

ANALYSIS OF PROCESSING WASTES FROM CADBURY NIGERIA PLC

BY

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**AGRICULTURAL ENGINEERING DEPARTMENT
FEDERAL UNIVERSITY OF TECHNOLOGY, MINNA**

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**AGRICULTURAL ENGINEERING DEPARTMENT
FEDERAL UNIVERSITY OF TECHNOLOGY, MINNA
PROJECT**

**SUBMITTED IN PARTIAL FULFILMENT OF THE REQUIREMENT FOR THE
AWARD OF BACHELOR OF ENGINEERING (B.ENG.) DEGREE IN
AGRICULTURAL ENGINEERING**

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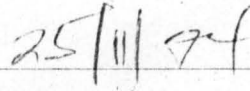
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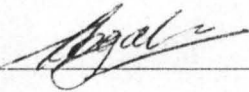


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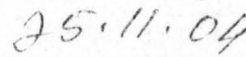


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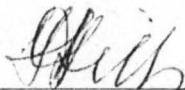


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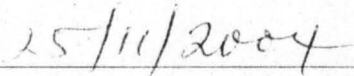
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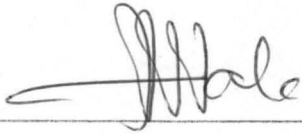
DEDICATION

This project is dedicated to my parents, Mr & Mrs Abdul - Gafar O. Kolapo , who have shown endless support.

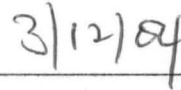
DECLARATION

I hereby declare that this project is a record of my research work. It has neither been presented nor accepted in any previous application for a degree.

All sources of information have been specifically acknowledged.



Signature: Kolapo, K.A.



Date

ACKNOWLEDGEMENT

TO GOD BE THE GLORY

I wish to express my sincere gratitude to my supervisor, Engr. (Deacon) O. Chukwu for his contributions towards this study. His wealth of experience in teaching and research were highly instrumental to the attainment of my set goals.

I wish to express a depth of gratitude to Engr. (Dr) D. Adgidzi, Engr. (Prof.) E.S.A Ajisegiri, Engr. (Dr.) Osunde (Mrs), Engr. P.Idah, Engr (Dr.) N.A. Egharevba, Engr. (Dr.) B.A. Alabadan and Engr. M. Bashir, Engr. F.B. Akande and Engr Balami and all the other academic staff members of the Department for their valuable contributions to the success of this research.

The cooperation of all other technical and administrative staff of the Department is gratefully acknowledged.

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My special gratitude goes to Miss Jumoke Akinloye (Arewa), Mrs. Adeyemo; Elder David Adeoye, Abdulakeem Olatubosun, Abdul Latif Ibrahim (uncle), Mallam Musa (GODFATHER), Uncle Ishiaq Kolapo, Uncle Peter Adekoya and Bro. Qaseem and other people too numerous to mention for the supportive role they played towards the success completion of this project.

To my friends and colleagues and Federal University of Technology (F.U.T), Minna our academic home for five years, all of whom have made possible our rewarding career and rich friendship.

ABSTRACT

The visit made to Cadbury Nigeria Plc, together with discussions with staff and floor men (factory men) have made it possible to identify the following methods of dealing with wastes produced by Cadbury Nigeria Plc.

For liquid wastes:

Industrial wastewater was often merely discharged into the public Sewers system, i.e. the open-trench channel; in nearly all cases this was done with or without any pre-treatment of wastewater before discharged.

For solid wastes

Solid wastes may have resale value – cellulose, plastics cartons drums, etc. in these cases, the wastes are collected, packed and sold.

Solid wastes without value are placed in containers and taken away by the local disposal authorities.

For gaseous wastes

It was observed that Cadbury Nigeria Plc flare gaseous pollutants by erecting chimney stack above the roof of the factories.

Investigations were made into the composite effluent sample of Cadbury Nigeria Plc. The analysis was conducted looking at the general waste water (effluent) indicative parameters (temperature, turbidity, pH electrical conductivity and dissolved oxygen). The organic content of the wastewater as determined by either the chemical or biochemical oxygen demand (COD or BOD); the reducing anion (sulphates); aesthetics (colour and odour), oil and grease; the eutrophication agents (phosphates); both the total suspended

and dissolved solids content and finally the trace metals (especially iron, zinc, magnesium and calcium).

The physico-chemical analyses of parameters were carried out following the Standard Methods for the Examination of Water and Wastewater.

The values obtained for Biochemical and Chemical Oxygen Demand, Total Suspended and Dissolved Solids were above the maximum acceptable limit set by the Federal Environmental Protection Agency (FEPA). While others are within the maximum permissible limits.

TABLE OF CONTENTS

TITLE PAGE	i
APPROVAL	ii
DEDICATION	iii
DECLARATION	iv
ACKNOWLEDGEMENT	v
ABSTRACT	vii
TABLE OF CONTENTS	ix
LIST OF TABLES	xii
LIST OF FIGURES	xiii
CHAPTER ONE:	
1.0 INTRODUCTION	1
1.1 Definitions of waste	1
1.2 Classification of waste	2
1.3 Cadbury Nigeria Plc. as Plant	3
1.3.1 Production Line	5
1.3.2 Material Balancing	6
1.4 Statement of the Problem	7
1.5 Justification of the Study	8
1.6 Objectives of the Study	8
1.7 Scope of the Study	9

CHAPTER TWO

2.0	LITERATURE REVIEW	10
2.1	Waste Legislations	13
2.1.1	Government Institutional Responsibilities	15
2.1.2	Enforcement of Waste Regulations	15
2.2	Types of Waste	16
2.2.1	Liquid Waste	16
2.2.2	Solid Waste	17
2.2.3	Gaseous Waste	19
2.3	History of Waste Treatment Disposal	26
2.4	Waste treatment Operations, Processes and Concepts	29
2.5	Recycling, Recovery and Low – Waste Technology	32
2.6	Regulation and Standard for Food Processing	33
2.7	Properties and Requirement of Processing Water	34
2.8	Wastewater Compositions	37
2.9	Wastewater Treatment Process	37
2.10	Waste Management	63

CHAPTER THREE

3.0	MATERIALS AND METHOD	70
3.1	List of reagents used	72
3.2	Sample Collection Techniques	73
3.3	Sample Identification	74

3.4	Sample Preservation	74
3.5	Experimental Procedures	75
3.5.1	Determination of Physical Parameters of liquid Waste	75
3.5.2	Determination of Inorganic Matter Composition liquid waste	79
3.5.3	Determination of Organic Matter Composition	81

CHAPTER FOUR

4.0	Presentation and Discussions of Results	84
4.1	Results	84
4.2	Discussions	89

CHAPTER FIVE

5.0	Conclusion and Recommendations	95
5.1	Conclusions	95
5.2	Recommendations	96

Reference	100
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Appendices	102
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LIST OF TABLES

TABLE		PAGE
1.1	Material Balances of the Production Line	6
2.1	Typical Composition of "Clean" dry	20
2.2	Gaseous Air Pollutants	25
2.3	National Interim Primary Drinking Water Regulations	36
2.4	Removal or Destruction of Bacteria by different Treatment Process	49
4.1	Results of Physical Parameters of the waste	105
4.2	Results of Organic Matter Composition	105
4.3	Results of Inorganic Matter Composition of Cadbury Nig. Plc	106
4.4	Effluent limitation guidelines in Nigeria for all categories of industries.	107

LIST OF FIGURES

FIGURE	Page
1.1 Production Line	5
2.2 Waste water treatment plant.	38

CHAPTER ONE

1.0 INTRODUCTION

The conversion of raw agricultural materials into finished food product, like other manufacturing processes can be detrimental to the environment if precautions are not taken.

There are several special environmental problems associated with food processing that must be considered. Food processing can have adverse environmental effects on both air and water quality as well as producing toxic by-products. In general, the major environmental problem associated with food processing is the large amounts of solid and liquid waste products produced. These wastes are nearly always of biological origin and can pollute waterways and soil if not properly treated (Norman, 1995). In the past little consideration was given to wastes arising from industrial processes. Although not all these wastes were hazardous, many contained small quantities of components which were dangerous or potentially dangerous to the environment (Paul, 2002).

1.1 DEFINITION OF WASTES

Waste may be defined as unwanted matter or material of any type (Procter, 1996). The definition of waste can be very subjective, what represents waste to one person may represent a valuable resource to another. However, waste could be hazardous or non hazardous. By definition, hazardous wastes are the wastes that poses a substantial present or potential hazard to human health or the environment when improperly treated, stored, transported or disposed off or otherwise managed while non hazardous wastes are refer to the wastes that are converted into economical use either by analysis or treatment (Gilbert, 1998). The regulations covering waste use variety of terms to describe the

different types of waste including controlled, household, industrial, commercial, special etc. in such case, strict definitions of waste have financial and legal implications for businesses, local authorities and government.

In addition, for the requirement of a legal definition of waste, agreement on definitions and classifications of waste are required for the accurate formulation of local, regional and national waste management planning. In Nigeria, Federal Environmental Protection Agency(FEPA) now Federal Ministry of Environment(FME) is responsible for the collection of data on waste which is used by local authority planning departments in the preparation of their waste local plans and for waste management planning.

1.2 WASTE CLASSIFICATION OF PARTICULAR CONCERN

Special Waste

Special waste is controlled waste of any kind that is or may be so dangerous or difficult to treat, keep or dispose of that special provision is required for dealing with it. Such waste is known to containing substances which are dangerous to life.

Industrial Waste

Waste from factory premises. Factors described within the factories Act of 1960, premises used for public transport services by land, water or air, premises used for the supply of gas, water, electricity or sewage services, postal or telecommunications services. Examples include industrial waste producers from the manufacture of textiles, chemicals etc.

Household Waste

Household waste means waste from private domestic accommodation, caravans, residential homes, universities or schools or other educational establishments, hospital premises and nursing homes.

Commercial Waste

Waste from premises used wholly or mainly for the purposes of a trade or business for the purposes of sport, recreation or entertainment. Excluded from the commercial waste category are household and industrial waste, mine and quarry waste, and waste from agricultural premises. Examples include waste from offices, hotels, shops, local authorities, markets, fairs etc.

Controlled Waste

Household, industrial and commercial waste. Sewage sludge disposed of to landfill and by incineration is controlled waste, but disposal at sea and spreading on agricultural land is regulated separately (Paul, 2002). Information on waste technology, particularly on industrial and hazardous wastes, is often difficult to assemble. The inefficient data collection methods, and some industrialist are reluctant to give informations.

1.3 Cadbury Nigeria Plc as a Plant

What is known today as Cadbury Nigeria Plc, started as a small business entity in 1965 with a purpose –built factory commissioned at the present Lateef Jakande Road, Agidingbi, Ikeja, Lagos State. Full scale production of Pronto (introduced in 1956)and Bournvita (1960) began then, using cocoa powder as basic raw material. Today, the core

business of the company is run in three streams namely: Food Drinks, Confectionery and Foods (Cadbury, 2004).

The epoch –making cereal conversion plant also produces a range of intermediate products like sorghum malt extract and glucose syrup, while a purpose built plant near Jos produces tomato paste.

Cadbury Nigeria obtains most of it's agricultural raw materials (maize, soyabean and sorghum) locally from contract farmers and out growers in a partnering arrangement that enables them benefit from the technical advice and assistance of the company's agricultural services department and at the same time, guarantees to the company continuous supply of raw materials that meet the high quality standards.

The main production units were designed in line with modern manufacturing methods which ensure efficient production of the following products.

The confectionery range includes hard–boiled and chocolate confectionery namely TomTom, Butter Mint, Malta sweet, Cadbury chocolate, Éclairs, Luckies, Trebor peppermint original, Fruities, Ginger, Orange, Koff –Stick, Tofti, Jollies Goody Goody, Sherber Lemon and Hacks.

The food drinks range consists of Pronto, Bournvita, Richoco and Cadbury's Chocolate drink a ready – to drink beverage.

The food ranges is made up of Knorr cubes (premium quality seasoning) and its Chick cubes variant, Knorr chicken, Dadawa cubes (made from locust beans), Chef Pepper soup cubes (made up of wholly indigenous ingredients), Cheff tomato puree and Tomato (choice blend of tomato puree and ground pepper). The company's objective is to satisfy the requirements of consumers with high quality food products, processing perishable local raw materials into products with long shelf life, adapted to the tastes and food habits of the consumers.

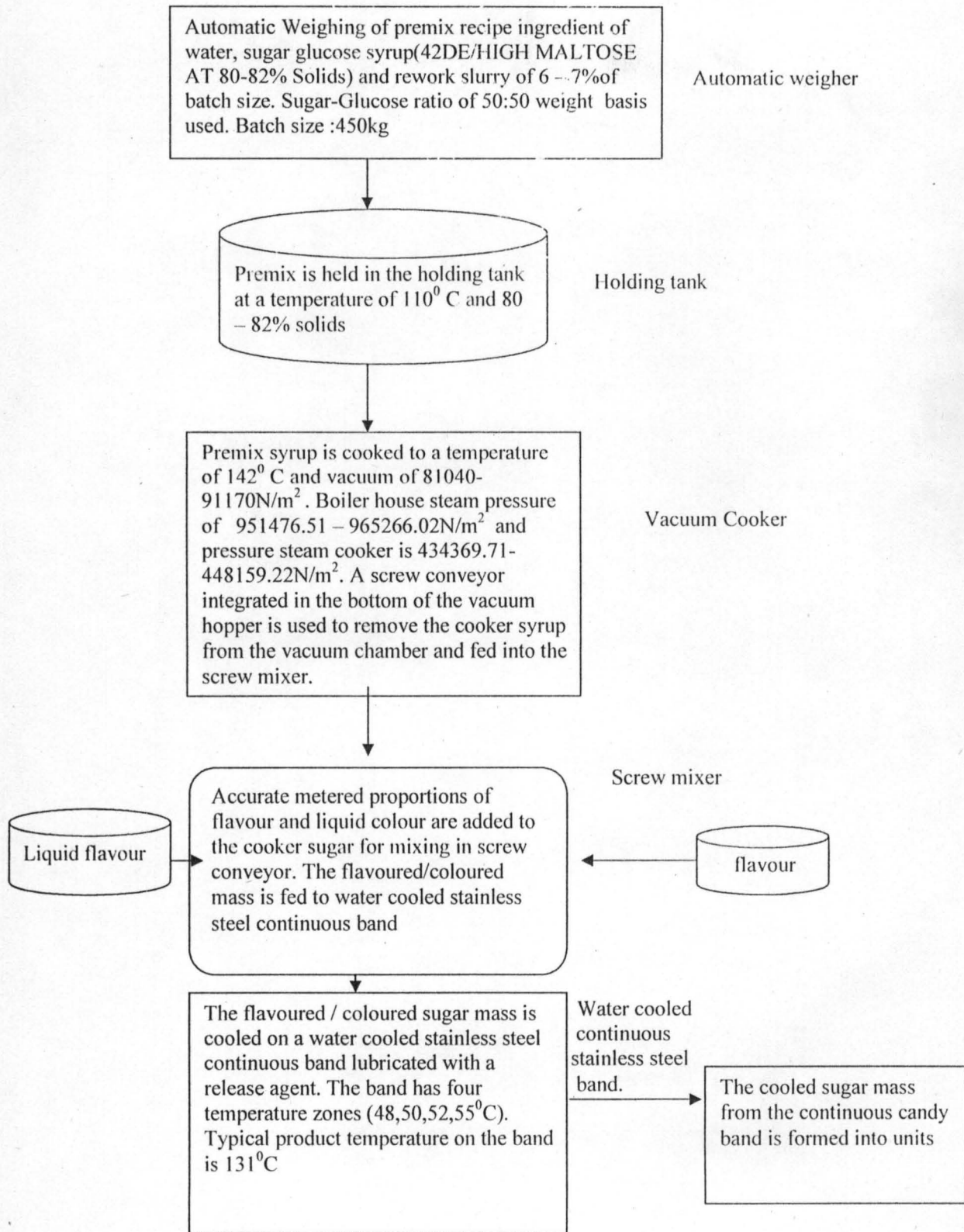


FIG. 1.1: Production Line of Cadbury Showing Continuous Candy Band (Klockner Hansel) Process Map. Rated Capacity: 1.2 Tonnes of Cooked Sugar/ Hr (Cadbury Nigeria Plc., 2004).

