological Waste:** Includes microbial impurities like bacteria or fungi, which may be caused by inadequate sanitation in cleaning operations (Ranade and Bhandari, 2014).

iv. **Toxic Waste:** Less common in the food and beverage sector, toxic waste in the form of heavy metals or man-made chemicals can be introduced as package materials or cleaning compounds (Pareek, 1992).

Understanding these sources and categories is vital in determining treatment systems that are appropriate for a plant like the International Breweries Limited, where organic and inorganic wastes will likely be at the core.

Table 2.1: Principal Components of Industrial Liquid Waste

S/N	COMPONENT CATEGORY	DESCRIPTION	EXAMPLES
1.	Organic Compounds	Biodegradable or non-biodegradable carbon-based substances	Oils, grease, solvents, phenols
2.	Inorganic Compounds	Non-carbon-based materials often salts or minerals	Sodium chloride, sulfates, nitrates
3.	Heavy Metals	Toxic metallic elements	Lead, mercury, cadmium, chromium
4.	Suspended Solids	Particulate matter suspended in the liquid	Sediment, silt, metal particles
5.	Dissolved Solids	Substances dissolved in the liquid	Salts, sugars, acids

6.	Acids and Bases	pH-altering chemicals	Sulfuric acid, hydrochloric acid, sodium hydroxide
7.	Nutrients	Components that can promote biological growth	Nitrogen, phosphorus
8.	Pathogens	Microorganisms that may pose health risks	Bacteria
9.	Oils and Emulsions	Hydrocarbon-based liquids	Petroleum oils, cutting fluids
10.	Toxic Substances	Hazardous chemicals with environmental/ health risks	Pesticides, cyanides, dioxins

Source: Tchobanoglous et al., p.52-53

2.2.1 Sources of Waste Water

Wastewater is a product of human existence and a mixture of liquid discharges with variable characteristics and sources. All residential, industrial, commercial and agricultural activities bring in different contaminants and amounts into the total waste stream, where it begins. Wastewater management becomes more and more important to avoid environmental degradation as well as to maintain public health with growing population and industrialization. Introduction to these sources is brief given below:

i. **Domestic Wastewaters:** They are generated by domestic use and households. It includes shower water, washing machines, toilets, kitchen and sink water. It consists of organic wastes e.g., feces, soaps and detergents, food wastes. It is referred to as sewage when it is being combined with human excreta.

ii. **Institutional Wastewater:** These are produced by public or semi-public institutions such as schools, hospitals, government offices and prisons. Similar to domestic wastewater but possibly with higher levels of some contaminants depending on the institution, e.g., hospital medical wastes for disinfectants. Volume and pollutant load are directly correlated with the size of the institution and activity with a larger need for other special waste streams.

iii. **Commercial Wastewater:** These are operation wastewaters of business enterprises such as restaurants, hotels, offices and shops. These wastes are very heterogeneous since restaurants can release grease and food wastages whereas offices release wastewater that is essentially indistinguishable from domestic sources.

iv. **Industrial Wastewater:** These are generated as a result of industrial, processing, or manufacturing activities. They contain heavy metals, hazardous chemicals, oils, acids, bases, and industry-specific organic or inorganic chemicals. It has to be processed properly before disposal otherwise, it can become an enormous environmental issue if not processed.

v. **Agricultural Wastewater:** It is induced by agricultural activities in agriculture such as irrigation, husbandry, and application of pesticides/herbicides and fertilizers. It is climatically and seasonally dependent but rich in nutrients (phosphorus and nitrogen), herbicides/pesticides, sediments, and organic matter (manure). It can end up causing nutrient pollution of water bodies if not managed properly.

2.3 Environmental Impact of Industrial Liquid Waste

Excessive discharge of industrial liquid waste poses grave environmental consequences to water bodies, land, and the atmosphere. Effluent when not treated can induce eutrophication, where increased levels of nutrients like nitrogen and phosphorus enhance the growth of algal blooms, consume oxygen, and cause the death of aquatic organisms. Discharge of this kind is a situation being observed at Onitsha, where River Niger will most likely be contaminated by raw effluent from International Breweries Limited. High COD and BOD of highly organic-loaded wastewater, which is prevalent in the beverage industry, increases the requirement of oxygen, therefore making water uninhabitable for aquatic life (Ranade and Bhandari, 2014). Inorganic pollutants, like heavy metals or salts, can become entrapped in the soil and groundwater and lower the fertility of water resources and drinking water. Effluent from factories also has a tendency to contaminate groundwater in the event it is not treated, such that heavy metals such as lead and cadmium are present in superabundant amounts (Adeyemi and Ojekunle, 2021). Effluent microbial contaminants pose health risk, such as water-borne disease cholera, to society utilizing contaminated bodies of water. Again, pollution of the environment in urban Ghana review reports that air pollution is caused by industrial effluent due to the emission of volatile organic compounds emitted during the process of improper dumping, which impacts air quality and public health (Amoah and Kosoe, 2014). Such effects of the outcomes make it important to enhance waste management in Onitsha to safeguard the health of the people and the environment.

Table 2.2: Allowable Limits for Industrial Wastewater Discharge into Waterways (World Health Organization (WHO) Standards).

S/N	Parameter	Allowable Limit	Unit	Notes
1.	pH	6.5 – 8.5	-	Must be within this range for aquatic safety
2.	Biochemical Oxygen Demand (BOD)	30	mg/L	Maximum limit to prevent oxygen depletion in surface waters
3.	Chemical Oxygen Demand (COD)	125	mg/L	Maximum limit for surface waters
4.	Total Suspended Solids (TSS)	50	mg/L	Applies to treated effluent to protect aquatic life
5.	Total Dissolved Solids (TDS)	1000	mg/L	General limit for inland

				waters to prevent salinization
6.	Oil and Grease	10	mg/L	Maximum allowable concentration to avoid surface film formation
7.	Temperature	<40	°c	At point of discharge to protect aquatic organisms
8.	Lead(Pb)	0.01	mg/L	Heavy metal limit
9.	Cadmium(Cd)	0.003	mg/L	Heavy metal limit
10.	Chromium(Cr)	0.05	mg/L	Total chromium
11.	Mercury(Hg)	0.001	mg/L	Highly toxic, strict limit
12.	Arsenic(As)	0.01	mg/L	Toxic metal limit

13.	Total Nitrogen	10	mg/L	Includes nitrates and ammonia to prevent eutrophication
14.	Total Phosphorus	2	mg/L	To prevent eutrophication
15.	Cyanide	0.05	mg/L	Free cyanide limit
16.	Phenols	0.001	mg/L	Toxic organic compound

Source: WHO Guidelines for the Safe Use of Wastewater, Excreta, and Greywater (2006); WHO Guidelines for Drinking-Water Quality (2022).

The standard technology used by companies for compliance with such WHO regulations involves the use of anaerobic or aerobic biotechnology. More relevant to this assignment, however, is the environmental impact of discharging wastewaters that are not, or are poorly, treated. One of them is eutrophication, i.e., the addition of nutrients to water bodies with adverse environmental effects such as reduced biological diversity, excessive growth of aquatic weeds, algae bloom, and toxic scum formation in inland water bodies, which obstructs fishing, navigation, and flood control.

2.3.1 Industrial Effluent Effect on Stream Water Quality in Onitsha: A Water Quality Index Analysis

The impact on the environment of industrial effluents in Onitsha is horrifically clear in the local degradation in stream water quality, testified to by an extensive investigation of the Water Quality Index (WQI) of urban streams.

Discharge sites were compared to upstream sites of control in a study conducted in 2015 and described effluent and stream water samples of eight plants. The study confirmed that important physicochemical properties such as biological oxygen demand (BOD) between 12 and 180 mg/L, chemical oxygen demand (COD) of 48 to 420 mg/L, and lead concentrations of 0.01 to 0.48 mg/L were far above WHO-set limits upon discharge (Okafor et al., 2022). The microbial contamination was equally very critical with the total coliform content being a high risk of waterborne infections such as typhoid and cholera. The water quality index (WQI) analysis deemed stream water at point of discharge stations to be "very poor" to "unsuitable" for drinking and domestic uses and "good" to "fair" at the upstream stations, which reflected the decisive impact of industrial effluent discharge (Okafor et al., 2022). This pollution would be primarily directed to the River Niger, to which most of such streams are led, presenting the environmental challenge to the International Breweries Limited to gain liquid waste management in an environmental manner. The study acknowledges that real-time pretreatment of industrial effluents is required in an attempt to contain such effects, bearing in mind that Onitsha is extremely densely populated and local water bodies are utilized for domestic and economic uses.

2.4 Waste Disposal Practices in the Beverage Industry

Waste disposal practices in the beverage industry differ by scale, resource, and compliance with regulations. Some of the common practices include:

a. **Direct Discharge:** Some factories release untreated or half-treated effluent into water bodies or to municipal sewerage, which is likely to contaminate due to non-adherence (Dada, 2011). It was found during research studies on Nigerian beverage factories that small plants employ direct discharge since treatment plants are extremely expensive (Okafor et al., 2024).

b. **Physical Treatment:** Involves sedimentation and filtration to remove suspended matter. Clarification tanks in food plants and breweries are commonly utilized to remove solids before discharge (Ranade and Bhandari, 2014).

c. **Chemical Treatment:** Flocculation and coagulation remove particulate and organics by using chemicals like alum for agglomeration of contaminants to facilitate removal to be easily filtered out (Ranade and Bhandari, 2014). Chemical treatment is applied for COD reduction in effluent in a case study of Coca-Cola bottling plant in Ghana (Huzeima, 2014).

d. **Biological Treatment:** Uses microorganisms to destroy organic matter, reducing BOD and COD. Activated sludge treatment, in which bacteria break down organic wastes in aeration tanks, is best for big beverage factories (Ranade and Bhandari, 2014). It is claimed in one industrial waste study report in Ghana that biological treatment cannot be employed maximally in the beverage sector because it is too costly to run (Amoah and Kosoe 2014).

e. **Recycling and Reuse:** Advanced plants recycle effluent for reuse in non-potable purposes like irrigation or equipment washing. While sustainable, the practice is not prevalent to Nigeria by economic standards (Dada, 2011).

The processes are the basis for assessing the practice of the International Breweries Limited and deciding on sustainable intervention suitable for the Onitsha environment.