1.4 STATEMENT OF THE PROBLEM

Cadbury Nigeria Plc waste contributes to the increasing environmental problems. Improper disposal of effluent contribute to drainages blocks around Ikeja Industrial Estate and also destroys aquatic life. Some of the pollutants are readily biodegradable while some take a long time before they decompose.

The continuous discharge of untreated industrial effluents, laden with lethally toxic chemicals such as cadmium, lead, mercury and persistent organic such as dichloro-diphenyl – trichloroethane (DDT), into drains and surface water exacerbated by improper sewage disposal have rendered most of the sources of water milky, coloured, odouriferous and unwholesome for any beneficial use by man.

These are some of the basic reasons that led to the analysis of waste from Cadbury Nigeria Plc. Information obtained from this study will be used to design efficient end –use treatments and mitigation measures towards the impact of wastes on the Nigerian environments.

1.5 JUSTIFICATION OF THE STUDY

In developing country like Nigeria, the food processing industries are generally less developed compared to developed country. And the potential for generating waste is considerable.

The wastes generated by Cadbury Nigeria Plc contribute to the increasing industrial waste problems. Improper disposal constitute a nuisance to the environmental, and destroys recreational facilities. The perennial scarcity of inorganic fertilizers could be minimized if organic fertilizer is produced from the wastes generated by Cadbury Nigeria Plc.

1.6 OBJECTIVES OF THE STUDY

The main objective of this research study was to analyze the waste from food processing industry.

- a. To identify the wastes generated by Cadbury Nigeria Plc.
- b. To carry out qualitative analysis of wastes (solid and liquid) from Cadbury Nigeria Plc.
- c. To ascertain the conformity of Cadbury's wastes to Federal Environmental Protection Agency (FEPA) and Food and Agricultural Organization Standards (FAO).
- d. To identify the necessary treatments the wastes generated by Cadbury Nigeria Plc undergo.

1.7 SCOPE OF THE STUDY

Research was conducted on the wastes generated by Cadbury Nigeria Plc both solid and liquid.

- a. To find out the process the wastes generated by Cadbury Nigeria Plc undergo.
- b. To determine the pollutants inherent in the waste and hence the waste treatment processes applicable to the industry.
- c. The research does not include assessment of toxicological nature as well as the pathological nature of the waste, because of the limited analytical facilities.

CHAPTER TWO

2.0 LITERATURE REVIEW

In Nigeria, the evolution of organized food processing was started by multinational organizations in the 1950s and 1960s. Raw materials were imported (import substitution programme) to produce largely, foreign-based foods to cater primarily for the needs of expatriate workers and foreign tourists in Nigeria. The multinational food industries still dominate the scene. They include Cadbury Nigeria Plc., Nestle Foods Nigeria Plc, Unilever Nigeria Plc. (formerly Lever Brothers Nigeria Plc.,) U.A.C Foods Nigeria Plc, Guinness Nigeria Plc, Nasco Nigerian Foods Ltd and Flour Mills Nigeria Plc, e.t.c

The food processing industry has grown to diverse proportions and can be classified into several groups (at least five) based on: (i) ownership (ii) scale of operation (iii) level of technology (iv) types of products and (v) management employed (Isah and Aisha, 1994). They are:

- a. The large scale multinational industries;
- b. The large scale government –owned industries some of which have now been privatized.
- c. The medium –scale indigenous food industries.
- d. The small –scale indigenous food industries.
- e. The cottage food industries.

The industries in the first group (a) have the following features:

- i. Employ the most sophisticated imported technology;
- ii. High capital base and skilled manpower;

- iii. May be established through joint venture agreement with local entrepreneurs;
- iv. May be established by multinational corporations;
- v. They provide consumer products that have become popular through acquired taste;
- vi. They are engaged in the production of beverages (alcoholic and non –alcoholic); wheat milling and biscuit production; sweets; confectionery; baby foods and canned products and vegetable extraction refining.

The pioneering efforts both in the public and private sectors saw to the establishment of some food processing factories based on major primary agricultural export raw materials. That is, Palm Oil Mills; Groundnut Oil Mills; Breweries; Cocoa processing; and Palm Kernel processing.

Food is a basic necessity for growth and development. The food industry contributed about 35 percent of the total manufacturing outfit in the 1990s. However, given the harsh economic, social and political environment in Nigeria since the 1990s, it would appear that the food industry must battle for survival, in spite of it's strategic position (Isah and Aisha, 1994).

Nigeria's agriculture and food supply continue to be vulnerable because of the low level of technology input. The low agricultural yield per hectare per farm worker is exacerbated by high post production losses due to poor food processing and handling practices.

The Lagos area dominates the industrial landscape of the country and harbours the majority of food processing industries. Available information from the Association of Food, Beverage and Tobacco Employers (AFBTE) showed that Lagos alone accounts for greater than 45% of the industrial activities in Nigeria.

The proliferation of urban settlement and slums in the city of Lagos has also meant increased human pressures and generation of domestic wastes which eventually find their way into Lagos lagoon. The lagoon receives a complex mixture of domestic and industrial wastes and has served as the ultimate sink for the disposal of domestic sewage since the latter part of the 19th century.

The food processing sub sector of the manufacturing sector of the Nigerian economy is made up of industries with firms that convert raw materials derived from agriculture into edible products. These products come in various forms as solids, semi – solids and liquids. Using the Federal Office of Statistics (FOS) 1994 classification, the major food groups involved in the conversion processes are:

- i. Grain and flour milling products;
- ii. Vegetable Oil extraction/fat extraction;
- iii. Fruits and Vegetables (including roots and tubers);
- iv. Beverage (alcoholic and non –alcoholic).

Entrepreneurs in the food processing sector have encountered difficulties in building up their business due to lack of managerial skill and organization. Every manager aims at achieving a set objective and because of individual differences, their objectives may vary. However, management principles are universal, and apply equally to people in high and low position in all kinds of organizations.

2.1 WASTE LEGISLATION IN NIGERIA

The disposal of wastes from a food processing plant is an integral part of the total production system. To reduce the cost associated with conventional waste treatment, wastes should be recycled and by – product recovery and utilization should be studied as alternatives. These will serve as mechanisms for preventing intrusion of undesirable degradable materials into the environment (Carl et al., 1988). Waste generation is the sole responsibility of the processing industry as well as its disposal but the latter has to be in line with the public sewers and environment. This has led to the enactment of environmental legislation and the law established a stringent regulatory system stating detailed pollution abatement requirements with heavy penalties for violations. Different countries have defined wastes policies on their respective national laws.

Nigeria has been subject to a long history of legislative control. However, there has been no single Parliamentary Act dealing with the broad aspects of waste management. Consequently, waste treatment and disposal of waste is covered by a number of different controlling authorities. Local authorities had powers via various statute dating back to medieval times to control waste as a public health problem. The local authority powers of waste management became established through the Public Health Acts of 1917 and 1991, the Mineral Act 1984, and the Nigerian Urban Regional Planning Acts of 1978 and 1992 (Osuntokun,1998). The increasing concern for the environment and the toxic waste dumping incidents led to demands for tighter legislative controls on waste disposal. In the United Kingdom, as a direct result of the Nuneaton Cyanide dumping incident, emergency legislation was introduced in the form of deposit of Poisonous Waste Act, 1972. The act made it an offence to deposit wastes which were poisonous,

noxious or polluting and liable to give rise to an environmental hazard. Further legislation on waste treatment and disposal followed in 1974 with the control of pollution Act, which controlled waste disposal on land (Paul, 2002). Waste Disposal Authorities were required to prepare plans for the disposal of all households, commercial and industrial wastes likely to arise in their areas. The plans would be required to include information on the types, quantities and sources of wastes arising in the area; the methods of disposal, the sites and equipment being provided and the cost (Osuntokun, 1998).

The late 1980s and 1990s saw further development of waste management legislation and the increasing influence of the Federal Environmental Protection Agency (FEPA), established by Decree 58 of 1988 and amended by Decree 59 of 1992 now Federal Ministry of Environment has the mandate to protect, restore and preserve the ecosystem of the Nigerian Environment and ensure compliance with existing environmental laws. FEPA's approach to waste pollution control is the systematic and integrated abatement and control of waste pollution sources. In the exercise of its mandate as provided in section 16 of Decree 58 of 1988 and amended by Decree 59 of 1992, the National Effluent Limitation Regulations, S.1.8 of 1991 and the Pollution Abatement in industries Facilities Generating Wastes Regulations, S.1.9 are already in force from 15th August, 1991.

Furthermore, section 15 of the FEPA Decree empowers the Agency to set water quality standards for inter state waters of Nigeria, to protect the public health or welfare and enhance the quality of water. In fulfillment of this mandate regarding the Nigerian aquatic environment, the Agency set National Water Quality Guidelines and Standards for various uses, (Aina and Adedipe, 1991).

2.1.1 GOVERNMENT INSTITUTIONAL RESPONSIBILITIES

Several Nigerian Ministries and Agencies, including FEPA, have issued a large number of laws, guidelines, rules and regulations for environmental pollution control in various fields, such as water quality, effluent limitations, air quality, noise control, hazardous substances and wastes. The Nigerian laws are derived from the pre-1990 English Status and have been adapted so that they address the specific problems of environmental degradation and resources depletion.

The main relevant Nigerian national laws which fully or partly concern the environment as contained in the Current Issues in Nigerian Environment Osuntokun, 1998 are;

- 1) Federal Environmental Protection Agency Act Cap 131 Law of Federation of Nigeria 1990.
- 2) Standards Organizations Cap 412 Law of Federation of Nigeria 1990.
- 3) National Resources Conservation Agency Council Act Cap 286 Law of Federation of Nigeria 1990.
- 4) Harmful Waste Act Cap 165 Law of Federation of Nigeria 1990.
- 5) Factories Act Cap 126 Law of Federation of Nigeria 1990.
- 6) Land Use Act Cap 202 Law of Federation of Nigeria 1990.
- 7) Endangered Species Decree Cap 108 Law of Federation of Nigeria 1990.

2.1.2 ENFORCEMENT OF WASTE REGULATIONS

The legal apparatus seems to cover all the main environmental concerns in detail but still needs to be improved upon so as to provide a comprehensive legislation for the environment. This task would lie with Federal Ministry of Justice and the Law Reform

Commission in collaboration with the Federal Ministry of Environment. Moreover, the enforcement of these regulations is a difficult problem. The principal device used by the Ministry in order to induce industries to comply with the existing environmental legislation is of a coercive nature. Penalties ranging from fines, levies, pollution taxes up to arrest of offenders and seizure of equipment have been instituted. No incentives such as tax reduction, subventions or grants have yet been established.

An important component of the enforcement of the environmental regulations is the capacity to verify the compliance of industries through an adapted network of controls. Such a comprehensive mechanism has not yet been put in place, mainly owing to lack of equipment and lack of an efficient structure for control. Receiving the most attention are pathogenic organisms, the removal of organic and inorganic substances such as VOC, and total dissolved solids.

2.2 TYPES OF WASTE

Every industry produces Liquid, Solid and Gaseous wastes.

2.2.1 LIQUID WASTE

The liquid portion, wastewater is essentially the water supply of the industry after it has been fouled by a variety of uses. From the standpoint of sources of generation, wastewater may be defined as combination of the liquid or wastewater removed from residues, institutions and commercial and industrial establishments, together with such groundwater, surface water, and storm water as may be present (Metcalf and Eddy, 1991). If untreated wastewater is allowed to accumulate, the decomposition of the organic materials it contains can lead to the production of large quantities of malodorous gases. In addition, untreated wastewater usually contains numerous pathogenic, or

disease-causing, micro organisms that dwell in the human intestinal tract or that may be present in certain industrial waste. Wastewater also contains nutrients, which can stimulate the growth of aquatic plants, and it may contain toxic compounds. For these reasons, the immediate and nuisance free removal of wastewater from its sources of generation, followed by treatment and disposal, is not only desirable but also necessary in an industrialized society.

The food production and processing industries are concerned particularly with three broad aspects of water technology: Microbiological and Chemical purity and safety, impurities that affect suitability for processing use; and decontamination after use. Contamination affects the difficulty and cost of disposing of wastewater and ultimately affects the cost of manufacturing food (Norman and Joseph, 1995). There are strict environmental regulations regarding the discharge of polluted water from processing plants in Nigeria. Plants which contaminate water with food processing wastes must treat the water to return it to an uncontaminated state before discharging it into surface water.

2.2.2 SOLID WASTE

The processing of raw material is the beginning of solid waste generation. Thereafter, solid wastes are generated at every step in the process as raw materials are converted to goods for consumption. Waste can be any garbage, sludge, gaseous, and other discharged materials resulting from various industrial activities. Solid waste is classified into garbage and rubbish. Garbage are putrefied waste food processing industries, while rubbish are non-perishable waste that are either combustible or non-combustible such as paper, carton, wood, polythene, iron, glasses and ceramics.

operations. Inorganic waste typically includes excessive packaging items, that is plastic, glass and metal. Organic wastes are finding ever-increasing markets for resale and companies are slowly switching to more biodegradable and recycle products for packaging. Excessive packaging has been reduced and recyclable products such as foil, glass and High Density Polythene (HDPE), are being used where applicable.

Solid wastes may have some resale value: cellulose, plastics, metals, empty drums, etc. in these cases, the wastes are collected, packed and sold. Solid waste without value was placed in containers and taken away by the local disposal authorities, for example, Lagos State Urban Waste Management Agency (LSUWMA) or by private contractors.

Activities and actions of Lagos State in environmental protection and industrial pollution control started in the mid seventies (70s), actually before FEPA's creation in 1988. Lagos State Waste Management Agency manages exclusively solid wastes. For this purpose, it has a fleet of vehicles and five dump sites. These include Abule-Egba, Achakpo, Isolo, Ojota and Oworonshoki .

The visits made to the Industry, together with discussions of a move wide – ranging nature with staff and industrialist have made it possible to present a picture of how solid waste are managed in industries at present. Obtaining such information was not easy since the notation of what can constitute a waste pollution is not clearly defined in many people's mind. For this reason, people are often not aware that a pollution problem exists.

Furthermore, the relative poverty of the local population means that many people make a living from wastes, either by sorting and selling plastic bottles, carton, cellophane or metal drums. found at waste dumps or by taking away wastes directly from plants in order to use or resell. Hazardous solid wastes by contrast are usually lost in the general waste evacuation circuits. Only in very rare cases are they kept separate and possibly disposed in burrow pits.

2.2.3 GASEOUS WASTE

Compared to other industries, for example, metal fabrication and pulp and paper making, the food processing industry is not considered energy –intensive. Machines usually require electrical power, which is supplied Nigerian Electric Power Authority (NEPA), to run food processing machinery, but fossil fuel used is low compare to other industries. In some cases, natural gas is used to operate facility boilers. Most operations typically utilize electric power and rarely emit harmful compounds to the environment during normal production operations.

Over the past decades, releases from process industries facilities and the technologies used to minimize them, have come under increased scrutiny from regularly agencies and the public a variety of federal, state and local laws have been enacted to limit releases. While the pending Nigeria Clean Air Acts are expected to be a major driving force toward increased emission control, the law will likely mandate that the maximum achievable control technology (MACT) be installed for those industrial sources and source categories defined by FEPA as major emitters of toxic chemicals. It is clear that all affected facilities must commit to using proven control equipment to minimize toxic chemical releases. Toxic air pollutants (often called simply air toxics) and

acid rain, which is caused by emission of sulphur oxides (SO_x) and nitrogen oxides (NO_x) are currently receiving a great deal of attention in processing industries.

Some gases exist in such small amounts that their volume fraction is measured in parts per million (ppm). However, examination shows that clean air contains methane, nitrogen dioxide, carbon monoxide and sulphur dioxide, all of which are considered to be primary air pollutants. Such substances originate from natural sources such as forest fires and volcanic eruptions, which also add finely divided particulates such as dust to the atmosphere. This is shown in Table 2.1.

Constituent	Molecular formula	Volume
Nitrogen	N ₂	78.09%
Oxygen	O ₂	20.94%
Argon	Ar	0.93%
Carbon dioxide	CO ₂	0.037%
Methane	CH ₄	1.3ppm
Krypton	Kr	1.0ppm
Hydrogen	H ₂	0.5ppm
Nitrous oxide	N ₂ O	0.25ppm
Carbon monoxide	CO	0.1ppm
Ozone	O ₃	0.02ppm
Sulphur dioxide	SO ₂	0.001ppm
Nitrogen atmospheric air.	NO ₂	0.001ppm
Helium	He	5.2ppm

Table 2.1: Typical composition of "clean" dry

Source: Kannappa and David; 1989.

Since "clean air" is not found in nature, it is appropriate to define polluted air as air which contains polluting substances in such concentrations as to cause an unwanted effect. Although such pollutants can be natural, the focus of this project is more concerned with man-made sources.

The gaseous pollutants of greatest importance are carbon monoxide, hydrocarbons, sulphur dioxide, and nitrogen dioxide. Carbon dioxide is listed because of its possible effect in producing changes in the global climate.

EFFECTS OF GASEOUS EMISSION

Human health

All humans require breathe and therefore air pollutants enter the body through the lungs. Pollutants such as sulphur dioxide, nitrogen dioxide and ozone are pungent gases which can harm lung tissue, and are associated with bronchitis, asthma, emphysema and possibly lung cancer. Particulates can also enter the lungs and some, such as lead, fumes and asbestos fibres, are especially dangerous because of their toxic and cancer producing properties (Kannappa and David, 1989).

Carbon monoxide is virtually undetectable by our senses since it is both colourless and odourless. It can be inhaled without irritation or discomfort. It is, however, extremely toxic and can induce illness, coma and even death through asphyxiation.

However, health effects are greatly increased when weather phenomena such as thermal inversions cause pollutants to be trapped and concentrated in an urban area. Many episodes of this have been recorded in which high concentrations of sulphur dioxide and particulates have resulted in a corresponding increase in the death rate of the inhabitants of the area. In some cities, such as Mexico city for example, the geography of the

surroundings hinders the dispersal of polluted air, causing high concentrations and consequent health problems (Wentz, 1989).

Atmosphere and Climate

Suspended particulate matter and gaseous pollutants such as nitrogen oxides and hydrocarbons are responsible for a reduction of visibility in the atmosphere. This can result from scattering of the light rays or from the formation of photochemical smog.

Particulates in the air can appreciably reduce the amount of solar radiation that reaches the surface of the earth, thus causing a decline in average global temperatures. This is seemingly counter-balanced by the so called greenhouse effect in which carbon dioxide from fuel combustion processes acts as a blanket of insulation when trapped in the troposphere. This prevents the re-radiation of heat from the earth surface thus tending to increase average global temperatures.

An ozone layer in the upper atmosphere absorbs harmful ultra-violet radiation from the sun. However, certain air pollutants are thought to be destroying the ozone layer surface to potential hazard.

Vegetation and animals

Many air pollutants have adverse thus exposing the earth effects on vegetation and can damage fruits, vegetables, trees and flowers. Agricultural crops are damaged when leaves are bleached or discoloured. Leaf tissues can collapse causing growth alteration. Animals and livestock can be harmed when they consume forage contaminated by a pollutant.

MEASUREMENT OF GASEOUS EMISSION

If the amount or concentration of the various air pollutants is to be controlled, it is necessary to measure and evaluate air quality. There are two basic methods of collecting the necessary air sample.

1. **AMBIENT AIR QUALITY:** Ambient atmospheric samples are collected from the "open air", that is after the pollutants have dispersed and mixed together under natural weather conditions. This provides background air quality data in urban and rural areas to determine whether established standards are being met or exceeded.

2. **SOURCE SAMPLING:** - Samples of pollutant emission are taken at the point of discharge, for example, from a smoke stacks or factory chimney. The pollutants have not dispersed and mixed with the ambient air. Source sampling evaluates the pollution discharge from a particular machine or process. This provides data to determine whether the discharge from the source is meeting or exceeding emission standards.

The units commonly used to measure pollutant concentrations are $\mu\text{g per m}^3$ (micrograms per cubic metre) or ppm (parts per million). The unit $\mu\text{g per m}^3$ is a mass density measurement and can be used to state both gaseous pollutant and particulate matter concentrations. The unit ppm refers to concentration by volume only, and is used more particular for gaseous pollutants (Kannapa and David, 1989).

GASEOUS POLLUTANTS

Sulphur oxides, (SO_x) specifically Sulphur dioxide (SO_2) and Sulphur trioxide (SO_3) are emitted primarily from facilities burning fossil fuels that contain sulphur.

While

Fossil –fuel combustion is by far the most wide spread source of atmospheric SOX, numerous sources within a typical plant can emit these compounds, including boilers and incinerators.

Nitrogen oxides (NO_x), like sulphur oxides, are mainly formed during combustion, although a few industries also emit this gas from process operations.

NO_x are formed by the oxidation of fuel bound nitrogen (called “fuel NO_x”) and by the fixation of nitrogen in the combustion air at the high temperature associated with combustion (“thermal NO_x”). For example, NO_x emissions from industrial solid –waste incinerators may be comprised of 75 -80% fuel NO_x (Kannappa and David,1989).

These pollutants are categorized as : primary and secondary pollutants. A primary pollutant is one that is emitted directly into the atmosphere and a secondary pollutant is one that is formed in the atmosphere through some type of reaction. Examples of secondary pollutants are acid rain and photochemical smog.

Acid rain refers to rainfall with a pH value significantly below its normal uncontaminated value of about 5.6. Sulphur oxides and nitrogen oxides are emitted from process industries and automobiles, and react with moisture in the atmosphere to form Sulphuric and nitric acids. These acids fall to the earth’s surface as acid rain causing serious damage to forests, fresh water lakes, agricultural crops and materials such as concrete and metal.

Photochemical smog results when nitrogen oxides are acted upon by sunlight to produce ozone. This in turn reacts with hydrocarbons to form a series of complex compounds which seriously reduce visibility and endanger health.

Table 2.1: Gaseous air pollutants

Name	Chemical Formula	Properties Importance	of Significance As Air Pollutant
Sulphur	SO ₂	Colourless gas, intense choking odour, forms sulphurous acid	Damage to vegetation, property and health
Hydrogen Sulphide	H ₂ S	Rotten egg odour	Highly poisonous
Nitric Oxide	NO	Colourless gas	Produced during high temperature combustion. Oxidizes to NO ₂
Nitrogen dioxide	NO ₂	Brown to orange gas	Important role in production of photochemical smog
Carbon monoxide	CO	Colourless and odourless	Poisonous product of incomplete combustion
Carbon dioxide	CO ₂	Colourless and odourless	Formed during combustion. Possibly affects global climate
Ozone	O ₃	Highly reactive	Damages vegetation and materials. Important role in production of photochemical smog
Hydrocarbons	C _x H _y or HC	Many	Emitted from motor vehicles and industry

Source: Kannappa and David, 1989

2.3 HISTORY OF WASTE TREATMENT AND DISPOSAL

The historical development of waste treatment and disposal has been motivated by concern for public health. The industrial revolution between 1750 and 1850 led to many people moving from rural areas to the cities, a massive expansion of the population living in towns and cities, and a consequent increase in the volume of wastes produced.

The production of domestic waste was matched by increases in industrial waste for developing new large scale manufacturing processes. The waste generated contained a range of materials such as broken glass, rusty metal, food residue and human waste, and was dangerous to human health. In addition, it attracted flies, rats and other Vermin which in turn posed potential threats through the transfer of diseases (Paul, 2002). To deal with this potential threat to human health, legislation was introduced on a local and national basis in many countries. For example, in Nigeria, throughout the latter half of the nineteenth century, a series of Nuisance Removal and Diseases Prevention Acts were introduced which empowered local authorities. These Acts were reinforced by the Public Health Acts of 1917 and 1991 which covered a range of measures, some of which were associated with the management and disposal of waste. The 1917 Act placed a duty on local authorities to arrange for the removal and disposal of waste. The 1991 Act introduced regulation to control the disposal of waste into water, and defined the statutory nuisance associated with any trade, business, manufacture or process which might lead to the degradation of health or of the neighborhood.

Following the Second World War, waste treatment and disposal was not seen as a priority environmental issue by the general public and legislature, and little was done to regulate the disposal of waste. However, a series of incidents in the late 1960s and 1970s

highlighted waste as a potential major source of environmental pollution. A series of toxic chemical waste dumping incidents led to increasing awareness of the importance of waste management and the need for a more stringent legislative control of waste. Amongst the most notorious incidents were the discovery, in 1972 of drums of toxic cyanide waste dumped indiscriminately on a site used as children's playground near Numeaton in the UK. The dumping of 3000 tonnes of arsenic and cyanide waste into a lake in Germany in 1871, and the leak of Polychlorinated biphenyls (PCBS) into rice oil in Japan in 1968, the "Yusho " incident. The industrialized countries have experienced very serious environmental disaster from waste pollution as a price of their industrial development. For example, the Japanese heavy metal poisoning caused by mercury (Manamata disease) and Cadmium (Itai-Itai disease) in 1960's cannot be easily forgotten. During the 1970's in the U.S.A., pesticide and polychlorinated biphenyl (PCBS) Contamination of fish in the upper great lakes brought a flourishing commercial fish industry to an abrupt halt. The Love Canal episode in Niagara falls, USA, in the 1970's and early 1980's also come readily to mind. Ground water contaminated by toxic chemicals and leachate resulted in high prevalence of spontaneous abortion in pregnant women. There were also, several birth defects and high incidence of cancer among the residents. The entire Love Canal community had to be evacuated and relocated.

Since the 1960's many developed countries have established institutional framework and regulatory machinery for waste pollution control for different uses. The first United Nations Conference on Human Environment was held in Stockholm in Sweden, 1972 to address the need for international action to stem the catalogue of

environmental woes arising from waste pollution and other forms of environment pollution (Paul, 2002). ✓

The history of waste pollution problems in Nigeria dates back to late 1970's and early 1980's when outbreak of cholera epidemics and other water-borne disease occurred as a result of gross organic pollution of river water with raw human wastes. Industrial and technological developments in the country further compounded the waste pollution problem. For example, the accidental discharge of waste containing high ammonia level into Okrika River from NAFCON ,a fertilizer company near Port-Harcourt in 1988 caused massive fish kill and socio-economic problem for the artisan fishery industries in the surrounding village. The villagers claimed about ₦3 million compensation from the company.

Petroleum product spillage from the Kaduna Refinery in 1987 into Romi and Rido River. Well waters in Rido village as well as the Rido and Romi River were grossly polluted. Compensation of more ₦3million had been paid had to the villagers affected by the waste pollution problems caused.

In 1979, industrial effluent from Ikeja Industrial Estate through WEMABOD Treatment plant which had broken-down, spilled into Idimangoro area due to the blockage one the man-holes on the effluent channel. Well water, in the area were grossly polluted. Surface and ground waters have been beset with waste pollution problems of toxic synthetic chemicals such as heavy metal and pesticides, nutrient enrichment and recently, acidification (Aina and Adedipe, 1991). ✓

2.4 WASTE TREATMENT OPERATIONS, PROCESSES AND CONCEPTS

These are methods of removing toxic and hazardous components. If these components are incorporated into gases, as is the case with stack emission, physical methods such as cyclone separation, electrical precipitation or filtration can be used, as chemical treatments such as liquid scrubbing or oxidation techniques. In the case of liquids filtration, electrolysis, electro dialysis, reverse osmosis, chlorination, hydrolysis, freeze-thaw, oxidation, chemical precipitation, solidifications, biological and ion - exchange techniques are all available. In all these cases the hazardous material is separated as a minor component from the bulk gas or liquid, usually as a solid or slurry requiring subsequent disposal. For solids, dewatering, chemical treatment, oxidation, incineration, pyrolysis and encapsulation can all be considered. Chemical methods such as oxidation and chlorination may also be used.

(a) Incineration

Industrial wastes have a variety of physical forms and a large range of calorific values, which makes virtually impossible the design of an incinerator capable of oxidizing both liquids and solids completely; this usually requires high temperatures and long residence times. Because of this, units have either been used outside their design limits, with resultant unsatisfactory performance, or several smaller, incinerators have had to be used for each individual purpose.