2.5 Nigerian Environmental Regulations on Industrial Waste

Nigeria's industrial effluent release is governed by the World Health Organization (WHO) and sets global standards for applying wastewater, excreta, and greywater to meet public and environmental protection. The WHO Guidelines for the Safe Use of Wastewater, Excreta, and Greywater (2006) imposed discharge parameters, i.e., a 30 mg/L BOD limit, Total Suspended Solids (TSS) of 50 mg/L, and pH ranging from 6.5 to 8.5 for avoiding environmental contamination (WHO, 2006). Such regulations are imposed on drinking plants such as the International Breweries Limited for helping in water body conservation such as the River Niger. Enforcement is normally ineffective owing to the insufficiency of adequate monitoring capacity and resources (Omani and Acakpovi, 2022). Nigeria's environmental policy is studied in a paper stating that most industries fail to adhere to it because treatment facilities are costly and noncompliance fines are unrealistically low (Adeyemi and Ojekunle, 2021). Second, recycling and proper waste disposal practice is encouraged by the WHO, although compliance in industrial zones is unstable as a function of local context (Environmental Sanitation Policy of Nigeria, 1999). The policy is then used as a benchmark against which compliance by the International Breweries Limited will be assessed and from which locally suited solutions will have to be developed.

2.6 Industrial Liquid Waste Management Challenges in Developing Nations

Industrial liquid waste disposal in developing countries is further worsened by a series of problems that preclude proper application of sustainable methods. Economic problems are one of the biggest obstacles, where most industries, particularly small and medium-scale industries, lack the accessible capital to utilize advanced treatment systems (Pareek, 1992). This is also compounded by the electricity and maintenance cost for treatment plants in Nigeria, which make it impossible to achieve WHO standards (Adeyemi and Ojekunle, 2021). West African water treatment is clearly suggested by research to show that the lack of technical expertise and experience is the cause of hindrance towards adopting or using improved treatment technology (Omani and Acakpovi, 2022). Inadequacies in infrastructure and infrastructure shortage, for example, non-centralized treatment plants in cities like Onitsha, promote industries to suboptimal behavior like direct discharge (Agunwamba et al., 1998). Corruption and poor enforcement of guidelines also impair improvement since there are minimal disincentives for noncompliance with WHO effluent standards (Mshelia, 2015). These problems are why cost-effective, locally viable substitutes are needed in plants like the Life Brewries Company, whose same problems Onitsha resursively duplicates.

2.7 Industrial Liquid Waste Treatment Using New Technologies

New technologies used in wastewater treatment are very promising for the treatment of industrial liquid wastes, particularly food and beverage production. Membrane bioreactors (MBRs) combine membrane filtration and biodegradation and have the ability to attain high efficiencies of suspended solids and organic matter removal and are hence employed for concentration of effluent from beverage factory by organic matter (Metcalf and Eddy, 2003).

Industrial wastewater treatment is the research area that defines the use of high-tech oxidation treatments such as ozonation and UV treatment to break down recalcitrant pollutants, though these are beyond the affordability of developing countries (Wang et al., 2011). Low-technology systems including constructed wetlands use natural processes that include microorganisms and vegetation to treat wastewaters and is an appropriate solution for small-scale industries in Nigeria (Huzeima, 2014). Wastewater recycling in the soft drink industry study reveals the possibilities of how anaerobic digestion can be used in the disposal of organic waste to generate biogas that can be harnessed in reducing energy costs—a future for the International Breweries Limited (Okafor et al., 2024). Such innovations present a series of solutions for enhancing waste management in Onitsha, tilting the balance toward efficiency and affordability.

2.8 Socioeconomic Impacts of Industrial Liquid Waste on Urban Areas

Urban liquid waste in the city lives like Onitsha has compelling socioeconomic impacts, extending to livelihood, health, and well-being of communities. Untreated effluent released to watercourses such as River Niger may pollute aquatic environments, resulting in a decrease in fish population and affecting the livelihood of the fisher folk. Nigeria's environmental contamination is under research, and the research contends that contaminated water sources lead to high healthcare costs due to waterborne disease, which places economic burdens on urban dwellers (Adeyemi and Ojekunle, 2021). In Onitsha, with dense population, wasteful disposal has the ability to increase social tensions because societies will blame companies like the International Breweries Limited for ruining the environment (Mshelia, 2015). Ghana urban waste management research shows that polluted bodies of water deter tourism and recreation use, thereby affecting the region's economy (Amoah and Kosoe, 2014). It is through planning for waste management to incorporate citizens' needs and optimizing International Breweries Limited solutions for the environment and Onitsha residents' advantage. For instance, the use of WHO-compatible treatment regimens will restore public confidence and boost economic activities in domestic economic activities like tourism and fishing (Okafor et al., 2022).

2.9 Economic Cost of Onitsha Waste Management

According to a report submitted by Anambra State Waste Management Authority (ASWAMA), the amount spent on solid waste management and disposal every year is estimated at N1.5 billion financed by the state government, which shows the huge economic impact of environmental sanitation (Vanguard Nigeria, 2021). About 30% is harvested within Onitsha alone, which generates more than 400 tons of solid waste on a daily basis, while the remainder is dumped on dumping grounds, typically blocking drainage and sewerage lines (Vanguard Nigeria, 2021). Such inefficiency in the disposal of solid wastes can result in the implication that disposal of liquid wastes, even effluent of organizations like the International Breweries Limited, may also be tainted with the lack of proper infrastructure. The financial cost of Onitsha waste treatment facilities keeps away investment in environmentally sound industrial liquid waste plants that are imposing environmental pressure on the River Niger. This puts into perspective the need for low-cost intervention in the context of Onitsha to allow the International Breweries Limited to dispose of its effluent sustainably under resource constraint.

2.10 Empirical Framework

2.10.1 Prior Studies on Industrial Waste Disposal

There have been some studies on industrial waste disposal in Nigeria that sought to underscore challenges and opportunities. A Nigerian research on domestic wastewater treatment discovers that inadequate infrastructure leads to the release of untreated effluent, an observation repeated in industries (Oji et al., 2018). West African research, with a case study on Nigeria, discovers that high organic load, technological obsolescence, and non-compliance with rules are significant hindrances to good governance (Omani and Acakpovi, 2022). In the beverage and food industry, in sachet water production, it is noted in a report that the discharge of untreated wastewater is common due to loopholes in regulation as well as unaffordability, and contributes to environmental pollution in urban settings (Dada, 2011). A study of waste management of industrial effluent in Lagos finds that the majority of beverage plants lack proper treatment of effluent, and therefore effluent runs down through surface drains and eventually into water bodies. A study of Onitsha solid waste management, while not directly on liquid waste, documents poor infrastructure by implication to treat liquid waste (Agunwamba et al., 1998). Studies in the Kumasi Ghana Coca-Cola bottling plant find that although some soft drinks factories have biological treatment, there are the challenges of maintenance and operating costs, thus treatment in part or complete discharge (Huzeima, 2014). Research on waste management at Henkel Reghaïa, Algeria, brings out the significant gaps in the treatment of special waste, bringing out the need for increased sustainability due to insufficient knowledge among employees (Keddari et al., 2024). Zero liquid discharge (ZLD) process study explores their ability to decrease the production of liquid waste, drawing on the past to compare primary methodologies and restrictions, all the while highlighting the necessity for the need for more work so they can further develop as a process (Liang et al., 2021). A systematic evaluation of industrial wastewater management investigates challenges and facilitators for a decade, acknowledging regulatory frameworks, technological innovation, and sustainability considerations, and emphasizing the importance of inter-disciplinary cooperation (Singh et al., 2023). A study of industrial wastewater treatment systems particularly designed for ZLD operation is committed to dedicated processes in order to make it efficient and sustainable, with pre-treatment processes like ultra-filtration being given priority (Ronny and Perez Yael, 2021). Research on pre-treatment of industrial wastewater for environmental policy involves diversified treatment methods specific to each pollutant and ranked based on opportunities for pollution control (Chaudhry and Garg, 2019). Low-temperature evaporation technology is a new treatment process with reduced outsourcing handling capacity by over 70%, enhancing efficiency and sustainability in hazardous waste management (Jianhua et al., 2016). Heavy metal liquid waste disposal by spraying it onto a soil bed allows the evaporation and recovery of the metal, without causing environmental pollution, yet enabling resource recovery (Wright, 1978). An accelerated pollution survey technique for developing nations integrates liquid waste control practices, encouraging harmonized environmental monitoring plans to plan treatment activities on a priority basis (Economopoulos, 1984). A process engineering fundamentals and case studies manual of industrial waste treatment processes offers pollution prevention practices (Celenza, 2019). A bibliometric analysis of 1991-2014 industrial wastewater articles lists avenues for future studies and treatment methods and lists trendsetter articles in the field (Zheng et al., 2015). Industrial waste injection in North

Dakota illustrates the use of geology in waste storage safely by reservoir simulation (Mohamed et al., 2016). A publication on a sustainable wastewater treatment technology demonstrates innovations like membrane processes, with higher reuse value (Hailemariam, 2023). Industrial wastewater injection well forecasts between 1973 and 2000 assess environmental and regulatory responses (Warner, 1975). A quantification of occupational exposure risks due to e-waste-caused contamination of liquid crystal monomers is made considering the need for monitoring (Cheng et al., 2022). A disposal scheme for waste vats of dye before treatment prevents emission of odors, providing an easier process (Horst, 2000). New bioprocesses of wastewater treatment offer green technologies for resources recovery (Romani et al., 2024). Concentrated liquid waste deep-well injection is geologic and location compatibility for safe disposal (Warner, 1968). A review article on future wastewater treatment processes mentions microbial fuel cells and nanofiltration as sustainable choices (Malik et al., 2022). Environmental evaluation by Rapid Impact Assessment Matrix (RIAM) describes sanitary landfill as the best waste management method (Hoveidi et al., 2013). Two-injection well system carries out waste stream adsorption, enhancing ground injection efficiency (Donaldson and Johansen, 1973). Environmental protection is regulated in waste oil and gas industry waste injection (Sabović and Isabegović, 2012). Case study of a Nouri petrochemical complex evaluates disposal methods like crystallization, improving resource recovery (Heidari et al., 2018). A goal programming linear model optimizes deep-well injection with cost and compliance tradeoff (Mogharabi, 1991). An adsorption-reverse osmosis system can remove heavy metal zinc very efficiently (Journal of Environmental Engineering and Science, 2022). The coagulation technology is suggested as a very effective treatment of wastewater from the chemical industry (Tathod and Ramteke, 2024). Sodium sulfide-integrated process recycles copper and de-toxicizes waste (Imamura et al., 1994). A confinement vessel is utilized by a professional waste treatment system for orderly storage (Coffman and Bradshaw, 1981). Negative-pressure thermal decomposition burns industrial waste for recycling (Motoda, 1996). A case study on polymers production evaluates physical and chemical process treatment processes to minimize pollution (Nazih et al., 2008). Tertiary treatment technologies like ultrafiltration enable recycling of wastewater to ZLD (Santos Sánchez, 2021). Microfilter technology-aided advanced treatment enables water and salt recovery under a Zero Liquid Discharge (ZLD) (Rajamani, 2016). A review compares the effluent treatment practices to implement integrated water reuse designs (Sathya et al., 2022). Co-disposal with municipal solid waste heavily contaminates groundwater, necessitating improved practices (Zhang et al., 2023). Numerical simulation confirms safe hydraulic impact of deep-well injection (Mehnert et al., 2017). Hybrid SBR-RO technology achieves effective removal of TDS and COD for pharma effluents (Reddy et al., 2020). Geophysical methods calculate waste layer thicknesses at unauthorized dumping sites (Yamanaka et al., 2015). Benefits of subsurface injection have been proved in case histories under proper safety precautions (Donaldson et al., 1974). Activated sludge treatment demarcates the potential to industrial wastewaters (Orhon et al., 2009). Dynamic modeling for environmental performance improvement is a study that measures recycling treated industrial wastewater for reuse in urban irrigation, evaluating storage capacity considerations for optimizing sustainable water use (O'Connor et al., 2011). Subsurface disposal of liquid and slurry wastes is a field that investigates injection into nonhydrocarbon-bearing rocks with their containment capability irrespective of past research (Aubert et al., 1994). Landfilling disposal of industrial wastewater sludge environmental studies attest to its nonhazardous nature by sampling and leaching toxicity tests and regulatory approval (McCabe, 1979). A review of economic disposal of industrial wastes by feeding them to cement and lime kilns utilizes waste heat to render a sustainable solution without influencing product quality (Hinz and Press, 1976). A review of industrial wastewater treatment via biological treatment using activated carbon enhances oxidation to reduce oxygen demand, with it being effective (Hutton and Robertaccio, 1971). A review of petroleum industry wastewater and sludge treatment presents biological and physicochemical processes based on low-cost oil separation (Kulkarni, 2016). Treatment of wastewater by precipitation of heavy metals with a neutralization agent allows room for the removal of impurities, producing sludge for efficient wastewater treatment (Herman et al., 1982). A discourse on developing concepts in industrial wastewater treatment leads toward pollution prevention and source separation and introduces in-plant control programs (Brenner, 1999). Changing hazardous industrial waste treatment covers treatment of landfill leachate and bioremediation and illustrates regulatory improvements (Wang et al., 2008). Physicochemical properties of wastewater effluents studies emphasize treatment requirement and regulation adherence to prevent local pollution, particularly from food processing units (Gökçeküş et al., 2023). A study on bioremediation technology for industrial wastewaters with organic and inorganic pollutants recommends green technologies like phytoremediation (Bharagava et al., 2020). Decomposition of chelating agents for heavy metals and ultrafiltration cleanse industrial wastewater for effluent discharge, minimizing the risks to the environment (Oswald and Schuessler, 1980).

These studies collectively highlight the requirement for on-site research of liquid waste management in Onitsha beverage industry, to which this project is a response.

CHAPTER THREE

METHODOLOGY

3.1 The Study Area

3.1.1 Overview of Study Area

Onitsha (Igbo: Ọ̀nị̀chà Mmílí or Ọ̀nị̀chà) is a city on the east bank of the Niger River, in Anambra State, Nigeria. Onitsha and other towns and cities of south Anambra State, north Imo State and surrounding Delta State on the western bank of Niger River form a big metropolitan conurbation (Onitsha – Wikipedia, 2025).

At a 2016 estimate, the greater Onitsha conurbation has about 8 million inhabitants in central and southern Anambra state bordering to the west into adjacent Delta state and to the south into Imo state. Thinly scattered throughout these 3 states, the greater Onitsha is reckoned to be one of Nigeria's greatest urban metropolitan areas by area and number of people. Its unrelenting metropolitan expansion or conurbation covers many autonomous cities and satellite and suburb towns like Asaba, Obosi, Oba, Ogbaru, Nnewi, Anambra State capital city Awka all the way to Orlu in Imo State. Onitsha proper city population stands at 1,695,000 as of early 2024 (Onitsha – Wikipedia, 2025). Onitsha has two prevalent seasons: a warm, heavy, and cloudy wet (rain) season from the months of March to October, and a warm and seasonally partly cloudy dry season from the months of November to February both heavily dominated by the SW and NE trade winds of the Atlantic International Convergence Zone (ITCZ). Saharan harmattan winds are experienced in winter as haze and reduced visibility and thunderstorms take place during the period March/April and late September/October. The temperature is generally between 19 °C (67 °F) and 31 °C (88 °F) all year round and is never below 15 °C (59 °F) or more than 33 °C (92 °F) (Onitsha – Wikipedia, 2025).

Igbo are the indigenous Onitsha people who speak the Igbo language with the largest city and commercial hub of Nigeria's Igboland region, the Igbo people's origin, being Onitsha. They are also called Ndi Onicha in Igbo. English and Nigerian Pidgin English are also widely spoken. While the population is predominantly made up of Igbo ethnic groups, there are a small number of other ethnic groups from other Nigerian ethnic groups indigenous to the Onitsha southeast region of the country present in the Onitsha region due to Onitsha's economic hub location (Onitsha – Wikipedia, 2025).

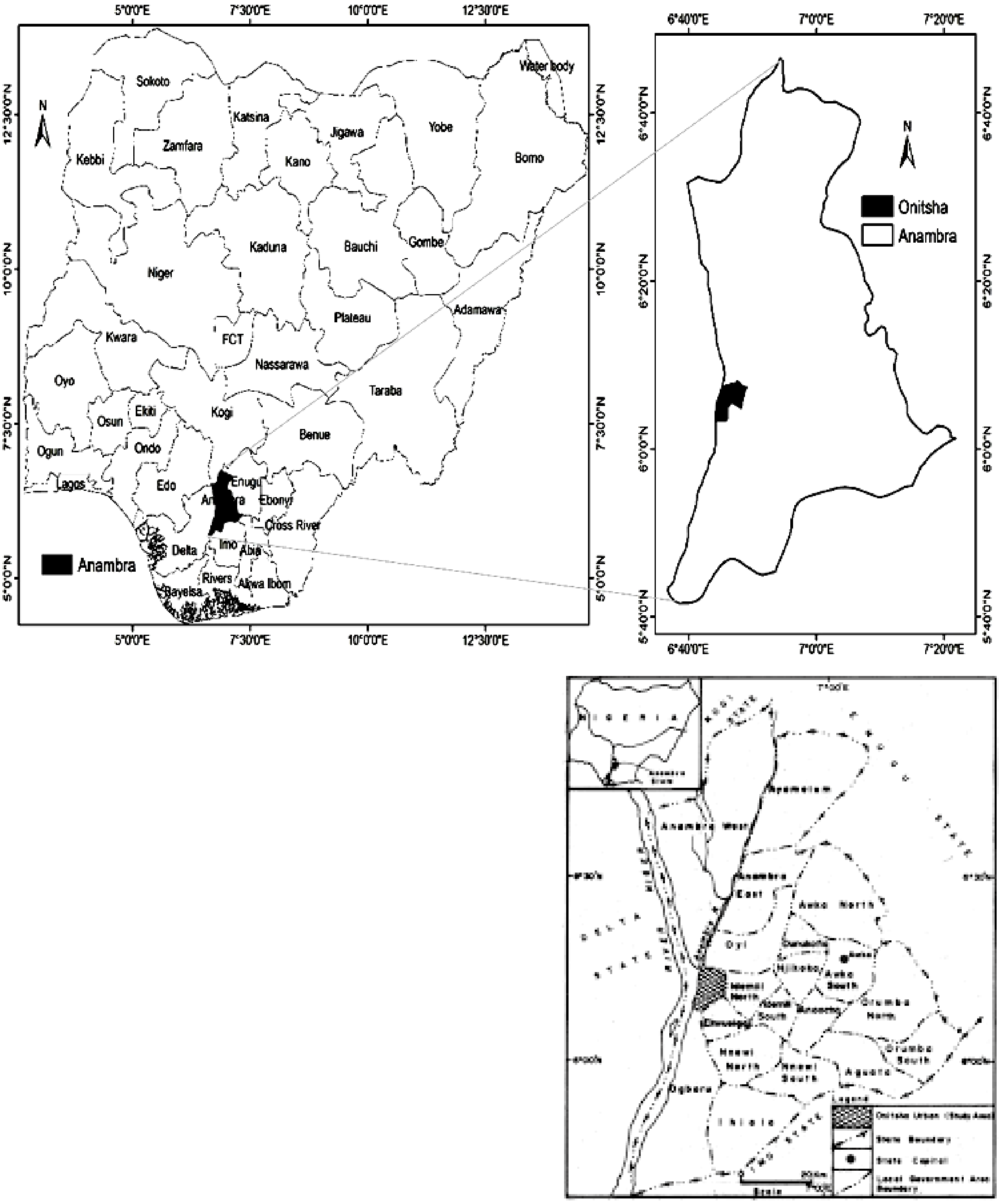

Figure 3.1: Map of Nigeria showing Onitsha (Encyclopedia Britannia, 2025)