Incineration can efficiently decompose most organic substances and should be mandatory for pathogenic materials; it is preferred for pesticides and other physiologically active wastes. It has been found that temperatures in excess of 1000C and residence times of more than two (2) seconds are generally needed for complete

combustion. Since many of these wastes contain sulphur, phosphorus or halogens it is essential to have efficient gas scrubbing equipment to remove the acidic oxides produced, it increasing the cost (Paul, 2002).

(b) Pyrolysis

When complete combustion of a substance to gaseous oxides is not attained, either intentionally as in the production of charcoal or unintentionally as a consequence of poor combustion in an incinerator, then the substance is said to have undergone pyrolysis. The method is not usually used to destroy dangerous waste materials, since the products are often more hazardous than their progenitor (Paul,2002).s

(c) Biological Treatment

Various biological methods are used for the treatment of sewage and for wastes with a high Biological Oxygen Demand (BOD), such as those from the food processing industry.

(d) Chemical Treatment

Because of the need to comply with limits when discharging an effluent, most industrial firms who need to do so treat their own waste before it leaves the premises. Very few treatment facilities exist in the disposal industry and those that do consist mainly of precipitation, neutralization, hydrolysis, and cyanide treatment plants.

(e) Physical Treatment

Filtration, distillation, separation, and centrifuge techniques are all used for removal of hazardous materials from quantities of inert bulk waste.

They are in general not used for treatment of waste containing a high concentration of dangerous waste.

(f) Encapsulation

There are two types of encapsulation. One is where material is enclosed in a bunker, bottle, can drum or rock chamber made of an impervious inert material so that no reaction can take place. The other is where the waste intimately mixed with an inert matrix, usually based on complex silicates or aluminates, but inert plastics or bitumen may also be used, in which the waste is held by chemical and physical forces.

A simple method is to encase a waste in concrete or bitumen within a steel drum; the whole may then be land filled with a high degree of integrity and the method is used for difficult materials such as beryllium, arsenic, antimony, cadmium, mercury, and other compounds.

(g) Dilution, delay and dispersion

Disposal requires the solid, liquid or gas to be diluted to such an extent that the concentration of the hazardous substance becomes so low that it is effectively non-hazardous. This can be achieved either by dispersing a small amount of the waste into a large volume of the waste so that only limited quantities can enter the environment.

(H) Landfill

Approximately 80% of notifiable waste is land filled and the amount is probably nearer 98% for all general waste and refuse.

Since notifiable wastes account for only about 4 million tonnes, and industrial, commercial and household wastes for 43 million tonnes, if the wastes were dispersed evenly there would be a built-in dilution factor of 10:1 excluding any other attenuating mechanisms. (Paul, 2002). Wastes containing calcium, selenium, antimony, thallium, beryllium, tellurium and mercury may be land filled.

Landfill is not an ideal disposal option for organic substances but, nonetheless, large quantities are dumped in spite of their potential as a source of heat. In many cases, especially with solids which are water insoluble and solvents which evaporate, the technique is generally adequate. There are problematic substances amongst these, namely many phenolic compounds which can migrate large distances through rock structure..

Landfill therefore is a satisfactory disposal option for many wastes provided:

1. The site is geologically and hydro geologically suitable.;
2. The quantity and type of material introduced is controlled so that overloading or dangerous mixtures are avoided;
3. The liquid intake is controlled;
4. Sufficient inert material can, if necessary be introduced as diluents.

(i) Storage

For some materials it may be prudent to consider permanent storage. For example, a formulation containing an organic pesticide together with a mercury compound is a case in point. Incineration cannot be used because of the mercury; landfill cannot be used because of the pesticide. Chemical treatment could be used but it would be expensive and, in practice, it is not always possible to persuade a commercial concern to undertake such a potentially dangerous programme of work (Paul, 2002).

2.5 RECYCLING, RECOVERY AND LOW-WASTE TECHNOLOGY

The ultimate method of waste control is not to produce waste. This can partially be achieved by recycling or recovering materials as close as possible to the point of origin, which is easier than attempting to abstract the material at a later stage. Many industries are technologically capable of implementing material recovery systems but the decision

to do so is usually made on economic and not environmental grounds, although with increasing public concern this position may change. One reason for this lack of commitment is that the industry is based on a large number of small concerns to whom the capital cost of the equipment would be prohibitive. Only the larger concerns are considering the installation of recycling plant.

If recycling within the manufacturing stage is impractical, then materials can be removed from the effluents. Most effluent or gas treatment facilities recover the waste as a precipitated sludge and the economics of material recovery from these are generally unfavorable. However, restrictive legislation, increasing disposal costs, and increasing commodity prices may alter the situation.

Reductions in the amount of hazardous wastes produced may also be made by attention to plant design and further progress should be possible in this area.

If a waste that is noxious and difficult to handle is being produced, then it may be advantageous to alter the manufacturing process itself to avoid its generation.

To eliminate or reduce such wastes an assessment should first be made of all possible plant and manufacturing route improvements and all recycling and recovery procedures. If, for practical reasons, no further reduction in waste output can be made, then the aim should be to produce as little as possible and to segregate any hazardous material from the main bulk. Having done this, the remainder has to be disposed of or treated.

2.6. REGULATION AND STANDARDS OF FOOD PROCESSING

The availability of sufficient and suitable water and means for disposal of plant wastes always have been prime factors in determining food plant locations. Enforcement of antipollution laws is now challenging the economic feasibility of many existing food

production and processing operations. Today, materials that were formally considered wastes are converted to useful by-products in order to dispose of them more economically. In the past, the food engineer primarily was concerned with purity and chemical composition of water as it affect processing and food properties; problems of waste disposal were left mostly to the sanitary engineer. Now the food engineer and the sanitary engineer commonly plan and work together, since the increasing problems in handling food wastes are having direct effects on acceptable methods of food processing and disposition of the less desirable fractions of food raw materials (Norman and Joseph, 1995). Regulations in the food industry has to do with making a set of quality control standards specified by the regulatory body. In Nigeria, the Standard Organization of Nigeria (SON), established in 1970 and the National Agency for Food and Drug Administration and Control (NAFDAC) have joint responsibility to monitor the standards described for processed food and / or regulate the activities of the industry.

For food destined for the export market, food processors must produce foods which meet the specifications and standards set by both the National Agency as well as the Codex Alimentarius Commission (CAC). Codex Alimentarius Commission (CAC), established in 1962 sets international standards for food and agricultural products (Isah and Aisha, 1994).

2.7 PROPERTIES AND REQUIREMENTS OF PROCESSING WATERS

Water entering a food processing plant must meet health standards for portable (drinking) water. The Federal Environmental Protection Agency has issued National Primary Drinking Water Regulations (Table 2.3)

Regulations covering radioactive contaminants and certain volatile synthetic organic chemicals have been added. These regulations are primarily concerned with health. Secondary regulations deal with colour, taste, and other aesthetic qualities. In addition to the chemical limits for safety of portable water, this water must be free from contamination with sewage, pathogenic organisms, and organisms of intestinal origin. Regulations call for such water to contain no more than one coliform organism (statistical value) per 100ml. Coliform organisms of the type assayed are not pathogenic in themselves but serve as a sensitive index of possible sewage contamination, which if present could harbour many kinds of human pathogens. Such water from municipal supplies or from private wells meeting these EPA recommendations for drinking purposes may not be suitable for certain food processing uses. On the other hand, this same water may be used as a heat exchange medium to condense vapours from an evaporator, to heat canned food in a retort, or to pre-chill orange concentrate en-route to a freezer. It then may still be quite suitable for subsequent plant reuse without further purification, for cleaning or conveying fruits and vegetables, or for plant cleanup purposes. Such reuse of water within the plant cuts down on water cost, minimizes the volume of plant waste water that is discharged and represents efficient operation.

Table 2.3: EPA National Interim Primary Drinking Water Regulations.

Characteristics	Limit not to be Exceeded
Inorganic chemicals	
Arsenic	0.05mg/litre
Barium	1.0
Cadmium	0.010
Chromium	0.05
Lead	0.05
Mercury	0.002
Nitrate	10.0
Selenium	0.01
Silver	0.05
Fluoride	1.4 – 2.4
Organic chemicals	
Limit not to be Exceeded	
Endrin	0.0002mg/litre
Lindane	0.004
Methoxychlor	0.1
Toxaphene	0.005
2,4 -D	0.1
2,4,5-TP silver	0.01
Turbidity	1 unit (statistical value)
Coliform bacteria	1/100ml (statistical value)

Source: Adapted from Federal Environmental Protection Agency (1991)

2.8 WASTEWATER COMPOSITION

Water is essential for all forms of life on earth. The end result of water use is, of course, wastewater or polluted water. The concern for water pollution is necessary not only for human health but also to conserve natural beauty and resources.

Wastewater is characterized in terms of its physical and biological composition. Before wastewater can be controlled it is, of course, necessary to measure water quality. This can be difficult since the pollutants are often at low concentrations and sometimes the substances responsible for the pollution are not known.

The results of the analysis of wastewater samples are expressed in terms of physical and chemical units of measurements. Measurements of chemical parameters are usually expressed in the physical unit of milligrams per liter (mg/l) or grams per cubic metre (g/m³).

The most important physical characteristics of wastewater is its total solids content, which is composed of floating matter, settleable matter, colloidal matter, and matter in solution. Other important physical characteristics include odours, temperature, density, colour and turbidity

2.9 WASTE WATER TREATMENT PROCESS

After treatment objectives have been established for a specific project and the applicable state and federal regulations have been reviewed, the degree of treatment can be determined by comparing the influent wastewater characteristics to the required effluent wastewater characteristics. Treatment is used either to render a substance harmless, or to change its physical characteristics to facilitate subsequent disposal.

Wastewater is processed in a sewage treatment plant which is shown diagrammatically in figure 2.2.

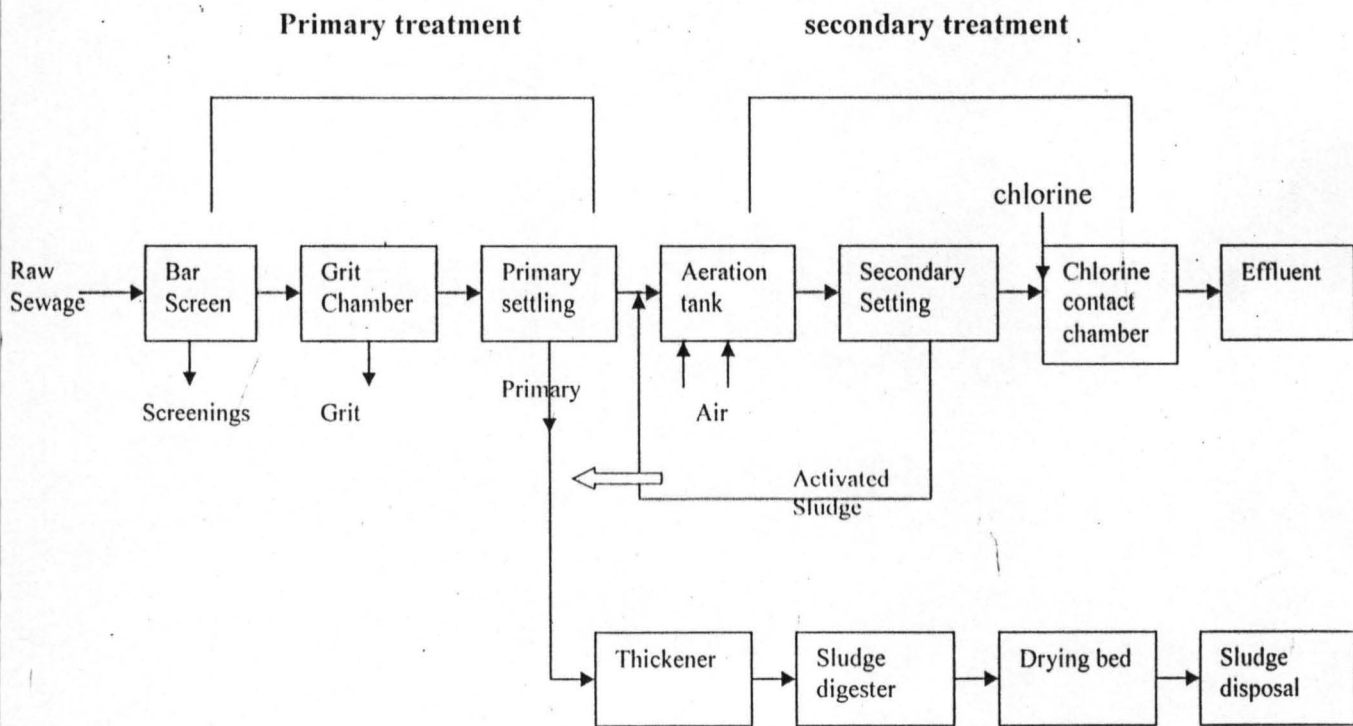


Fig 2.2 Wastewater Treatment Plant

The contaminants in wastewater are removed by physical, chemical and biological means. The individual methods usually are classified as physical unit operations, chemical unit process, and biological unit processes.

PHYSICAL UNIT OPERATIONS

Treatment methods in which the application of physical forces predominates are known as physical unit operations. Because most of these methods evolved directly from man's first observations of nature, they were the first to be used for wastewater treatment.

The unit operations most commonly used in wastewater treatment is flow meterings;

screening; flow equalization; mixing; sedimentation; accelerated gravity setting; flotation; filtration; gas transfer; and volatilization and gas stripping.

FLOW MEASUREMENT

A complete flow measurement system consists of two elements: (1) a sensor or detector and (2) a converter device. The sensor or detector is exposed to or affected by the flow; the converter is the device used to translate the signal or reading from the sensor into a flow reading.

Important criteria that must be considered in the selection of flow metering devices include type of application, proper sizing, fluid composition, accuracy, head loss, operating environment, and ease of maintenance.

SCREENING

The first unit operation encountered in wastewater treatment plants is screening. A screen is a device with openings, generally of uniform size, that is used to retain the coarse solids found in wastewater.

The screening element may consist of parallel rods or wires, grating, wire mesh, or perforated plate, and the openings may be of any shape but generally are circular or rectangular slots. A screen composed of parallel bars or rods is called a bar rack (sometimes called a bar screen)

FLOW EQUALIZATION

Flow equalization is used to overcome the operational problems caused by flow rate variations, to improve the performance of the downstream processes, and to reduce the size and cost of downstream treatment facilities.