3.1.2 Population of Study Area

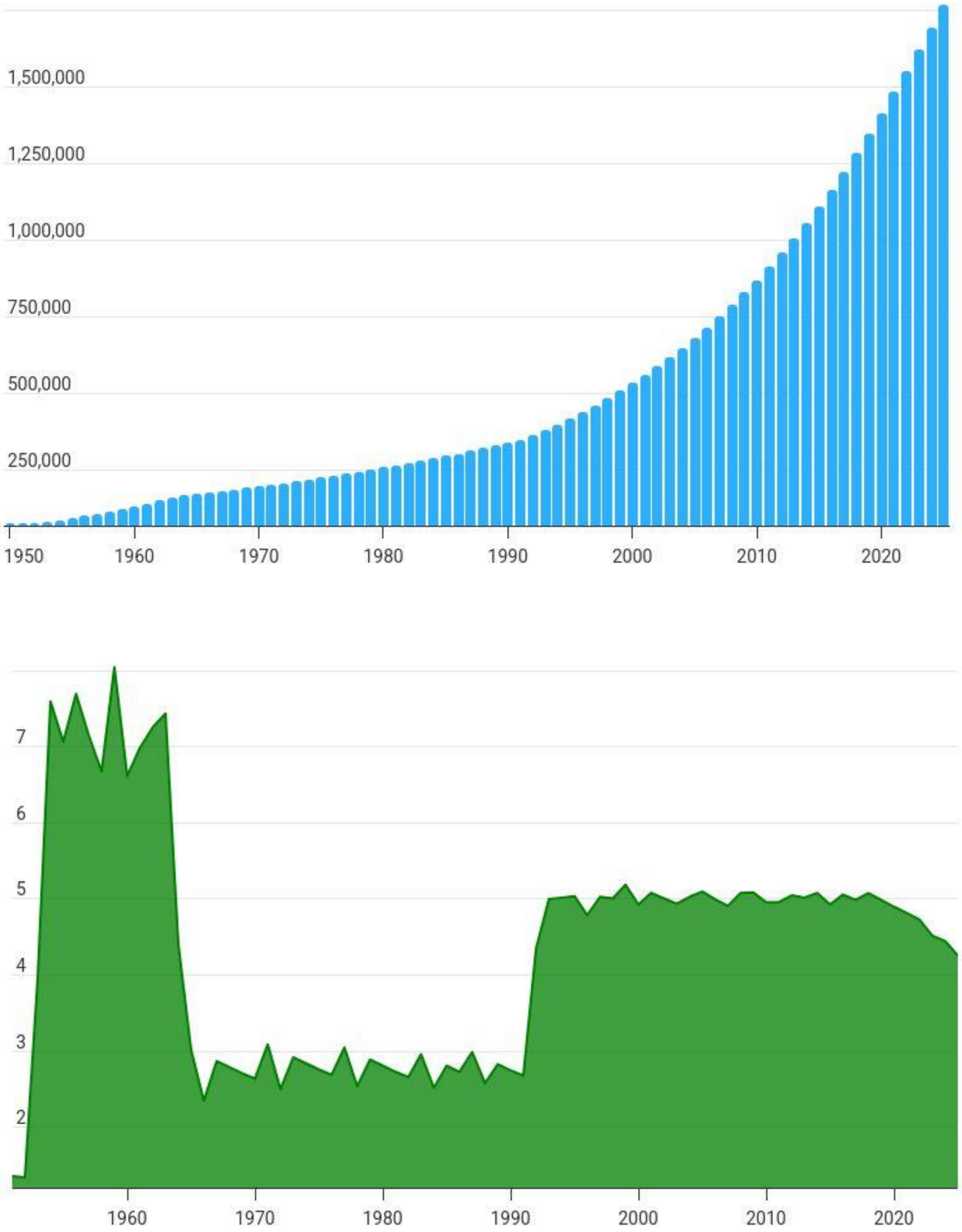

Figure 3.2: Charts showing total population and annual % change for Onitsha, Nigeria from 1950 to 2025. (Macrotrends.net, 2025)

3.1.3 Geography of Study Area

Onitsha is situated on the eastern bank of an ideal east–west Niger River crossing opposite Asaba, Delta State and at the northern terminus of the river normally accessible to ocean-going vessels, at 6°08'02" north longitude and 6°46'38" east latitude. It is the western end of central Anambra hills. These have transformed Onitsha into a principal hub of commerce between the coast and the north, and between east and west Nigeria. Onitsha is one of the only highway bridge crossings of the mile-wide Niger River and there are plans for a second bridge south of the existing one (Onitsha – Wikipedia, 2025).

Urbanization here is beneficial to the economy but detrimental to natural vegetation and terrain of the area. The region is highly susceptible to erosion as well.

3.2 History of International Breweries PLC

International Breweries PLC is a key player in Nigeria's beverage industry, known for its diverse beer and non-alcoholic offerings. It operates from a headquarters in Lagos, with significant production facilities across the country, ensuring wide market reach.

Incorporated in December 1971 under the name International Breweries Limited, the company commenced production in December 1978 with an installed capacity of 200,000 hectoliters per annum, which increased to 500,000 hl/a by 1982 (Crunchbase – International Breweries PLC, 2025). It became a public limited liability company on April 26, 1994, and was listed on the Nigerian Stock Exchange, marking a significant milestone in its corporate journey (Wikipedia – International Breweries PLC, 2025). Initially, it had a technical services agreement with Brauhaase International Management GMBH, a subsidiary of Warsteiner Group of Germany, which held 72.03% equity. In 2012, SABMiller took operational management control, and following AB InBev's acquisition of SABMiller in 2016, International Breweries became part of AB InBev Nigeria Holdings BV, integrating into a global brewing powerhouse.

This evolution reflects the company's growth from a regional player to a subsidiary of one of the world's largest brewers, leveraging global resources while maintaining a strong local presence. The merger with Pabod Breweries Limited and Intafact Beverages Limited in December 2017 further consolidated its operations, enhancing its market position (Wikipedia – International Breweries PLC, 2025).

3.2.1 Location and Operations of International Breweries PLC

International Breweries PLC is headquartered in Lagos, Nigeria, specifically at Desiderata Building, Plot 5A Abuja Street, Banana Island, Ikoyi, Lagos, Nigeria, as per recent corporate filings (Investing.com – International Breweries PLC, 2025). This location serves as the administrative and corporate hub, facilitating strategic management and business operations. The company's main brewery is situated in Ilesa, Osun State, at Omi-Asoro, Lawrence Omole Cl, Ilesa 112102, Osun State, which aligns with its registered office as noted in historical annual reports. Additionally, it operates breweries in Sagamu, Ogun State (Along abeokuta, Sagamu 110105), Port Harcourt, Rivers State (Trans Amadi, Port Harcourt 500102), and Onitsha, Anambra State, ensuring a robust production capacity across different regions. Distribution centers are also present in Ibadan, Lagos, and Ilorin, enhancing its market reach.

3.2.2 Products of International Breweries PLC

International Breweries produces a range of beverages, including beers such as Trophy Lager, Trophy Stout, Budweiser, Hero, Eagle Lager, Eagle Stout, Castle Lite, and Flying Fish, and non-alcoholic options like Grand Malt and Betamalt (Wikipedia – International Breweries PLC, 2025).

Figure 3.3: Picture of International Breweries PLC Headquaters

3.3 Research Methodology

The overall aim of this study is to scrutinize and improve Onitsha International Breweries factory's industrial liquid waste disposal system with a view to improving environmental sustainability and World Health Organization (WHO) standards. The research process is categorized into three wide phases:

i. Data Collection and Site Assessment.
ii. Laboratory and Field Analysis.
iii. Development of Evaluation and Improvement Strategy.

3.3.1 Data Collection and Site Assessment

During this stage, I collected the data in advance, alongside the assessment of the working environment of the International Breweries Company to create a baseline for analyzing its liquid waste disposal processes in the areas of:

a. **Sampling Strategy – Sampling Point Locations:** I took samples from two strategic points in the plant:

1. The pre-treatment effluent outlet after preliminary filtration
2. The post-treatment effluent prior to discharge

This multi-point approach captured changes in waste composition over the course of the treatment process.

b. **Sampling and Time Frequency:** I took my samples on two occasions in August 2025, at 9:00 AM to capture maximum production of waste generation. This gave me an in depth representation over periods of operation for tallying diurnal and weekly variations of industrial effluent.

c. **Sample Size and Volume:** I will took a total of 2 samples, one from a representative location on each of the 2 visits, with each sample taken to be 2 liters to allow for adequate room for extensive multi-parameter analysis. The sample volume was to offer statistical power and adequate information for preliminary characterization of the waste as proposed in environmental studies.

d. **Containers and Instruments:** I used Sterile 2-liter polyethylene bottles to store the samples to minimize contamination. Gloves and masks were worn while adhering to normal safety standards.

e. **Preservation and Transportation:** I kept the samples immediately upon collection by adding 2 mL of 4% sodium thiosulfate to deactivate any residual chlorine and kept them in a refrigerator, at a temperature of 4°C. Transportation was within 5 hours to the lab in order to maintain integrity, according to American Public Health Association (APHA) guidelines.

3.3.2 Laboratory and Field Analysis

This experiment involved thorough testing to determine the physical, chemical, and biological tests of the waste liquid under Objectives 1, 2, and 3 in the following:

3.2.2.1 Physical Tests: The following tests were conducted under physical properties: Temperature, pH, Turbidity, Total Suspended Solids and Colour.

a. **Temperature**:

Aim

To measure the temperature of the liquid waste samples to assess thermal pollution and its potential impact on oxygen solubility and aquatic life (River Niger) from International Breweries Limited.

Apparatus/ Equipment

I used the following apparatus/equipments: Digital pH meter with a temperature probe, Deionized water for rinsing, Lint-free cloth for probe cleaning, Field notebook and pen for documentation and Cooler for sample storage (if needed for post-measurement).

Procedure

I followed these steps (American Public Health Association et al., 1917):

i. I calibrated the digital pH meter with temperature probe using standards at 0°C and 50°C before each measurement session to ensure accuracy.

ii. I collected samples from the pre-treatment effluent outlet and discharge point during visits, coinciding with peak production waste output.

iii. I immersed the temperature probe into the liquid waste at each sampling point, ensuring it did not touch the container walls or bottom, allowing the reading to stabilize for 1-2 minutes.

iv. I recorded the temperature in degrees Celsius (°C) to the nearest 0.1°C in the field notebook, taking duplicate measurements with a 5-minute interval to calculate the average.

v. I rinsed the probe with deionized water and stored it in its protective case after use, transferring data to a spreadsheet for analysis.

Precautions

I took the following precautions (American Public Health Association et al., 1917):

1. I calibrated the temperature probe with standards at 0°C and 50°C before use to ensure accuracy.
2. I avoided touching the probe to container walls or bottoms during measurement to prevent false readings.
3. I conducted measurements under stable weather conditions to minimize external temperature influences.
4. I rinsed the probe with deionized water and stored it in its protective case after use to prevent damage and contamination.
5. I performed blank measurements with deionized water to verify probe accuracy, recalibrating if deviations exceed 0.2°C.

b. **pH:**

Aim

To determine the pH of the liquid waste samples to assess the acidity or alkalinity of the effluent from International Breweries Limited.

Apparatus/ Equipment

I used the following equipment: Digital pH meter with a glass electrode, pH buffer solutions (pH 4, 7, and 10) for calibration, Deionized water for rinsing, Lint-free cloth for electrode cleaning, Field notebook and pen for documentation and Cooler for sample storage (if needed post-measurement).

Procedure

I followed these steps (American Public Health Association et al., 1917):

i. I calibrated the digital pH meter with buffer solutions at pH 4, 7, and 10 before each measurement session to ensure accuracy.

ii. I collected samples from the pre-treatment effluent outlet and discharge point during visits storing them at 4°C if not measured immediately.

iii. I immersed the electrode into the sample, ensuring it did not touch the container walls or sediment, and allowing the reading to stabilize for 1-2 minutes.

iv. I recorded the pH value to the nearest 0.1 unit in the field notebook, taking duplicate measurements with a 5-minute interval to calculate the average.

v. I rinsed the electrode with deionized water and store it in a storage solution or deionized water after use, transferring data to a spreadsheet for analysis.

Precautions

I took the following precautions (American Public Health Association et al., 1917):

1. I calibrated the pH meter with buffer solutions at pH 4, 7, and 10 before each measurement session to ensure accuracy.
2. I rinsed the electrode with deionized water and gently bloted it with a lint-free cloth between samples to prevent cross-contamination.
3. I immersed the electrode fully in the sample, avoiding contact with container walls or sediment, to obtain accurate readings.
4. I allowed the reading to stabilize for 1-2 minutes before recording to account for electrode response time.
5. I stored the electrode in a storage solution after use to maintain its sensitivity, recalibrating if drift exceeded 0.2 pH units.

c. **Turbidity:**

Aim

To assess the turbidity of the liquid waste samples to measure the cloudiness caused by suspended particles from International Breweries Limited.

Apparatus/ Equipment

I used the following equipment: Turbidity meter, Calibration standards (e.g., 0 NTU, 10 NTU, 100 NTU), Deionized water for rinsing, Clean sample vials with caps, Lint-free cloth for cleaning and Field notebook and pen for documentation.

Procedure

I followed these steps (American Public Health Association et al., 1917):

i. I calibrated the turbidity meter with standards at 0 NTU, 10 NTU, and 100 NTU before each measurement session to ensure accuracy.
ii. I collected samples from the pre-treatment effluent outlet and discharge point during visits, storing them at 4°C if not measured immediately.
iii. I filled a clean sample vial with the liquid waste, ensuring no air bubbles, and wiped the exterior with a lint-free cloth to remove smudges.
iv. I placed the vial into the turbidity meter and recorded the reading in Nephelometric Turbidity Units (NTU) after stabilization, taking duplicate measurements with a 5-minute interval to calculate the average.
v. I rinsed the vial with deionized water between samples and transfer data to a spreadsheet for analysis.

Precautions

I took the following precautions (American Public Health Association et al., 1917):

1. I calibrated the turbidity meter with standards at 0 NTU, 10 NTU, and 100 NTU before each measurement session to ensure accuracy.
2. I filled sample vials without air bubbles and wiped them with a lint-free cloth to remove smudges, preventing interference with light transmission.
3. I avoided exposing samples to sunlight during measurement to prevent algal growth or particle settling.
4. I took readings within 30 minutes of sample collection to minimize changes in suspended particle stability.
5. I rinsed the sample vials with deionized water between uses and stored the meter in a protective case to maintain equipment integrity.

d. Total Suspended Solids

Aim

To assess the Total Suspended Solids in the liquid waste samples to measure the concentration of solid particles suspended in the effluent from International Breweries Limited.

Apparatus/Equipment

I used the following apparatus/equipment: Whatman GF/C glass fiber filters (0.45 μm pore size), Analytical balance (readable to 0.1 mg), Vacuum filtration unit with a Buchner funnel, Drying oven set at 105°C, Desiccator for cooling, Aluminum weighing dishes, Pipettes and volumetric flasks, Deionized water for rinsing, Field notebook and pen for documentation, Cooler for sample storage.

Procedure

I followed these steps (American Public Health Association et al., 1917):

i. I pre-weighed the clean, dry Whatman GF/C filter papers in aluminum dishes using the analytical balance and recorded the initial weight to the nearest 0.1 mg, storing them in a desiccator until use.
ii. I collected 100 mL samples from the pre-treatment effluent outlet and discharge point during visits, storing them at 4°C if not filtered immediately.
iii. I filtered each sample through a pre-weighed filter using the vacuum filtration unit, rinsing the filter with 10-20 mL of deionized water to remove soluble salts, and discarded the filtrate.
iv. I dried the filter and residue in the oven at 105°C for 24 hours, cooled it in a desiccator for 1 hour, and re-weighed it using the analytical balance to determine the weight of suspended solids.
v. I calculated the TSS concentration in mg/L by subtracting the initial filter weight from the final weight and dividing by the sample volume, recording the result in the field notebook and transferring data to a spreadsheet.

Precautions

I took the following precautions (American Public Health Association et al., 1917):

1. I calibrated the analytical balance with standard weights before use to ensure accuracy, checking zero-point stability.

2. I handled filters with forceps to avoid contamination from skin oils or dust.
3. I filtered samples within 24 hours of collection and stored them at 4°C to prevent particle settling or degradation.
4. I dried filters at a consistent 105°C ± 2°C for 24 hours to ensure complete evaporation without burning the residue.
5. I cooled filters in a desiccator to room temperature before weighing to avoid moisture absorption, disposing of used materials according to safety protocols.

e. **Colour**

Aim

To measure the colour of the liquid waste samples to identify discolouration caused by inorganic or inorganic contaminants from International Breweries Company.

Apparatus/Equipment

I used the following apparatus/equipment: Spectrophotometer, Platinum-cobalt standard solutions (e.g., 15, 30, 50 color units) for calibration, Quartz or glass cuvettes (1 cm path length), Deionized water for rinsing, Lint-free cloth for cuvette cleaning, Pipettes and volumetric flasks, Field notebook and pen for documentation, Cooler for sample storage (if needed post-measurement).

Procedure

I followed these steps (American Public Health Association et al., 1917):

i. I calibrated the spectrophotometer with platinum-cobalt standard solutions at 15, 30, and 50 color units before each measurement session to ensure accuracy.

ii. I collected samples from the pre-treatment effluent outlet and discharge point during visits, storing them at 4°C if not measured immediately.

iii. I transferred 10 mL of the sample into a clean cuvette, ensuring no air bubbles, and wiped the exterior with a lint-free cloth to remove smudges.

iv. I placed the cuvette in the spectrophotometer, set it to 455 nm, and recorded the color intensity in platinum-cobalt units (PCU) after stabilization, taking duplicate measurements with a 5-minute interval to calculate the average.

v. I rinseed the cuvette with deionized water between samples and transfered data to a spreadsheet for analysis.

Precautions

I took the following precautions (American Public Health Association et al., 1917):

1. I calibrated the spectrophotometer with platinum-cobalt standards before use, recalibrating if deviations exceed 5 PCU.
2. I filled cuvettes carefully to avoid air bubbles and wiped them with a lint-free cloth to prevent light scattering.
3. I avoided exposing samples to sunlight during measurement to prevent photodegradation of colour-causing compounds.
4. I measured samples within 1 hour of collection and stored them at 4°C to minimize color changes due to settling or oxidation.
5. I handled cuvettes gently to avoid scratches and stored the spectrophotometer in a protective case after use.

3.2.2.2 Chemical Tests: The following tests were conducted under chemical properties: Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Heavy Metals and Nutrient levels.

a. **Biochemical Oxygen Demand (BOD):**

Aim

To determine the amount of oxygen required by microorganisms to decompose organic matter in the liquid waste from International Breweries Limited.

Apparatus/ Equipment

I used the following equipment: BOD incubator, Dissolved oxygen (DO) meter with probe, 300 mL BOD bottles with glass stoppers, Pipettes and volumetric flasks, Deionized water for dilution, Nutrient buffer solution (e.g., phosphate buffer), Field notebook and pen for documentation, Cooler for sample storage.

Procedure

I followed these steps (American Public Health Association et al., 1917):

i. I calibrated the DO meter with air-saturated water before each measurement session to ensure accuracy.

ii. I collected samples from the pre-treatment effluent outlet and discharge point during visits, storing them at 4°C if not processed immediately.

iii. I filled a 300 mL BOD bottle with the sample to overflow, adding nutrient buffer solution and sealing it without air bubbles, then I measured the initial DO with the meter.

iv. I incubated the bottle in the BOD incubator at 20°C ± 1°C for 5 days, after which I measured the final DO using the same meter.

v. I calculated the BOD in mg/L by subtracting the final DO from the initial DO, recording the result in the field notebook and transferring data to a spreadsheet for analysis.

Precautions

I took the following precautions (American Public Health Association et al., 1917):

1. I calibrated the DO meter with air-saturated water before use to ensure accuracy.
2. I filled BOD bottles to overflow without air bubbles to prevent oxygen contamination.
3. I stored samples in a cooler at 4°C and began incubation within 6 hours of collection to minimize microbial activity changes.
4. I maintained the incubator at a constant 20°C ± 1°C throughout the 5-day period to ensure consistent microbial activity.
5. I used sterile techniques when handling nutrient solutions and avoided exposure to sunlight to prevent photo-oxidation.

b. **Chemical Oxygen Demand (COD):**

Aim

To assess the Chemical Oxygen Demand (COD) of the liquid waste samples to quantify the total amount of oxygen required to oxidize both organic and inorganic matter from International Breweries Limited.