Flow equalization simply is the damping of flow rate variations so that a constant or nearly constant flow rate is achieved. This technique can be applied in a number of different situations, depending on the characteristics of the collection system. The principal applications are for the equalization of

- (1) Dry weather flows
- (2) Wet -weather flows from separate sanitary sewage
- (3) Combined storm water and sanitary wastewater flows
- (4) Mixing

Mixing is an important unit operation in many phases of wastewater treatment, including (i) the mixing of one substance completely with another, (ii) the mixing of liquid suspension (iii) the blending of miscible liquids, (iv) flocculation, and (v) heat transfer. An example is the mixing of chemicals with wastewater, i.e. where chlorine or hypochlorite is mixed with the effluent from secondary setting tanks. Most mixing operations in wastewater can be classified as continuous -rapid (30s or less) or continuous. Continuous -rapid mixing is used most often where one substance is to be mixed with another. Continuous mixing is used where the contents of a reactor or holding tank or basin must be kept in suspension.

SEDIMENTATION

Sedimentation is the separation from water, by gravitational setting, of suspended particles that are heavier than water. It is one of the most widely used unit operations in wastewater treatment. The terms sedimentation and setting are used interchangeably. A sedimentation basin may also be referred to as a sedimentation tank, settling basin, or settling tank.

Sedimentation is used for grit removal, particulate -matter removal in the primary settling basin, biological - floc removal in the activated -sludge settling basin; and chemical floc removal when the chemical coagulation process is used. It is also used for solids concentrations in sludge thickeners. In most cases, the primary purpose is to produce a clarified effluent, but it is also necessary to produce sludge with a solids concentration that can be easily handled and treated. On the basis of the concentrations and the tendency of particles to interact, four types of settling can occur: discrete particle, flocculants, hindered (also called zone), and compressions. During a sedimentation operation, it is common to have more than one type of settling occurring at a given time, and it is possible to have all four occurring simultaneously.

ACCELERATED GRAVITY SEPARATION

Sedimentation, as described in the previous section, occurs under the force of gravity in a constant acceleration field. The removal of settle able particles can also be accomplished by taking advantage of a changing acceleration field.

A number of devices that take advantage of both gravitational and centrifugal forces and induced velocities have been developed for the removal of grit from wastewater.

The principles involved in one such device, known as the Tea-cup separator. In appearance, the tea-cup separator looks like a squat tin can. Wastewater, from which grit is to be separated is introduced tangentially near the bottom and exists tangentially through the opening in the top of the unit. Grit is removed through the opening in the bottom of the unit.

FLOATATION

Flotation is a unit operation used to separate solid or liquid particles from a liquid phase. Separation is brought about by introducing fine gas (usually air) bubbles into the liquid phase. The bubbles attach to the particulate matter, and the buoyant force of the combined particle and gas bubbles is great enough to cause the particle to rise to the surface. Particles that have a higher density than the liquid can thus be made to rise. The rising of particles with lower density than the liquid can also be facilitated (e.g. oil suspension in water).

In wastewater treatment, flotation is used principally to remove suspended matter and to concentrate biological sludge. The principal advantage of flotation over sedimentation is that very small or light particles that settle slowly can be removed more completely and in a shorter time. Once the particles have been floated to the surface, they can be collected by a skimming operation.

GRANULAR -MEDIUM FILTRATION

Although filtration is one of the principal unit operation used in the treatment of potable water, the filtration of effluents from wastewater treatment processes is a relatively recent practice. Filtration is now used extensively for achieving supplemental removals of suspended solids (including particulate BOD) from wastewater effluents of

biological and chemical treatment processes. Filtration is also used to remove chemically precipitated phosphorus.

The complete filtration operation is comprised of two phases: filtration and cleaning or regeneration (commonly called backwashing). While the description of the phenomena occurring during the filtration phase is essentially the same for all the filters used for wastewater filtration, the cleaning phase is quite different depending on whether the filter operation is of the semi-continuous or continuous type. As the name implies, in semi-continuous filtration the filtering and cleaning phases occur sequentially, whereas in continuous filtration the filtering and cleaning phases occur simultaneously.

GAS TRANSFER

Gas transfer may be defined as the process by which gas is transferred from one phase to another, usually from the gaseous to the liquid phase. It is a vital part of a number of wastewater treatment processes. For example, the functioning of aerobic processes, such as activated-sludge biological filtration and aerobic digestion, depends on the availability of sufficient quantities of oxygen. Chlorine, when used as a gas, must be transferred to solution in the water for disinfection purposes. Oxygen is often added to treated effluent after chlorination (pasteurization). One process for removing nitrogen compounds consists of converting the nitrogen to ammonia and transferring the ammonia gas from the water to air.

The most common application of gas transfer in the field of wastewater treatment is in the transfer of oxygen in the biological treatment of wastewater. Because of the low solubility of oxygen and the consequent low rate of oxygen transfer, sufficient oxygen to meet the requirements of aerobic waste treatment does not enter water through normal

surface air-water interfaces. To transfer the large quantities of oxygen that are needed, additional interfaces must be formed. Either air or oxygen can be introduced into the liquid, or the liquid in the form of droplets can be exposed to the atmosphere.

VOLATIZING AND GAS STRIPPING OF VOLATILE ORGANIC COMPOUNDS (VOCs) FROM WASTEWATER MANAGEMENT FACILITIES

In the past few years a number of volatile organic compounds (VOCs) such as trichloroethylene (TCE), and 1,2-dibromo - 3- chloropropane (DBCP) have been detected in wastewater. The uncontrolled release of such compounds that now occurs in wastewater collection systems and wastewater treatments plants is an area of growing concern. The principal mechanisms governing the emission of VOCs in wastewater collection and treatment facilities are (i) Volatilization and (ii) gas stripping volatilization. The release of VOCs from wastewater surface to the atmosphere is termed volatilization. Volatile organic compounds are released because they partition between the gas and water phase until equilibrium concentrations are reached. The mass transfer (movement) of a constituent between these two phases is a function of the constituent concentration in each phase relative to the equilibrium concentration. Thus, the transfer of a constituent between phase is greatest when the concentration in one of the phases is far from equilibrium. Because the concentration of VOCs in the atmosphere is extremely low, the transfer of VOCs usually occurs from wastewater to the atmosphere.

Gas stripping of VOCs occurs when a gas (usually air) is temporarily entrained in wastewater or is introduced purposefully to achieve a treatment objective. When gas is introduced into a wastewater, VOCs are transferred from the wastewater to the gas. The forces governing the transfer between phases are the same as described above. For this

reason, gas (air) stripping is most effective when contaminated wastewater is exposed to contaminant free air. In wastewater treatment, air stripping occurs most commonly in aerated grit chambers, aerated biological treatment processes, and in aerated transfer channels.

CHEMICAL UNIT PROCESSES

Treatment methods in which the removal or conversion of contaminants is brought about by the addition of chemicals or by other chemical reactions are known as chemical unit processes. The methods are: Precipitation; Adsorption, and Disinfection are the most common examples used in wastewater treatment. In chemical precipitation, treatment is accomplished by producing a chemical precipitate that will settle. In most case, the settled precipitate will contain both the constituents that may have reacted with the added chemicals and the constituents that were swept out of the wastewater as the precipitate settled.

Adsorption involves the removal of specific compounds from the wastewater on solid surfaces using the forces of attraction between bodies.

CHEMICAL PRECIPITATION

Chemical precipitation in wastewater treatment involves the addition of chemicals to alter the physical state of dissolved and suspended solids and to facilitate their removal by sedimentation. Over the years a number of different substances have been used as precipitants. The most common chemicals are (1) alum, (2) lime (3) ferrous sulphate (copperas) and lime (4) ferric chloride (5) ferric chloride and lime and (6) ferric sulphate and lime. It is possible by chemical precipitation to obtain a clear effluent, substantially free from matter in suspension or in the colloidal state.

From 80 to 90% of the total suspended matter, 40 to 70% of the BOD5, 30 to 40% of the COD, and 80 to 90% of the bacteria can be removed by chemical precipitation. In comparison, when plain sedimentation is used, only 50 to 70% of the total suspended matter and 30 to 40% of the organic matter settles out. (Metcalf and Eddy, 1991)

ADSORPTION

Adsorption, in general, is the process of collection of soluble substances that are in solution on a suitable interface. The interface can be between the liquid and a gas, a solid or another liquid. In the past, the adsorption process has not been used extensively in wastewater treatment, but demands for a better quality of treated wastewater effluent have led to an intensive examination and use of the process of adsorption on activated carbon. Activated – carbon treatment of wastewater is usually thought of as a polishing process for water that has already received normal biological treatment. The carbon in this case is used to remove a portion of the remaining dissolved organic matter. Depending on the means of contacting the carbon with the water, the particulate matter that is present may also be removed.

DISINFECTION

Disinfection refers to the selective destruction of disease –causing organisms. All the organisms are not destroyed during the process. This differentials disinfection from sterilization, which is the destruction of all organisms. In the study of wastewater treatment the three categories of human enteric organisms of the greatest consequence in producing disease are bacteria, viruses and amoebic cysts. Diseases caused by water borne bacteria include typhoid, cholera, paratyphoid, and bacillary dysentery; disease caused by water borne viruses include poliomyelitis and infections hepatitis. Disinfection

is most commonly accomplished by the use of (1) Chemical agents, (2) Physical agents, (3) Mechanical means, and (4) Radiation.

Chemical Agents

Chemical agents that have been used as disinfectants include (1) Chlorine and its compounds, (2) bromine, (3) iodine, (4) ozone, (5) Phenol and phenolic compounds, (6) alcohols, (7) Heavy metals and related compounds, (8) dyes, (9) soaps and synthetic detergents, (10) Quaternary Ammonium compounds, (11) Hydrogen peroxide and (12) various alkalis and acids.

Of these, the most common disinfectants are the oxidizing chemicals, and chlorine is the one most universally used. Bromine and iodine have also been used for wastewater disinfection. Ozone is a highly effective disinfectant, and its use is increasing even though it leaves no residual.

Highly acidic or alkaline water can also be used to destroy pathogenic bacteria because water with a pH greater than 11 or less than 3 is relatively toxic to most bacteria.

Physical Agents

Physical disinfectants that can be used are heat and light. Heating water to the boiling point, for example, will destroy the major disease – producing non spore – forming bacteria. Heat is commonly used in the beverage and dairy industry, but it is not a feasible means of disinfecting large quantities of wastewater because of the high cost.

Sunlight is also a good disinfectant. In particular, ultraviolet radiation can be used. Special lamps that emit ultraviolet rays have been used successfully to sterilize small quantities of water. The efficiency of the process depends on the penetration of the rays into water. The contact geometry between the ultra violet light source and the water

is extremely important because suspended matter, dissolved organic molecules and water itself, as well as the micro-organisms, will absorb the radiation. It is therefore difficult to use ultraviolet radiation in aqueous systems, especially when large amounts of particulate matter are present.

Radiation

The major types of radiation are electromagnetic acoustic, and particle gamma rays are emitted from radioisotopes such as cobalt 60. Because of their penetration power, gamma rays have been used to disinfectant (sterilize) both water and wastewater.

Mechanical Means

Bacteria and other organisms are also removed by mechanical means during wastewater treatment. Typical removal efficiencies for various treatment operations and processes are reported in table 2.4. The first four operations listed may be considered to be physical. The removals accomplished are a by-product of the primary function of the process.

Table 2.4: Removal or destruction of bacteria by different treatment processes

<i>Process</i>	<i>Percent removal</i>
Coarse screens	0 -5
Fine screens	10 -20
Grit chambers	10-25
Plain sedimentation	25-75
Chemical sedimentation	40-80
Trickling filters	90 -95
Activated sludge	90-98
Chlorination of treated wastewater	98 -99

MECHANISMS OF DISINFECTANTS

Four mechanisms that have been proposed to explain the action of disinfectants are (i) damage to the cell wall, (ii) alteration of cell permeability, (iii) alteration of the colloidal nature of the protoplasm, and (iv) Inhibition of enzymes activity.

Damage or destruction of the cell wall will result in cell lysis, and death. Some agents, such as penicillin, inhibit the synthesis of the bacterial cell wall.

Agents such as phenolic compounds and detergents alter the permeability of the cytoplasmic membrane. These substances destroy the selective permeability of the membrane and allow vital nutrients, such as nitrogen and phosphorus, to escape. Heat radiation and highly acidic or alkaline agents alter the colloidal nature of the protoplasm. Heat will coagulate the cell protein and acids or bases will denature proteins, producing a lethal effect.

Another mode of disinfection is the inhibition of enzyme activity. Oxidizing agents, such as chlorine, can alter the chemical arrangement of enzymes and deactivate the enzymes.

BIOLOGICAL UNIT PROCESSES

Treatment methods in which the removal of contaminants is brought about by biological activity are known as biological unit processes. Biological treatment is used primarily to remove the biodegradable organic substances (colloidal or dissolved) in wastewater. Basically, these substances are converted into gases that can escape to the atmosphere and into biological cell tissue that can be removed by settling.

Biological treatment is also used to remove nutrients (nitrogen and phosphorus) in wastewater. The objectives of the biological treatment of wastewater. The objectives of the biological treatment of wastewater are to coagulate and remove the non settleable colloidal solids and to stabilize the organic matter. For industrial wastewater, the major objective is to reduce the organic content and, in many cases, the nutrients such as nitrogen and phosphorus. In many locations, the removal of trace organic compounds that may be toxic is also an important treatment objective. For agricultural return wastewater, the objective is to remove the nutrients, specifically nitrogen and phosphorus, that are capable of stimulating the growth of aquatic plants. For industrial wastewater, the objective is to remove or reduce the concentration of organic and inorganic compounds.

Because many of these compounds are toxic to micro-organisms, pretreatment may be required.

The major biological processes used for wastewater treatment are aerobic processes, anoxic processes, anaerobic processes, combined aerobic, anoxic, and

anaerobic processes, and pond processes. The individual processes are further subdivided, depending on whether treatment is accomplished in suspended – growth systems, attached –growth systems, or combinations thereof.

The principal applications of biological treatment processes are for (1) the removal of the carbonaceous organic matter in wastewaters, usually measured as BOD, total organic carbon (TOC), or chemical oxygen demand (COD); (2) nitrification; (3) denitrification; (4) phosphorus removal; and (5) waste stabilization

2.9.1 TOTAL SOLIDS

Analytically, the total solids content of a wastewater is defined as all the matter that remains as residue upon evaporation at 103 - 1050C. Matter that has a significant vapour pressure at this temperature is lost during evaporation and is not defined as a solid. Total solids, or residue upon evaporation, can be further classified as non filterable suspended or filterable by passing a known volume of liquid through a filter.

The filterable–solids fraction consists of colloidal and dissolved solids. The colloidal fraction consists of the particulate matter with an approximate size range of from 0.001 to 1 μ m. The dissolved solids consist of both organic and inorganic molecules and ions that are present in true solution in water. The colloidal fraction cannot be removed by settling. Generally, biological oxidation or coagulation, followed by sedimentation is required to remove these particles from suspension.