Apparatus/ Equipment

I used the following equipment: COD digestion apparatus, COD vials with pre-measured dichromate reagent, Spectrophotometer, Pipettes and volumetric flasks, Deionized water for dilution, Heating block or oven for digestion, Field notebook and pen for documentation, Cooler for sample storage.

Procedure

I followed these steps (American Public Health Association et al., 1917):

i. I calibrated the spectrophotometer with a blank COD vial before each measurement session to ensure accuracy.
ii. I collected samples from the pre-treatment effluent outlet and discharge point during visits, storing them at 4°C if not processed immediately.
iii. I added 2 mL of the sample to a COD vial using a pipette, sealed it tightly, and placed it in the digestion apparatus and set it at 150°C for 2 hours to oxidize the contents.
iv. I allowed the vial to cool to room temperature, then measured the absorbance at 620 nm using the spectrophotometer, recording the COD value in mg/L.
v. I took duplicate measurements with a 10-minute interval to calculate the average, recording the result in the field notebook and transferring data to a spreadsheet for analysis.

Precautions

I took the following precautions (American Public Health Association et al., 1917):

1. I calibrated the spectrophotometer with a blank COD vial before use to ensure accuracy.
2. I handled COD reagents with gloves and in a well-ventilated area to avoid exposure to toxic chemicals like dichromate.

3. I used pipettes to add samples to COD vials without introducing air bubbles, preventing interference with the digestion process.
4. I maintained the digestion temperature at 150°C ± 2°C for 2 hours in the heating block to ensure complete oxidation.
5. I allowed vials to cool to room temperature before measurement to avoid thermal damage to the spectrophotometer, and disposed of used vials according to safety protocols.

c. **Heavy Metals**

Aim

To analyze the presence and concentration of heavy metals e.g., lead, cadmium, chromium in the liquid waste sample to identify toxic contaminants from International Breweries Limited.

Apparatus/Equipment

I used the following apparatus/equipment: Atomic absorption spectrophotometer (AAS), Nitric acid (HNO_3, concentrated) for digestion, Hot plate or digestion block, Volumetric flasks and pipettes, Deionized water for dilution Standard metal solutions (e.g., 1 mg/L for lead, cadmium, chromium), Glass beakers and watch glasses, Fume hood for safety, Field notebook and pen for documentation, Cooler for sample storage.

Procedure

I followed these steps (American Public Health Association et al., 1917):

i. I calibrated the AAS with standard metal solutions (e.g., 1 mg/L for lead, cadmium, chromium) before each measurement session to ensure accuracy.

ii. I collected samples from the pre-treatment effluent outlet and discharge point during visits, storing them at 4°C if not processed immediately.

iii. I transferred 50 mL of each sample into a glass beaker, added 10 mL of concentrated nitric acid, and digested the mixture on a hot plate at 95°C under a fume hood until a clear solution formed, typically for 1-2 hours.

iv. I cooled the digested sample, diluted it to 100 mL with deionized water, and filtered it, then I aspirated it into the AAS to measure the concentration of each heavy metal in mg/L.

v. I took duplicate measurements for each metal with a 10-minute interval to calculate the average, recording the results in the field notebook and transferring data to a spreadsheet for analysis.

Precautions

I took the following precautions (American Public Health Association et al., 1917):

1. I calibrated the AAS with standard solutions before use, recalibrating if deviations exceed 0.1 mg/L.
2. I performed digestion in a fume hood with proper ventilation, wearing gloves and a lab coat to avoid exposure to nitric acid fumes.
3. I handled samples and reagents carefully to prevent contamination from external metal sources.
4. I cooled the digested sample to room temperature before dilution to avoid volume changes due to heat.

5. I disposed of acid waste and used materials according to hazardous waste protocols, ensuring safe storage of chemicals.

d. **Nutrient Levels**

Aim

To measure the concentrations of nitrogen (e.g., nitrates and ammonia) and phosphorus in the liquid waste samples to assess the nutrient content from International Breweries Limited.

Apparatus/Equipment

I used the following apparatus/equipment: Nutrient analysis kits, Spectrophotometer, Pipettes and volumetric flasks, Deionized water for dilution, Glass cuvettes (1 cm path length), Lint-free cloth for cuvette cleaning, Field notebook and pen for documentation, Cooler for sample storage.

Procedure

I followed these steps (American Public Health Association et al., 1917):

i. I calibrated the spectrophotometer with blank cuvettes and standard solutions (e.g., 1 mg/L nitrate-N, 1 mg/L phosphate-P) before each measurement session to ensure accuracy.

ii. I collected samples from the pre-treatment effluent outlet and discharge point during visits, storing them at 4°C if not analyzed immediately.

iii. I added the appropriate reagent from the nutrient analysis kit to 10 mL of sample in a cuvette (e.g., cadmium reduction method for nitrate, ascorbic acid method for phosphate), following the kit instructions.

iv. I allowed the reaction to develop for the specified time (e.g., 10 minutes for nitrogen, 15 minutes for phosphorus), then measured the absorbance at 540 nm for nitrogen and 880 nm for phosphorus using the spectrophotometer, recording the concentration in mg/L.

v. I took the duplicate measurements with a 10-minute interval to calculate the average, recording the results in the field notebook and transferring data to a spreadsheet for analysis.

Precautions

I took the following precautions (American Public Health Association et al., 1917):

1. I calibrated the spectrophotometer with standard solutions before use, recalibrating if deviations exceeded 0.1 mg/L.
2. I wore gloves and worked in a clean area to avoid contamination of reagents or samples.
3. I added reagents in the correct order and volume as per kit instructions to ensure accurate color development.
4. I measured absorbance within the specified reaction time to prevent over- or under-development of color.
5. I disposed of used reagents and cuvettes according to safety protocols, storing samples at 4°C if not processed immediately.

3.2.2.3 Biological Tests: The following tests were conducted under biological properties: Total Microbial Content, Coliform Counts and Pathogen Detection.

a. **Total Microbial Content:**

Aim

To measure the total microbial content to determine the overall population of microorganisms in the liquid waste from International Breweries Limited.

Apparatus/ Equipment

I used the following equipment: Autoclave for sterilization, Membrane filtration unit, Nutrient agar plates, Petri dishes, Incubator set at 37°C, Pipettes and sterile diluent (e.g., 0.9% saline solution), Sterile forceps and gloves, Field notebook and pen for documentation, Cooler for sample storage.

Procedure

I followed these steps (American Public Health Association et al., 1917):

i. I sterilized all equipment (e.g., filtration unit, forceps) in the autoclave at 121°C for 15 minutes to ensure a sterile environment.

ii. I collected samples from the pre-treatment effluent outlet and discharge point during visits, storing them at 4°C if not processed immediately.

iii. I filtered 100 mL of each sample through a 0.45 μm membrane using the filtration unit, transferring the filter to a petri dish with nutrient agar.

iv. I incubated the plates at 37°C ± 1°C for 24-48 hours, counting the total number of colony-forming units (CFU) visible on the filter under a colony counter.

v. I recorded the CFU count per 100 mL in the field notebook, taking duplicate measurements to calculate the average, and transfered data to a spreadsheet for analysis.

Precautions

I took the following precautions (American Public Health Association et al., 1917):

1. I sterilized all equipment (e.g., filtration unit, forceps) in the autoclave at 121°C for 15 minutes before use to prevent cross-contamination.
2. I wore sterile gloves and worked in a clean area to minimize airborne contaminants.
3. I filtered samples within 2 hours of collection to maintain microbial viability, storing them at 4°C if delayed.
4. I used sterile saline solution for dilutions and avoided touching the filter surface to ensure accurate counts.
5. I incubated plates in the dark at 37°C ± 1°C for 24-48 hours to prevent photo-induced microbial changes, and disposed of used materials as biohazard waste.

b. **Coliform Count:**

Aim

To quantify the coliform bacteria, including total and fecal coliforms, in the liquid waste samples using the Most Probable Number (MPN) technique from International Breweries Limited.

Apparatus/ Equipment

I used the following equipment: Sterile multiple-tube fermentation tubes (e.g., 10 mL, 1 mL, 0.1 mL volumes), Lauryl Tryptose Broth (LTB) or MacConkey Broth for presumptive test, Brilliant Green Lactose Bile Broth (BGLBB) or EC Broth for confirmatory test, Durham tubes for gas production detection, Incubator set at

35°C and 44.5°C for fecal coliforms, Pipettes and sterile diluent (e.g., 0.9% saline solution), Sterile gloves and forceps, Field notebook and pen for documentation and Cooler for sample storage.

Procedure

I followed these steps (American Public Health Association et al., 1917):

i. I sterilized all glassware and broth media in an autoclave at 121°C for 15 minutes to ensure a sterile environment.
ii. I collected samples from the pre-treatment effluent outlet and discharge point during visits, storing them at 4°C if not inoculated immediately.
iii. I inoculated three sets of five tubes with 10 mL, 1 mL, and 0.1 mL of sample diluted in sterile saline, adding LTB for the presumptive test, and incubated at 35°C for 24-48 hours, checking for gas production.
iv. I transfered positive tubes to BGLBB or EC Broth for confirmation, incubating at 35°C for total coliforms or 44.5°C for fecal coliforms for 24-48 hours, and recorded gas production to estimate MPN using standard tables.
v. I recorded the MPN per 100 mL in the field notebook, taking duplicate sets to calculate the average, and transfer data to a spreadsheet for analysis.

Precautions

I took the following precautions (American Public Health Association et al., 1917):

1. I sterilized all glassware and broth media in an autoclave at 121°C for 15 minutes before use to prevent cross-contamination.

2. I wore sterile gloves and worked in a clean area to minimize airborne contaminants.
3. I inoculated tubes within 2 hours of sample collection, storing samples at 4°C if delayed, to preserve microbial integrity.
4. I incubated tubes at 35°C ± 0.5°C for 24-48 hours for total coliforms and 44.5°C ± 0.2°C for fecal coliforms, checking for gas production to ensure accurate detection.
5. I disposed of used tubes and media as biohazard waste according to safety protocols, avoiding inhalation of aerosols during handling.

c. Pathogen Detection

Aim

To identify specific pathogens (e.g., Escherichia coli, Salmonella) in the liquid waste samples to assess the presence of disease-causing microorganisms from International Breweries Limited.