2.9.2 ODOURS

Odours in domestic wastewater usually are caused by gases produced by the decomposition of organic matter or by substances added to the wastewater. Fresh wastewater has a distinctive, somewhat disagreeable odour, which is less objectionable

than the odour of wastewater that has undergone anaerobic (devoid of oxygen) decomposition. The most characteristic odour of stale or septic wastewater is that of hydrogen sulphide, which is produced by anaerobic micro-organisms that reduce sulphate to sulphide. Industrial wastewater may contain either odorous compounds or compounds that produce odours during the process of wastewater treatment.

2.9.3 TEMPERATURE

The temperature of wastewater is commonly higher than that of the water supply, because of the addition of warm water from industrial activities. As the specific heat of water is much greater than that of air, the observed wastewater temperatures are higher than the local air temperatures during most of the year and are lower only during the hottest months. Depending on the geographic location and time of year, the effluent temperatures can either be higher or lower than the corresponding influent values.

In addition, oxygen is less soluble in warm water than in cold water. The increase in the rate of biochemical reactions that accompany an increase in temperature, combined with the decrease in the quantity of oxygen present in surface waters, can often cause serious depletions in dissolved oxygen concentrations in the hotter months. When significantly large quantities of heated water are discharged to natural receiving waters, these effects are magnified. It should also be realized that a sudden change in temperature can result in a high rate of mortality of aquatic life. Moreover, abnormally high temperatures can foster the growth of undesirable water plants and wastewater fungus.

Optimum temperatures for bacterial activity are in the range from about 25 - 35°C. Aerobic digestion and nitrification stop when the temperature rises to 50°C. When the temperature drops to about 15°C, methane-producing bacteria become quite

inactive, and at about 50C, the autotrophic nitrifying bacteria practically cease functioning. At 20C, even the chemoheterotrophic bacteria acting on carbonaceous material become essentially dormant (Metcalf and Eddy, 1991).

2.9.4 DENSITY

The density of wastewater ρ_w is defined as its mass per unit volume expressed as kg/m³. Density is an important physical characteristic of wastewater because of the potential for the formation of density currents in sedimentation tanks and other treatment units. The density of domestic wastewater that does not contain significant amounts of industrial waste is essentially the same as that of water at the same temperature. In some cases, the relative density of the wastewater R_w , defined as $R_w = \rho_w / \rho_0$ where ρ_0 is the density of water, is used in place of the density. Both the density and relative density of wastewater are temperature dependent and will vary with the concentration of total solids in the wastewater.

2.9.5 COLOUR

Historically, the term "condition" was used along with composition and concentration to describe wastewater. Condition refers to the age of the wastewater, which is determined qualitatively by its colour and odour. Fresh wastewater is usually a light brownish-grey colour. However, as the travel time in the collection system increases and more anaerobic conditions develop, the colour of the wastewater changes sequentially from grey to dark grey and ultimately to black. When the colour of the wastewater is black the wastewater is often described as septic. Some industrial wastewaters may also add colour to domestic wastewater. In most cases, the grey, dark

grey and black colour of the wastewater is due to the formation of metallic sulphides, which form as the sulphide produced under anaerobic conditions reacts with the metals in the wastewater.

2.9.6 TURBIDITY

Turbidity is measured by devices which determine the amount of light scatter electronically, and is another test used to indicate the quality of waste discharges and natural waters with respect to colloidal and residual suspended matter. The measurement of turbidity is based on comparison of the intensity of light scattered by a sample as compared to the light scattered by a reference suspension under the same conditions. Colloidal matter will scatter or absorb light and thus prevent its transmission. In general, there is no relationship between turbidity and the concentration of suspended solids in untreated wastewater.

The most important chemical characteristics of wastewater is its organic matter, the measurement of organic content, inorganic matter and gases. The measurement of organic content is discussed also because of its importance.

2.9.7 ORGANIC MATTER

In a wastewater of medium strength, about 75 percent of the suspended solids and 40 percent of the filtrateable solids are organic in nature (Metcalf and Eddy, 1991). These solids are derived from both the animal and plant kingdoms and these activities of man as related to the synthesis of organic compounds. Organic compounds are normally composed of a combination of carbon, hydrogen, and oxygen, together with nitrogen in

some cases. Other important elements, such as sulphur, phosphorus, and iron, may also be present. The principal groups of organic substances found in wastewater are proteins (40 to 60 percent), carbohydrates (25 to 50 percent) and fats and oils (10 percent). Urea, the chief constituent of urine, is another important organic compound contributing to waste water.

Along with the proteins, carbohydrates, fats and oils, and urea, wastewater contains small quantities of a large number of different synthetic organic molecules ranging from simple to extremely complex in structure. Typical examples include surfactants, organic priority pollutants, volatile organic compounds and agricultural pesticides (Metcalf and Eddy, 1991).

2.9.8. CARBOHYDRATES

Widely distributed in nature, carbohydrate includes sugars, starches, cellulose, and wood fibre. All are found in waste water. Carbohydrates contain carbon, hydrogen, and oxygen.

2.9.9. PROTEINS

Proteins are common to all organic substances, as well as hydrogen and oxygen. In addition, they contain , as their distinguishing characteristics, a fairly high and constant proportion of nitrogen, about 16 percent. In many cases sulphur, phosphorus and iron are also constituents. Urea and proteins are the chief sources of nitrogen in wastewater. When proteins are present in large quantities, extremely foul odours are produced by their decomposition.

2.9.10 FATS, OILS AND GREASE

Fats and oils are the third major component of foodstuffs. The term "grease" as commonly used includes the fats, oils, waxes, and other related constituents found in wastewater. Grease content is determined by extraction of the waste sample with trichlorofluoroethane. Other extractable substances include mineral oils, such as kerosene and lubricating and road oils.

Fats and oils are compounds (esters) of alcohol or glycerol (glycerin) with fatty acids. The glycerides of fatty acids that are liquid at ordinary temperatures are called oils, and those that are solids are called fats. They are quite similar, chemically, being composed of carbon, hydrogen, and oxygen in varying proportions.

Lubricating oils are derived from petroleum and contain essentially carbon and hydrogen. These oils sometimes reach the sewers in considerable volume from the plant. They float on the wastewater, although a portion is carried into the sludge on settling solids.

2.9.11 SURFACTANTS

Surfactants, or surface-active agents are large organic molecules that are slightly soluble in water and cause foaming in wastewater treatment plants and in the surface waters into which the waste effluent is discharged. Surfactants tend to collect at the air-water interface. During aeration of wastewater, these compounds collect on the surface of the air bubbles and thus create a very stable foam. The determination of surfactants is accomplished by measuring the colour change in a standard solution of methylene blue dye. Another name for surfactants is methylene blue active substance (MBAS).

2.9.12. VOLATILE ORGANIC COMPOUNDS (VOCs)

Organic compounds that have a boiling point $\leq 1000^{\circ}\text{C}$ and/or vapour pressure $> 1\text{mm Hg}$ at 25°C are generally considered to be volatile organic compounds (VOCs). For example, vinyl chloride, which has a boiling point of -13.90°C and a vapour pressure of 2548mm Hg at 20°C , is an example of an extremely volatile organic compound. Volatile organic compounds are of great concern because (1) once such compounds are in the vapour state they are much more mobile, and therefore more likely to be released to the environment; (2) the presence of some of these compounds in the atmosphere may pose a significant public health and (3) they contribute to a general increase in reactive hydrocarbons in the atmosphere, which can lead to the formation of photochemical oxidants.

2.9.13 INORGANIC MATTER

Several inorganic components of wastewaters and natural waters are important in establishing and controlling water quality. The concentrations of inorganic substances in water are increased both by the geologic formation with which the water comes in contact and by the wastewaters, treated or untreated, that are discharged to it. The natural waters dissolve some of the rocks and minerals with which they come in contact. Wastewaters, with the exception of some industrial wastes, are seldom treated for removal of the inorganic constituents that are added in the use cycle. Concentrations of inorganic constituents also are increased by the natural evaporation process, which removes some of the surface water and leaves the inorganic substance in the water. Because concentrations of various inorganic constituents can greatly affect the beneficial uses made of the waters, it is well to examine the nature of some of the constituents, particularly those added to surface water via the use cycle.

2.9.14 pH

The hydrogen ion concentration is an important quality parameter of both natural water and wastewaters. The concentration range suitable for the existence of most biological life is quite narrow and critical wastewater with an adverse concentration of hydrogen ion is difficult to treat by biological means, and if the concentration is not altered before discharge, the wastewater effluent may alter the concentration in the natural waters.

2.9.15. CHLORIDES

Another quality parameter of significance is the chlorides concentration. Chlorides in natural water results from the leaching of chlorides - containing rocks and soils with which the water comes in contact, and in coastal areas, from salt water intrusion. In addition, agricultural, industrial, and domestic waste waters discharged to surface waters are a source of chlorides.

2.9.16 ALKALINITY

Alkalinity in wastewater results from the presence of the hydroxides, carbonate, and bicarbonates of elements such as calcium, magnesium, sodium, potassium, or ammonia. Of these, calcium and magnesium bicarbonates are most common. Borates, silicates, phosphates and similar compounds can also contribute to the alkalinity. The alkalinity in wastewater helps to resist changes in pH caused by the addition of acids. Wastewater is normally alkaline, receiving its alkalinity from the water supply, the groundwater and the materials added during domestic use. Alkalinity is determined by titrating against a standard acid; the results are expressed in terms of calcium carbonate, CaCO_3 .

2.9.17 PHOSPHORUS

Phosphorus is also essential to the growth of algae and other biological organisms. Because of noxious algal blooms that occur in surface waters, there is presently much interest in controlling the amount of phosphorus compounds that enter surface waters in industrial waste discharges and natural runoff. Industrial wastewaters, for example, may contain from 4 to 10mg/l of phosphorus.

2.9.18 SULPHUR

The sulphate ion occurs naturally in most water supplies and is present in wastewaters as well. Sulphur is required in the synthesis of proteins and is released in their degradation. Sulphate is reduced biologically under anaerobic conditions to sulphide, which in turn can combine with hydrogen to form hydrogen sulphid (H₂S).

2.9.19 HEAVY METALS

Trace quantities of many metals such Nickel (Ni), Manganese (Mn), Lead (Pb), Chromium (Cr), Cadmium (Cd), Zinc(Zn), Copper (Cu), Iron (Fe), and Mercury (Hg), are important constituents of most waters. Some of these metals are necessary for growth of biological life, and absence of sufficient quantities of them could limit growth of algae for example. The presence of any of these metals in excessive quantities will interfere with many beneficial uses of the water because of their toxicity; therefore, it is frequently desirable to measure and control the concentrations of these substances. Methods for determining the concentrations of these substances vary in complexity according to the interfering substance that may be present. In addition quantities of many of these metals can be determined at very low concentrations by such instrumental methods as polarography and atomic absorption spectroscopy (Metcalf and Eddy, 1991).

2.9.20 GASES

Gases commonly found in untreated wastewater include nitrogen (N_2), Oxygen (O_2), Carbon dioxide (CO_2), hydrogen sulphide (H_2S), ammonia (NH_3) and methane (CH_4).

The first three are common gases of the atmosphere and will be found in all waters exposed to air. The latter three are derived from the decomposition of the organic matter present in wastewater. Although, not found in untreated wastewater, other gases include chlorine (Cl_2) and Ozone (O_3) (disinfection and odour control), and the oxides of sulphur and nitrogen.

2.9.21 METHANE

The principal by product of the anaerobic decomposition of the organic matter in wastewater is methane gas. Methane is a colourless, odourless, combustible hydrocarbon of high fuel value. Normally, large quantities are not encountered in untreated wastewater because even small amounts of oxygen tend to be toxic to the organisms responsible for the production of methane. Occasionally, however, as a result of anaerobic decay in accumulated bottom deposits methane is produced.

2.9.22 MICRO ORGANISMS

The principal groups of organisms found in wastewater are classified as eukaryotes, eubacteria, and archaebacteria. Most bacteria are classified as eubacteria. The category protista, contained within the eukaryote classification, includes algae, fungi, and protozoa. Plants including seed plants, ferns and mosses are classified as multi-cellular eukaryotes. Invertebrates and vertebrates are classified as multi-cellular eukaryotic

animals. Viruses, which are also found in wastewater, are classified according to the host infected (Ronald, 1997).

Bacteria

The simplest wholly contained life systems are bacteria or prokaryotes, which are the most diverse group of micro organisms. They are characterized by the lack of nuclear membrane and their machinery of metabolism is not contained in organelles. They reproduce by simple binary fission.

The bacteria cell is enclosed with a cell wall that is semi-rigid polymeric membrane on the order of 100nm thick. The cell wall maintains the integrity of the cell, holding it together against osmotic pressure gradients that occur because of concentrations differences between the cell contents and the surrounding liquid. The cytoplasmic membrane is immediately inside the cell wall and it controls passage of nutrients and other compounds into and out of the cell.

The cytoplasm is a solution that contains the bi-molecules essential for metabolism. The fundamental controlling bimolecular, deoxyribonucleic acid (DNA), and others are contained within the nuclear material (Ronald, 1997).

Fungi

Fungi are generally filamentous and have a true cell wall. Individual filaments are known as hyphae that may have no cross walls or be divided at irregular intervals by cross-walls. Yeasts are non filamentous fungi that are reproduced by a process known as budding. A small bubble is produced on the mother cell that grows to about the same size as the mother cell, then a cross wall is formed and the new cell separates.

Most fungi are aerobic. Fungi can tolerate a lower pH than bacteria and their nitrogen and phosphorus requirements are lower than those for bacteria. These characteristics make them valuable for treating some industrial wastewaters. However, filamentous forms are difficult to settle and significant growth of fungi in wastewater treatment plants can lead to poor effluent quality.

Algae

Algae are photosynthesizers that occur in all natural waters. They can be unicellular or multi-cellular. There are three large groups characterized by their colour: green, brown and red. The green colour of most algae is due to chlorophyll *a*, which is essential for capture of light and photosynthesis. All algae contain chlorophyll *a* but the green colour of chlorophyll *a* can be masked by other pigmented chlorophylls that absorb light different in wavelengths.

Algae play a role in some wastewater treatment processes, particularly stabilization ponds. Many algae species are harmless, but in water treatment algae are nuisance. Large amounts of certain algae species can lead to taste and odour problems from by products of their metabolism or decay of the cells. Some species produce toxins.

Protozoa

Protozoa are single-celled organisms. Many of these are motile because of flagella or cilia they move by means of pseudopodia (i.e. amoeboid protozoa). Many protozoa feed on prokaryotes and other eukaryotes. There are also protozoan that are saprobes; however, bacteria degrade organic matter more efficiently than protozoan.

Viruses

Viruses are non cellular entities that contain protein and nucleic acids. A protein (capsid) surrounds the nucleic acid molecule (genome). The longest dimension of the largest virus particle (the small pox virus) is 200nm. Viruses are unable to reproduce or metabolize on their own. They are obligate parasites that invade a cell and direct the cell metabolism to manufacturing new viruses. The host cell ultimately dies. Viruses are host specific, which make the analysis of viruses difficult.