Apparatus/Equipment

I used the following apparatus/equipment: Autoclave (e.g., Tuttnauer 2540M) for sterilization, Membrane filtration unit (e.g., Millipore) with 0.45 µm filters, Selective media (e.g., MacConkey Agar for E. coli, XLD agar for Salmonella), Petri dishes, Incubator set at 35°C and 37°C, Pipettes and sterile diluent (e.g., 0.9% saline solution), Sterile forceps, gloves, and loops, Field notebook and pen for documentation, Cooler for sample storage.

Procedure

I followed these steps (American Public Health Association et al., 1917):

i. I sterilized all equipment (e.g., filtration unit, forceps) in the autoclave at 121°C for 15 minutes to ensure a sterile environment.

ii. I collected samples from the pre-treatment effluent outlet and discharge point during visits storing them at 4°C if not processed immediately.

iii. I filtered 100 mL of each sample through a 0.45 µm membrane using the filtration unit, transferring the filter to a petri dish with MacConkey agar for E. coli and XLD agar for Salmonella.

iv. I incubated the plates at 35°C for 24 hours for E. coli and 37°C for 24-48 hours for Salmonella, observing for characteristic colony morphology (e.g., pink colonies for E. coli, black-centered colonies for Salmonella).

v. I recorded the presence and number of colonies per 100 mL in the field notebook, taking duplicate measurements to calculate the average, and transfer data to a spreadsheet for analysis.

Precautions

I took the following precautions (American Public Health Association et al., 1917):

1. I sterilized all equipment in the autoclave at 121°C for 15 minutes before use to prevent cross-contamination.
2. I wore sterile gloves and used a laminar flow hood to minimize airborne contamination during filtration and plating.

3. I processed samples within 2 hours of collection and stored them at 4°C to preserve pathogen viability.
4. I avoided cross-contamination between E. coli and Salmonella tests by using separate media and tools.
5. I disposed of used filters and media as biohazard waste, following safety protocols to prevent aerosol exposure.

3.3.3 Development of Evaluation and Improvement Strategy

This evaluated the sustainability and effectiveness of current disposal practices, meeting objective 4 and proposing improvements in the following (American Public Health Association et al., 1917):

a. **Improvement Strategy Development:** I proposed green alternatives based on my findings. Recommendations were cost-effective and indigenous, meeting sustainability objective.

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 Introduction

This chapter gives the outcome of the laboratory testing of liquid effluent samples obtained from the International Breweries PLC in Onitsha, Nigeria. The samples were taken at the pre-effluent (untreated effluent prior to entry into the treatment system) and post-effluent (treated effluent after treatment but prior to final discharge) stages. The testing is for 33 parameters, which are divided into physical, chemical, and microbiological characteristics, quantified in SI units. The results are compared to the World Health Organization (WHO) drinking-water quality guidelines (WHO, 2022) as a conservative environmental protection standard and the WHO guidelines for the safe use of wastewater in agriculture (WHO, 2006) that provide effluent discharge limits for the prevention of receiving water pollution like the River Niger. The comparisons reflect the performance of the treatment system, compliance rates, and any potential environmental hazards. Implications for aquatic ecosystems, public health, and sustainability are addressed, underpinning the research aims to determine effluent properties and to audit disposal practices. Results were obtained from accredited laboratory analysis, checked by duplicate measurements, and calibration.

The brewery plant rated is medium-to-large scale, with liquid waste resulting from cleaning operations, fermentation, and cool-down. The wastewater is discharged through a drain system to a treatment system before release.

Key Observations:

i. Waste streams consist of high-salinity process water, organic-rich effluents, and chemical residues.
ii. The plant has general treatment and containment facilities but lacks advanced biological treatment or filtration facilities.

To further clarify our data, NESREA effluent discharge regulations for the food, beverages, and tobacco sector (NESREA, 2009) were cross-referenced as well. NESREA specifications are stricter on certain parameters and reflect Nigeria's national environmental priorities.

4.2 Presentation of Results

The lab test results are presented in tabulated form in Table 4.1. All units are SI (e.g., mg/L for concentration, NTU for turbidity, CFU/mL for microbial presence). Pre-effluent (untreated) and post-effluent (treated) values are provided, compared to WHO drinking-water guidelines (for health-based standards) and effluent discharge regulations (for environmental discharge), and NESREA guidelines to determine relative stringency.

Table 4.1: Effluent Analysis Results and Comparison to WHO and NESREA Standards

S/N	**Parameter**	**Unit**	**Pre-Effluent Result**	**Post-Effluent Result**	**WHO Drinking-Water Limit (2022)**	**WHO Effluent Discharge Limit (2006)**	**NESREA Limit (2009)**
1	pH	-	6.1	5.0	6.5–8.5 (acceptability)	6.0–9.0 (for irrigation reuse)	6.5–8.8
2	Electrical Conductivity	µS/cm	9187	5656	No specific GV (related to TDS)	<2000 (recommended for reuse)	No specific limit
3	Salinity	g/L	4.15	2.56	No GV	<1.0 (for irrigation)	No specific limit
4	Colour	Pt.Co	1.8	0.8	<15 TCU (acceptability)	No specific limit	Colorless (appearance)
5	Turbidity	NTU	1.0	0.5	<5 NTU (threshold); ideally <1 NTU	<50 NTU (for surface water)	5.0 NTU
6	TSS	mg/L	2.3	1.1	No GV	<50 mg/L (for reuse)	25 mg/L
7	TDS	mg/L	4594	2829	<1000 mg/L (acceptability)	<2000 mg/L (for reuse)	500 mg/L

8	COD	mg/L	80.1	56.3	No GV	<250 mg/L (for restricted irrigation)	60 mg/L
9	HCO3	mg/L	183.4	104.3	No GV	No specific limit	150 mg/L
10	Na	mg/L	20.3	11.8	<200 mg/L (acceptability)	No specific limit	200 mg/L
11	K	mg/L	15.4	8.6	No GV	No specific limit	No specific limit
12	Ca	mg/L	31.4	17.3	No GV	No specific limit	No specific limit
13	Mg	mg/L	28.6	14.1	No GV	No specific limit	No specific limit
14	Cl	mg/L	3108	1104	<250 mg/L (acceptability)	<600 mg/L (for irrigation)	250 mg/L
15	P	mg/L	5.64	1.74	No GV	<5 mg/L (to prevent eutrophication)	2.0 mg/L
16	NH_4N	mg/L	18.31	8.74	<0.5 mg/L (acceptability)	<10 mg/L (for reuse)	1.0 mg/L
17	NO_2	mg/L	5.33	1.43	3 mg/L	<1 mg/L (for reuse)	No specific limit
18	NO_3	mg/L	15.14	6.66	50 mg/L	<30 mg/L (for irrigation)	10 mg/L

19	SO_4	mg/L	9.40	5.17	<250 mg/L (acceptability)	No specific limit	250 mg/L
20	Fe	mg/L	10.80	6.10	<0.3 mg/L (acceptability)	<5 mg/L (for irrigation)	<5 mg/L
21	Mn	mg/L	5.56	2.84	0.1 mg/L	<2 mg/L (for irrigation)	0.2 mg/L
22	Zn	mg/L	9.10	4.11	3 mg/L	<5 mg/L (for irrigation)	2 mg/L
23	Cu	mg/L	4.11	1.40	2 mg/L	<1 mg/L (for irrigation)	0.5 mg/L
24	Cr	mg/L	3.33	0.83	0.05 mg/L	<0.1 mg/L (for irrigation)	1.0 mg/L (total Cr)
25	Cd	mg/L	1.84	0.66	0.003 mg/L	<0.01 mg/L (for irrigation)	1.0 mg/L
26	Ni	mg/L	0.94	0.33	0.07 mg/L	<0.2 mg/L (for irrigation)	0.05 mg/L
27	Pb	mg/L	2.71	0.74	0.01 mg/L	<0.1 mg/L (for irrigation)	0.05 mg/L
28	V	mg/L	0.81	0.18	No GV	<0.1 mg/L (for irrigation)	No specific limit
29	Total Hydrocarbon Content	mg/L	ND	ND	No GV	No specific limit	No specific limit

30	Hardness	mg/L $CaCO_3$	196.2	101.3	<500 mg/L	No specific limit	No specific limit
31	Total Heterotrophic Bacteria	CFU/mL	10×10^3	0×10^3	<500 CFU/mL (operational)	<10^3 CFU/mL (for irrigation)	No specific limit
32	Total Coliform	CFU/mL	0×10^3	0×10^3	0 CFU/100 mL	<10^3 CFU/100 mL (restricted irrigation)	400 MPN/100 mL
33	Total E. coli	CFU/mL	0×10^3	0×10^3	0 CFU/100 mL	<10^3 CFU/100 mL (restricted irrigation)	No specific limit

Note: GV = Guideline Value.

4.3 Discussion of Results

4.3.1 Physical Parameters

The physical analysis was of mixed results. The pH decreased from 6.1 to 5.0, which fell below WHO (6.5–8.5 for drinking, 6.0–9.0 for effluent) and NESREA (6.5–8.8) values, reflecting acidification in the process of treatment, which could be due to organic acids. This would enhance metal solubility and toxicity to aquatic life in the River Niger as acidic pH disrupts fish osmoregulation. NESREA is stricter with a narrower range, reflecting greater environmental protection focus.

EC and salinity reduced (9187 to 5656 µS/cm; 4.15 to 2.56 g/L), but remained above WHO (<2000 µS/cm and <1.0 g/L) for reuse in effluent, with NESREA having no limit set for EC. High EC indicates ionic contamination, which can cause osmotic stress in freshwater species and lower soil permeability if reused in irrigation.

Turbidity (1.0 to 0.5 NTU) and color (1.8 to 0.8 Pt.Co) reduced, within NESREA (colorless, 5 NTU), <15 Pt.Co, and <5 NTU WHO standards. Turbidity and color appearance were controlled by treatment, alleviating light-blocking and aesthetic issues. NESREA is stricter in turbidity and appearance of color. TSS (2.3 to 1.1 mg/L) also reduced, within WHO (<50 mg/L) but below NESREA (25 mg/L), reducing sedimentation risks in the River Niger. NESREA is stricter for TSS.