Rotifers

Rotifers are simple multi-cellular organisms at the first stage above single-celled organisms. They have cilia, used for locomotion and food currents, located around their mouth. These aerobic micro organisms are naturally found in marine and fresh waters in relatively high numbers.

Worms

Worms have an elongated body and move with undulating motion. These simple animals are sometimes found in sewage treatment processes but their greater significance is the diseases that a number of them cause. There are many worms classified into a number of different phyla. Roundworms or nematodes are estimated to be the second and numerous group of organism after insects. Flatworms are distinguished by a flat body.

2.10 WASTE MANAGEMENT

There are scientific bases for urgent wastes management in the country, otherwise the country could experience large scale disasters similar to Minimata in Japan or Rhine in Switzerland or Love Canal in U.S.A. It is cheaper to control wastes than to clean up polluted environment. For example, polluted ground water can remain unusable or

hazardous for long periods of time. Use of industrial effluent for irrigation of farmlands and growing vegetables has been in practice here in Lagos State around the industrial estates.

The unsatisfactory waste management and water quality systems in the country has boosted the sale and consumption of bottled water but at a high cost unaffordable by the masses. The disposal of waste from a food processing plant is an integral part of the total production system. To reduce cost associated with conventional waste treatment, recycle, re-use and by-product recovery and utilization should be studied as alternatives to waste disposal and as mechanisms for prevention of intrusion of undesirable degradable material into the environment. (Carl, 1978). The establishment of the Federal Environmental Protection Agency (FEPA) by Decree 58 of 1988 now Federal Ministry of Environment, for overall protection of the national environment as well as the launching of the 1989 National Environmental Policy are positive steps taken by government to set the nation on the path to sustainable development.

It is only through the enactment of laws controlling the discharge of industrial effluents as well as standards protecting surface waters receiving domestic and industrial pollutants that we can halt the killing or desecration of our water resources, environment and protect public health too.

Nonetheless, the improvement in water quality and the health of the surface waters including associated resources is only achieved if the various regulatory measures put in place by FME are vigorously enforced. Ensuring compliance by polluters with FME (National Environmental (Effluent Limitation) Regulations 1991 and National Environmental Protection (Pollution Abatement in Industries and Facilities Generating

Wastes) Regulations 1991) regulation requires comprehensive monitoring programmes of Waste Waters and Wastes and Wastes in the country by FME. But FME requires strengthening of its capacity and capability in order to carry out its onerous tasks. The National Reference Laboratory in Surulere, Lagos should be equipped to International Standards and Staffed adequately with competent personnel.

i. ROLE OF EFFLUENT AND EMISSION STANDARDS

Rivers are generally used to convey wastes, provided they do not cause a pollution that affects natural flora and fauna extensively thereby preventing other legitimate users. Water pollution control in wastewater does not mean keeping the water in the original state, rather certain important contaminants are been treated and to minimize man's influence on water bodies. The entire catchments is difficult to protect, however the area upstream of the river is protected especially when used for drinking water. River specialization will ensure high standard and avoid contamination of drinking water abstraction points. The discharge of non biogenic toxic substances to which the community cannot actively respond but can only passively succumb should not be permitted.

ii. LEGISLATION FOR SURFACE WATER PROTECTION

The discharge of wastes to water courses must not be permitted except with permission of lawful authority. Permission may be refused particularly with certain hazardous waste in order to protect definite habitats to pollution. Permission should be granted through consent conditions with legal limit to concentration stated explicitly using standard wording and layout on the total load of pollutants that can be discharged. They should be reviewed from time to time depending on the existing condition on the receiving water in

order to maintain strict environmental control. The "Polluter pays Principle" should be used to determine fines and penalties for breach of standards. The fines should be rated per unit pollutant of COD, BOD, TOC, DO and metal species. The charges should reflect the administrative over heads incurred by the regulatory body. Rebates may be granted if discharges are at reduced level within consent conditions. There is a need to educate the industries on worthiness of the exercise so that they do not transfer the polluting load to another part of the environment or dumping the waste illegally.

iii. TREATMENT FACILITIES

Facilities for the treatment of wastes and wastewater from industries, agriculture and domestics have to be researched and provided for. Sewage and sewage purification play a major role in preventing oxygen depletion and in the control of eutrophication, especially when it is combined with phosphorus removal. Therefore, there is the necessity for mechanical and biological (or oxidation ponds) purification plants. Where industries cannot provide for themselves due to economic considerations, the channeling of such waste from such industries to a central treatment plant, (e.g. Agabara Industrial Estate Treatment Plant in Ogun State, Nigeria) and charges made. For the more toxic and /or non biodegradable wastes and wastewater, special handing and treatment facilities have to be provided for. The use of viscous fluid such as waste oil and grease should also take care of.

iv. GASEOUS POLLUTION CONTROL

From anthropogenic and non -anthropogenic sources (power stations, food industries, chimneys and transport), such pollutants like SO₂, NO₂ etc. which are products of combustion of fossil fuels and high temperature exhaust, constitute sources of water

pollution in form of acid rain, when they come into contact with rain water. A highly acidic water can be said to be low quality status. To enhance this, the relevant government organ must ensure the provision of laws that will regulate the air quality from such exhaust.

v. SOLID WASTE MANAGEMENT

Solid wastes are not treated as seriously as they should in most industries. Once it was remembered that water is a universal solvent, and then dissolvable solid waste can be a source of pollution when floating on a surface run-off transport which transport them to water bodies. Presently, solid waste is being managed with a certain military posture that it is nature and tendencies are not studied. Government should be made to realize that wastes should be managed by professional's in the field. This can be backed up by an adequate legal provision. The combined effect of poor solid waste management, general sanitation and poor hygiene can be seen in the vicious cycle of disease and poverty in urban slums, shabby towns and ferral. Industrialist should be educated on how to dispose solid waste and indeed all wastes willingly instead of compiling monthly collection by the Lagos State Environment Protection Agency (LSEPA).

vi. AGRICULTURAL WASTES MANAGEMENT

Of interest here are agricultural inputs such as fertilizers, pesticides and herbicides and their tendencies to pollute water resources, thus lowering the quality status of the water In 1989, during the later part of the planting season, outbreaks of strong diseases - diarrhea in some Local Government Areas due to drinking polluted or contaminated water. People died from this and from eating fish suspected to have poison in them. Even though medical personnel claimed otherwise, it is believed that these incidences are associated

with chemical poisoning due to application of pesticides, herbicides, and fertilizers on agricultural farms and in water where bioaccumulation/biomagnifications took place.

vii. TRANSPORT WASTES MANAGEMENT

A discharge of used oils by ships and boats directly into water is practice that should give us concern. Such actions must be prevented by strong legal provisions, particularly if we consider the problems associated with oil pollution of surface water and the problem is worse if ground water is polluted. It is also important to note that some of the lorries and trucks used in transporting solid wastes are not in good shape thereby cause pollution to the environment.

viii. WASTE AND DISEASES CONTROL

As much as 80% of all diseases are associated with waste pollution and poor sanitation. Disease such as Diarrhea, Cholera, Typhoid and Paratyphoid fever, Infectious Hepatitis, Amoebic and Basic dysentery, Impetigo and a host of other skin diseases are associated to waste water pollution. Some of them are due largely to inadequate supply of water. Therefore, even an increase in water quality status will not wipe such conditions especially diarrhea. Effort should be made not only in water quality improvement but also in adequate supply of the good quality water. As a matter of policy, water requirement as a basis for planning and development, in order to improve user's health condition. (Oso B.A, 2000)

PROTECTION OF AQUATIC PROCESSES

In order to protect the tropic levels within our water resources and thereby preserving primary production, all necessary steps need to be taken now to protect aquatic life in our water. The destruction of primary producers could lead to diminishing

consumer populations in water. The direct repercussion of this is diminishing fish yield with the resultant consequence that human diet suffers. Such conditions may arise through careless discharge of dangerous slowly biodegradable and non biodegradable wastes e.g. pesticides. The use of detergent that contain phosphorus may lead to eutrophication of inland lakes or dams. Anoxic conditions may arise, therefore that will make it difficult aquatic life to flourish.

On the other hand, aquatic life is one very important tool for water quality monitoring. The term for it biological indications of water of water quality, and uses aquatic life (e.g *Daphniamagna*) which are very sensitive to changes in pressure, pH, dissolved oxygen, toxicity and other chemical changes in water to give a measure of the purity of such a water. Benthic life forms such as worms have also been used as indicators for this and for bottom sediments. These organisms may become disfigured or their reproductive lives impaired or are killed outright by changes in the conditions enumerated above (Aina and Adedipe, 1991).

CHAPTER THREE

3.0 MATERIALS AND METHODS

The recent developments in the laboratory instrumentation have been of great benefit to the water and wastewater experts. The new instrument designs have incorporated automatic sample handling, sequential analysis and improved data presentation. The current change to digital output, in contrast to meter readings, has reduced error and increase the speed of the determination.

In addition to the expanded variety in the types of laboratory analyses performed, there has been an associated increase in the number of individual samples to be analyzed. To meet the increased work load, laboratory operations have been redesigned to take advantage of automatic instrumentation wherever possible. The elimination of manual analytical procedures, in favour of automated methods, permits a significant increase in the numbers of samples handled, without the necessity for additional laboratory personnel. The instruments and apparatus used in this research work are:

Atomic Absorption Spectrometer

Portable pH/ mv/ Temperature Meter (HACH MODEL EC10)

Dissolved Oxygen Meter (JENWAY MODEL 9071)

Conductivity Meter (HACH MODEL CO150)

Turbidity Meter

Thermometer

Conductivity Meter

pH meter

Incubator

Condenser

Electric Oven

Bunsen Burner

Analytical balance

Graduated Cylinders (100ml, 10ml, 1ml capacity).

Measuring Cylinders (100ml, 10ml, 1ml, capacity)

Pyrex Beakers (500ml, 100ml, 10ml capacity) .

Conical flask

Burette (50ml capacity)

Pasteur Pipette (2ml, 5ml, 10ml capacity)

Crucibles (25ml capacity)

Desiccators

Volumetric flask

Funnel

Filter paper

Pipette (25cm)

Sample bottles of borosilicate glass

Flame photometer

Steam bath

Distillation apparatus

Ground glass joint

Horizontal shaker LS 200 (for mixing liquids)

Refrigerator $4.0 \pm 5^{\circ}\text{C}$

Evaporating dish

3.1 LIST OF SOME OF THE REAGENTS USED :

Sodium hydroxide Pellets

Oxalic acid

Potassium permanganate KmnO_4

Sodium nitrite

Hydrochloric acid – HCl

Chloroform

Sodium sulphate

Manganese sulphate

Starch solution

Solid KI free from iodate

Sodium hydrogen trioxocarbonate (IV) NaHCO_3

Alkaline iodide

Sodium thiosulphate solution

Dipotassium chromate (VI) $\text{K}_2\text{Cr}_2\text{O}_7$

Silver nitrate

Chloride

Sodium chloride

Potassium chloride

Phosphoric acid

Soda lime

Calcium chloride

Sulphuric acid

Silver nitrate

Mercury Tetraoxosulphate (VI) HgSO_4

Silver Tetraoxosulphate (Ag_2SO_4)

Tetraoxosulphate(VI) acid (H_2SO_4)

Iron (II) Tetra sulphate (VI) Heptahydrate $\text{FeSO}_4 \cdot 7\text{H}_2\text{O}$

3.2 SAMPLE COLLECTION TECHNIQUES

Three different effluent samples were collected at intervals of one week from the discharged points for analyses.

Basically, three types of samples are known viz, grab, composite and the flow weighted composite sample type. The process by which a sample is obtained can greatly influence the result (Standard Methods, 1992).

The grab sample type accurately represents the wastewater quality at the moment of sampling. It however, does not give us any information on the quality of wastewater before or after the sampling. The mixing up of a series of grab samples gives us the composite sample. In situation where daily loading to wastewater treatment plants is calculated, the flow weighed composite is very useful. It is obtained by taking each samples so that the volume of the sample is proportional to the flow at the time. For the purpose of this research the composite sample method was employed. The effluent sample needed for the analyses of physicochemical parameters were collected as follows.

Effluent samples for trace metals determination were collected in 2 litres plastic bottles with hard plastic screw cap and acidified with nitric acid (HNO_3) to

pH < 2 on site. Plastics were used to prevent sample contamination from metallic samplers.

- I. Effluent samples for oil and grease determination were collected in 1litre separate solvent bottles.
- II. Effluent samples for chemical oxygen demand (COD) determination were collected in 2 litres separate plastic bottles.
- III. Effluent samples for other physicochemical parameters to be analyzed were also collected in 2 litres separate plastic bottles.
- IV. In each case, the previously acid washed plastic containers were rinsed three times with the effluents to be sampled before the actual samples were collected at the discharge points.
- V. Effluent samples for trace metals determination and other parameters were preserved in the refrigerator on arrival at the laboratory.

3.3 SAMPLE IDENTIFICATION

All samples carried self adhesive labels. These were affixed preferably on the sample bottles rather than the covers, since the later may easily be lost or misplaced causing sample mix -ups. The important information indicated on labels include sampling locations, date and time, parameter being sampled for and the preservation methods employed.

3.4 SAMPLE PRESERVATION

Unrelenting natural processes cause changes in the quality of effluent samples on holding. Microorganisms, for example degrade the organics in the effluent and use up the dissolved oxygen in the process. The reaction results in the release of carbon dioxide; an

acid gas which lowers pH and affects the concentration of pH sensitive species such as dissolved heavy metals, free ammonia and cyanide. To prevent deterioration, the samples were treated chemically by addition of appropriate reagents having selectively inhibitory effects on the processes affecting particular parameters and kept under refrigeration. Sample preservation materials and chemical fixing agents (usually concentrated acids and alkalis, mercury salts or in the case of oxygen, magnesium sulphate and alkaline iodide – azide solutions), refrigerating chamber for storage of collected samples, graduated dispensing pipettes with rubber bung, labels, pens chronometer and data record sheets.

3.5 EXPERIMENTAL PROCEDURES

It is quite common to determine temperature and dissolved oxygen as well as conductivity and pH of effluent on site. The preferred order of measurement is temperature, conductivity, dissolved oxygen and lastly, pH. This order is based on the relative response times of the parameters. Site determination, employing an electrochemical sensor, is also easier and therefore, usually preferred for dissolved oxygen though it is possible to fix DO (by addition of magnesium sulphate and alkaline iodide – azide solutions to the sample) and subsequent analysis in the laboratory. The brand names of portable instruments used include HACH and JENWAY.

3.5.1 DETERMINATION OF PHYSICAL PARAMETERS OF LIQUID WASTE

3.5.1.1 TEMPERATURE AND pH DETERMINATION

The temperature and pH of the effluent samples were determined at the discharge point with HACH MODEL EC 10 portable pH/mv/temperature Meter.