4.3.2 Chemical Parameters

Chemical analysis showed partial reductions. COD decreased from 80.1 to 56.3 mg/L (showing a 30% reduction), within WHO (<250 mg/L) but below NESREA (60 mg/L). This showed moderate organic removal, but remaining COD can lead to oxygen demand in the River Niger.

HCO3, Na, K, Ca, Mg, and SO4 reduced, within WHO limits (e.g., Na <200 mg/L, SO4 <250 mg/L), with NESREA the same for SO4 (250 mg/L). These ions cause hardness (196.2 to 101.3 mg/L $CaCO_3$ <500 mg/L), with no significant risks but potential scaling. No special NESREA limits for these ions in effluent.

Chloride fell from 3108 to 1104 mg/L (showing a 64% reduction), but it exceeded WHO (<250 mg/L for drinking, <600 mg/L for effluent) and NESREA (250 mg/L), with the risk of taste issues, corrosion, and toxicity to freshwater life.

Nutrients reduced: P (5.64 to 1.74 mg/L, pre exceeded WHO/NESREA <5 mg/L), NH_4N (18.31 to 8.74 mg/L, both exceeded WHO <0.5 mg/L, NESREA 1.0 mg/L), NO_2 (5.33 to 1.43 mg/L, pre exceeded WHO 3 mg/L, NESREA no specific), NO_3 (15.14 to 6.66 mg/L, within WHO 50 mg/L, NESREA 10 mg/L). Residual nutrients may cause eutrophication, with NESREA more stringent for NH_4N and NO_3.

Heavy metals reduced by 40-70%, but after effluent exceeded both standards: Fe (6.10 >WHO 0.3, NESREA <5), Mn (2.84 >WHO 0.1, NESREA 0.2), Zn (4.11 >WHO 3, NESREA 2), Cu (1.40 >WHO 2, NESREA 0.5), Cr (0.83 >WHO 0.05, NESREA 1.0 total), Cd (0.66 >WHO 0.003, NESREA 1.0), Ni (0.33 >WHO 0.07, NESREA 0.05), Pb (0.74 >WHO 0.01, NESREA 0.05). NESREA is tighter on Ni and Pb, but WHO on Cd and Cr. These exceedances carry chronic consequences, including bioaccumulation and carcinogenicity in the River Niger food chain. V (0.18 mg/L) exceeded WHO <0.1 mg/L (NESREA no specification). THC was ND, within both limits.

4.3.3 Biological Parameters

Total heterotrophic bacteria reduced from 10×10^3 to 0 CFU/mL, within WHO <500 CFU/mL (drinking) and $<10^3$ CFU/mL (effluent), indicating effective disinfection. Total coliform and E. coli at 0 CFU/mL complied with WHO zero-tolerance and NESREA 400 MPN/100 mL, eliminating risks of fecal contamination.

4.4 Treatment Efficiency

Table 4.2: Percentage Reduction in Key Parameters

Parameter	**Pre (Value)**	**Post (Value)**	**% Reduction**	**Interpretation**
pH	6.1	5.0	-18% (decrease)	Worsened; treatment induced acidity.
TDS	4594 mg/L	2829 mg/L	38%	Partial; still exceeded limits.
COD	80.1 mg/L	56.3 mg/L	30%	Moderate; within limits but residual load remains.
Colour	3108 mg/L	1104 mg/L	64%	Good; but post still exceeded.
Heavy Metals (Avg.)	–	–	55%	Partial; most post exceeded limits.
Nutrients (Avg.)	–	–	60%	Good for P/NO3; poor for NH4N/NO2.
Bacteria	10×10^3 CFU/mL	0 CFU/mL	100%	Excellent; complete removal.

The table showed treatment was efficient for microbial removal (100%) and chloride (64%), but inefficient for pH and heavy metals, indicating need for upgrades.

4.5 Environmental Implications

4.5.1 River Niger Risk

High TDS, Cl, and heavy metals can alter water chemistry, reducing biodiversity and bio-accumulating in fish, with chronic health effects. NESREA's lower metal thresholds would be more Eco protective.

4.5.2 Public Health

Microbial adhesion decreased acute risks, but heavy metals and nutrients induced methemoglobinemia and eutrophication issues. WHO is more restrictive for zero-tolerance of E. coli.

4.5.3 Sustainability

Partial treatment meant inefficiencies; high exceedances equated to environmental unsustainability with threats of algal blooms and hypoxia in River Niger. NESREA is more protective overall for 14 parameters (e.g., BOD, COD, TSS) and thus more protective under local conditions, while WHO is more protective for 9 (e.g., NO2, Ni, Cd).

4.6 Limitations

The calculation done in the present study was useful to know the International Breweries Company's effluent characteristics, but it was limited by factors that constrained the scope and range of the outcomes. The following were the limitations I encountered:

1. One major limitation was my inability to collect samples directly from the River Niger, upstream of the discharge point, to assess the effluent's direct impact on the water body. The primary incentive for this was a fear for my safety, as

riverbank sampling had risks of drowning from strong currents and extremely variable levels of water during rainy season in August, 2025. This was further worsened by the lack of professional assistance or specialized equipment, such as safety harnesses or boats, for river sampling.

2. Another justifiable limitation was logistical difficulties, for instance, restricted access to the river due to private property boundaries and security concerns in the Onitsha area, which hampered cooperation with local authorities and consumed a lot of time.
3. Limitations of resources, including insufficient funds for future sampling expeditions further restricted my ability to extend the study to river water analysis.
4. Data Conclusiveness and Viability: The limited sample size (two samples taken on two separate occasions) prevents the results from being conclusive enough to confidently state that the effluent is only partially treated. To ensure the viability of the results, multiple samples should have been collected to capture the full range of variability in the industrial waste stream.
5. Sample Integrity: The state of the effluent samples between collection and laboratory analysis could not be guaranteed. This raises a potential issue regarding the integrity of the results, as changes in temperature or chemical interactions during transport could have influenced parameters like pH and BOD concentrations.

These were factors that collectively limited my research to be unable to account for the entire environmental effect of the effluent along the Niger River, potentially underestimating downstream effects like dilution or concentration of pollutants.

CHAPTER FIVE

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

The laboratory analysis of the effluent from International Breweries PLC in Onitsha showed conclusively the critical inadequacy of the current wastewater treatment facility in addressing inorganic and metallic pollutants. Despite such a high-performing system for primary disinfection, with 100% reduction in pathogens and total coliforms, the inability of the system to take care of major chemical parameters made it consistently non-compliant with WHO and NESREA environmental standards. In particular, the post-treatment effluent showed acute environmental risks through severe exceedances in:

1. **Acidity and Metal Mobilization:** The effluent pH decreased to 5.0, way below the stipulated regulatory range of 6.5-8.8, a very acidic condition that greatly enhances heavy metals' solubility and chronic toxicity potential in the receiving water body.
2. **Salinity and Total Dissolved Solids (TDS):** The levels of chloride (Cl) at 1104mg/L and TDS 2829mg/L have grossly exceeded both drinking and effluent limits, thus posing an immediate threat of osmotic stress in freshwater species and long-term degradation of chemistry within the River Niger.
3. **Heavy Metals and Nutrients:** High levels of heavy metals were noted, including Fe 6.10mg/L, Mn 2.84 mg/L, Pb 0.74mg/L, coupled with high residual Ammonia NH at 8.74mg/L, confirming the persistence of bioaccumulation and eutrophication risks.

While it is not possible to definitively state from the limited, non-longitudinal sampling of this project that the effluent is, under all conditions, partially treated, the current data certainly confirms that the disposal practice is an unsustainable high-risk activity. Moreover, the omission of tertiary treatment directly compromises the ecosystem and health of the River Niger, and this critical gap within the localized management of effluents must be urgently addressed for national and global environmental sustainability.

5.2 Recommendations

Based on the findings, recommendations are advanced to relevant stakeholders in regards to advanced treatment and compliance.

i. **To International Breweries PLC (Corporate Organization):**

1. **Prioritization of ZLD Strategy:** In light of the critical salinity and heavy metal exceedances, the company has to commit to the Zero Liquid Discharge strategy. This includes the implementation of RO or MBR systems for water reuse, with the aim of absolutely eliminating high-concentration brine and toxic metals discharged into the River Niger.
2. **Immediate pH Correction:** Instantly deploy an automated pH Neutralization Unit (using lime or soda ash) to ensure the effluent pH is within the NESREA range (6.5-8.8) prior to any discharge, mitigating the risk of heavy metal mobilization and aquatic toxicity.
3. **Advanced Nutrient Management:** Integrate Tertiary Filtration and advanced BNR processes for reliable reduction of NH_4N and P below NESREA thresholds to guard against eutrophication.

4. **Improved Data Integrity:** Utilize continuous, automated sampling and data logging throughout the entire production cycle, representing 24-hour composites, which would more accurately characterize the waste stream variability than was done in this study due to data viability limitations.

ii. **To Government Agencies: NESREA, FMEnv, Anambra State Ministry of Environment**

1. **Mandate Tertiary Treatment/ZLD:** Change the NESREA regulations to clearly state that high-salinity and heavy-metal-discharging industries near major freshwater sources should adopt tertiary treatment, for example, RO or Ion Exchange.
2. **Subsidize Critical Infrastructure:** Incentivize this process with targeted tax credits or low-interest loans to defray large capital outlays for RO and MBR systems for long-term economic viability.
3. **Enhance Enforcement and Monitoring:** establish permanent third-party monitoring stations both upstream and downstream of large industrial clusters in Onitsha to assess real-time river impact, addressing the ecosystem assessment limitation.

iii. **To Future Researchers:**

1. **Longitudinal and Seasonal Study:** This program should include comprehensive, multi-point, longitudinal sampling over wet and dry seasons to capture the full range of effluent variability for a more realistic assessment.
2. **Ecosystem Impact Quantification:** Utilize the proper equipment to safely collect and analyze upstream and downstream river water samples to quantify the true

dilution, concentration, and bioaccumulation effects of the International Breweries PLC discharge on the aquatic life of the River Niger.

3. **Wastewater Reuse Feasibility:** Examine in detail the economic and technical feasibility of the post-treatment effluent for non-potable uses such as equipment washing or irrigation after RO polishing, contributing to water circularity.

Implementation of these recommendations will considerably enhance effluent quality, protect the ecosystem of River Niger, ensure regulatory compliance, and promote sustainable industrial practices within Nigeria's beverage sector.

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