The model EC 10 features a custom digital LCD display which simultaneously displays temperature and measurement results. This meter has all the features of a simple

pH meter plus a millivolt mode, sealed keypad, electrode holder, tilt –strand, ergonomic design and battery or line power.

The required MODE was selected using the keypad. The meter electrodes was rinsed with distilled water and both the pH electrode and temperature probe was immersed into the sample contained in a beaker. The display was allowed to stabilize and the results were read.

3.5.1.2 ELECTRICAL CONDUCTIVITY DETERMINATION

The conductivity of the effluent samples were determined at the industrial drain sites with HACH model CO 150 conductivity meter. This meter features a microprocessor design, which automates complicated and time –consuming calibration and measurement procedures for a wide variety of applications. Water quality, salinity, acids, bases and other samples can be easily analyzed for conductivity with the available conductivity probes.

The conductivity meter was pressed to conductivity mode. The probe was rinsed with distilled water and inserted into sample contained in a beaker, while the display was allowed to stabilize before recording measurements.

3.5.1.3 TURBIDITY DETERMINATION

Turbidity was detrmind by Nephelometric Method. Turbidimeter consists of a Nephelometric with a light source for illuminating the sample and one photoelectric detector with a readout device to indicate intensity of light scattered at 900 to the path of incident light.

The samples were thoroughly shaken to allow air bubbles disappear. Shaken samples were poured into turbidimeter tube and immersed in an ultrasonic bath for 2

seconds, causing complete bubble release. Turbidity was read directly from instrument scale as nephelometric turbidity units (NTU).

3.5.1.4 OIL AND GREASE DETERMINATION

The sample was acidified with a few drops of 6N HCl and 50ml trichlorotrifluoroethane was added and shaken vigorously. It was allowed to settle and solvent draw off into a clean dry beaker. Solvent was filtered through a dry filter paper into a 300ml conical flask, and another 50ml portion of trichlorotrifluoroethane was added and extraction was repeated, then allowed to settle and filtered into the same 300ml flask. The filter paper was carefully washed with fresh solvent discharged from a washing bottle with a fine tip. Solvent was then evaporated and the weight of residue left after evaporation was determined.

Calculation:

$$\text{Oil and grease} = \frac{(A - B) \times 1000}{25\text{ml of sample volume}} = \text{mg/l}$$

where A = total gain in weight of flask

and B = calculated residue from solvent blank of the same volume as that used in the test,
mg

Reagents

- a. 1,1,2 – trichloro – 1,2,2 trifluoroethane
- b. Hydrochloric acid, HCl (6N)
- c. filter paper

Apparatus

- a. conical flask
- b. floatable oil tube

3.5.1.5 TOTAL DISSOLVED SOLIDS DETERMINATION

A well mixed sample was filtered through a standard glass fibre filter and the filtrate was evaporated to dryness in a weighed dish and dried to constant weight at 180°C. The increase in dish weight represents the total dissolved solids.

Samples were stirred with a stirrer and pipette, 60ml was measured into a glass fiber with applied vacuum. Then, wash with three successive 10ml volumes of reagent – grade water allowing complete drainage between washings and continue suction for about 3min after filtration was completed. Total filtrate (with washings) was transferred into a weighed evaporating dish and evaporated to dryness on a steam bath. Dry for about 1h in an oven at 180°C, cool in a desiccator to balance temperature, and weigh. Analysis was repeated drying cycle of drying, cooling, desiccating and weighing until a constant weight was obtained.

Calculation

$$\text{Total dissolved solids} = \frac{(A - B) \times 1000}{25\text{ml of sample volume}} = \text{mg/l}$$

where A = weight of dried residue + dish

and B = weight of dish

3.5.1.6 TOTAL SUSPENDED SOLIDS DETERMINATION

A well mixed sample was filtered through a weighed standard glass fibre filter and the residue retained on the filter was dried to a constant weight at 105°C. The increase in weight of the filter represents the total suspended solids. Sample was stirred with a stirrer, and while stirring 25ml of sample was pipetted onto the seated glass –fibre filter. Wash with three successive 10ml volumes of reagent –grade water, allow complete drainage between washings, and continued suction for about 3min after filtration was

completed. The filter was carefully removed from filtration apparatus and transferred into stainless steel planchet as a support. Dry for about 1 hour at 105⁰C in an oven, cool in a desiccator to balance temperature and weighed. Analysis was repeated until a constant weight was obtained.

Calculation :

$$\text{Total Suspended solids} = \frac{(A - B) \times 1000}{25 \text{ml of sample volume}} = \text{mg/l}$$

where A = weight of filter + dried residue, and

B = weight of filter

3.5.2 DETERMINATION OF INORGANIC MATTER COMPOSITION OF LIQUID WASTE

3.5.2.1 CHLORIDE ION DETERMINATION

It was determined by titration with silver nitrate.

PROCEDURE/REAGENTS

1. The following three reagents were prepared.

- a. 48g of silver nitrate was dissolved in 1litre of distilled water and 1ml was equivalent to 1mg chloride.
- b. 1.6g of sodium chloride standard and 1ml contains 1mg chloride
- c. Potassium chromate indicator, 5g per 100ml was added to the silver nitrate solution to produce a slight red precipitate and was filtered.

2. 100ml of wastewater sample was measured into a flask, and 1ml of potassium chromate solution was added and then titrated with silver nitrate with constant stirring until a slight red colour persists.

$$\text{chloride} = \frac{\text{Volume of silver nitrate for sample - blank}}{\text{volume of wastewater sample (ml)}} \times 1000 = \text{mg/l}$$

3.5.2.2 PHOSPHATE ION DETERMINATION

Phosphate was determined by the stannous chlorine method. Phosphate in wastewater reacted with ammonium molybdate in acidic medium to form molybdophosphoric acid which is reduced to molybdenum blue complex by stannous chloride. The intensity of colour was measured using DR 2000 spectrophotometer at 600nm wavelength.

3.5.2.3 SULPHATE ION DETERMINATION

Sulphate ions were determined by the turbidimeter method. Colloidal Barium sulphate was formed by the reaction of sulphate with barium ion in a barium chloride hydrochloric acid solution in the presence of glycerol and ethyl alcohol. The colour intensity was measured using DR 2000 spectrophotometer at 42mm wavelength.

3.5.2.4 TRACE METALS DETERMINATION

Prior to trace metal analyses, each sample of 100ml was acidified with concentrated HNO₃ (0.5ml). 25 ml of each sample was poured into a beaker and diluted with 1.25ml HCl. The mixtures were heated for 15minutes on a steam bath and the final volume was adjusted to 25ml. Graded concentrations of the standard metal solutions were similarly prepared (0.2, 0.4, 0.6, 0.8, 1.0 and 1.2ppm) and aspirated into the flame and the absorbances read in the atomic absorption spectrophotometer. The absorbance of the standard were plotted against their concentrations to obtain a standard calibration curve from which the concentration of metals present in the samples were extrapolated. Metals detected are Iron, Zinc, Calcium and Magnesium.

3.5.3 DETERMINATION OF ORGANIC MATTER COMPOSITION OF LIQUID WASTE.

Over the years, a number of different tests have been developed to determine the organic content of wastewater. In general, the tests may be divided into those used to measure gross concentrations of organic matter greater than about 1mg/l and those used to measure trace concentrations in the range of 10^{-12} to 10^{-3} mg/l. Laboratory methods commonly used today to measure gross amounts of organic matter (greater than 1mg/l) in wastewater include: (1) biochemical oxygen demand (BOD); (2) Chemical Oxygen Demand (COD) and (3) Total Organic Carbon (TOC). Complementing these laboratory tests is the theoretical oxygen Demand and (ThOD), which is determined from the chemical formula of the organic matter.

Other methods used in the past included (1) total, albuminoid, organic and ammonia nitrogen, and (2) oxygen consumed. These determinations, with the exception of albuminoid nitrogen and oxygen consumed are still included in complete wastewater analyses. Their significance, however, has changed. Whereas formerly they were used almost exclusively to indicate organic matter, they are now used to determine the availability of nitrogen to sustain biological activity in industrial water treatment processes and to foster undesirable algal growths in receiving water.

Trace organics in the range of 10^{-12} to 10^{-3} mg/l are determined using instrumental methods including gas chromatography and mass spectroscopy. Within, the past 10years, the trace sensitivity of the methods used for the detection of trace organic compounds has improved significantly and detection of concentrations in the range of 10^{-9} mg/l is now almost a routine matter (Metcalf and Eddy, 1991).

The quantitative methods of analyses are either gravimetric, volumetric, or physicochemical. In the physicochemical methods, properties other than mass or volume are measured. Instrumental methods of analysis such as turbidity, calorimetry, potentiometry, polarography, adsorption spectrometry, fluorometry, spectroscopy and nuclear radiation are representative of the physicochemical analyses.

For the purposes of this study, the standard method for the examination of water and wastewater was used (American Public Health Association, 1992).

3.5.3.1 CHEMICAL OXYGEN DEMAND DETERMINATION

Chemical oxygen demand (COD) is the amount of oxygen required to stabilise organic matter. It is determined using a strong oxidant. Ideally the oxidant should be able to oxidise any organic compound and the oxidant should be inexpensive. Potassium dichromate was used as an oxidising agent and it was reacted with each of the samples. The dissolved oxygen count of the wastewater samples were determined first before oxidizing of the samples with $K_2Cr_2O_7$. After oxidation process was completed, the dissolved oxygen content of oxidised wastewater sample was determined. The difference gave the chemical oxygen demand for each sample.

3.5.3.2 DISSOLVED OXYGEN DETERMINATION

The dissolved oxygen (DO) was determined on the field with JENWAY Model 9071 Dissolved Oxygen Meter. The measurement system consists of a "clark" type polarographic oxygen electrode and an oxygen meter. The unit gives the user a readout of dissolved oxygen in either mg/l (ppm) or % and has a temperature measurement range of -30 to 150°C. The required mode was selected. The Dissolved Oxygen probe was immersed in the beaker containing the sample to be measured. The model 9071 Dissolved

Oxygen Meter simultaneously displays Dissolved Oxygen and measurement results. It is possible to fix DO by Winker's method and subsequent analysis in the laboratory.

3.5.3.3 BIOCHEMICAL OXYGEN DEMAND DETERMINATION

Biochemical Oxygen Demand (BOD) is defined as the amount of oxygen required for the biological decomposition of organic matter under aerobic conditions at a standardized temperature and time of incubation. The amount of oxygen required in various periods of time will depend upon the concentrations of organic matter, temperature, concentration of bacteria, nature of the organic matter, and the type of bacteria. The samples were diluted with aerated water and divided into segments. The dissolved oxygen was determined in one segment immediately and in the other segment after it was incubated for five days at a temperature of 20⁰C. The difference gave the amount of oxygen used by the bacteria.

CHAPTER FOUR

4.0 PRESENTATION AND DISCUSSION OF RESULTS

4.1 RESULTS

The results of physico - chemical analysis of composite effluent samples collected from Cadbury Nigeria Plc as food processing industry are presented in Tables 4.1, 4.2 and 4.3 while FEPA standard on Table 4.4.

Table 4.1: Results of Physical Parameters of the waste

Parameters	Sample 1	Sample 2	Sample 3
pH	8.0	6.0	10.7
Conductivity ($\mu\text{s}/\text{cm}$)	0.000258	0.000252	0.00021
Turbidity (NTU)	15.0	10.0	7.0
Temperature ($^{\circ}\text{C}$)	28.0	30.0	29.0
Total Suspended Solids	500.0	250.0	581.0
Total Dissolved Solids	2231.0	1692.0	1999.0
Totals solid	2731.0	1942.0	2580.0
Oil and grease	8.5	8.5	7.5
Colour	Brown	Yellow	Brown
Odour	Yes	Yes	Yes

Table 4.2: Results of Organic Matter Composition

Parameters	Sample 1	Sample 2	Sample 3
Dissolved oxygen	7.1	11.2	6.9
Chemical oxygen demand	220.0	748.0	176.0
Biochemical oxygen demand	102.0	144.0	60.0
Total organic carbon	4.0	36.0	40.0

Note: All values in mg/l except otherwise stated.

mg/l = Milligram per litre

$^{\circ}\text{C}$ = degree centigrade

NTU = Nephelometry Turbidity Units

$\mu\text{s/cm}$ = micro-second/centimetre

Table 4.3: Results of Inorganic Matter Composition of Cadbury Nig. Plc

Heavy Metals	Sample 1	Sample 2	Sample 3
Iron (Fe)	4.25	4.15	3.01
Zinc (Zn)	0.581	0.025	1.0
Sulphate (SO_4^{2-})	25.0	36.0	160.0
Chloride (Cl^-)	44.0	251.0	44.0
Calcium (Ca^{2+})	1.08	0.22	ND
Magnesium (Mg^{2+})	0.2	19.8	ND
Phosphate (PO_4^{3-})	5.0	8.5	5.3

Note: All values in mg/l (milligram per litre)

ND = Not Detected

Table 4.4 Effluent Limitation Guidelines in Nigeria for all categories of industries

<i>Parameters</i>	FEPA's Limit Standard
pH	6-9
Turbidity	NS
Temperature	400C
Conductivity (umbos)	NS
Colour (Lovibond units)	7
Odour	NS
Oil and Grease	10
Dissolved Oxygen (DO)	30
Biochemical Oxygen Demand (BOD) ₅	30
Chemical Oxygen Demand (COD)	80
Total organic carbon (TOC)	NS
Total dissolved solids (TDS)	2000
Total Suspended Solid (TSS)	30
Total Solid TS	2030

Magnesium (Mg ²⁺)	200
Phosphate (PO ₄ ³⁻)	5
Calcium (Ca ²⁺)	200
Sulphate (SO ₄ ²⁻)	500
Chloride (Cl)	600
Zinc (Zn)	<1
Iron (Fe)	20
Cyanide (CN)	0.1
Detergents	15
Pesticides (Total)	< 1

Note: Units in milligram per litre (mg/l) unless otherwise stated

Source FEPA MONOGRAPH (1991)

MATERIAL BALANCES FOR THE PRODUCTION LINE				
Basis:	450.00kg of	batch size		
Analysis of the initial material are as follows:				
Component	% by mass	mass (kg)		
Water	10.00	45.00		
Sugar	3.00	13.50		
Glucose syrup	80.00	360.00		
Rework slurry	7.00	31.50		
Total	100.00	450.00		
MATERIAL BALANCE AROUND THE HOLDING TANK				
	Input		Output	
Component	% by mass	mass, kg	% by mass	mass, kg
Water	10.00	45.00	10.00	45.00
Sugar	3.00	13.50	3.00	13.50
Glucose syrup	80.00	360.00	80.00	360.00
Rework slurry	7.00	31.50	7.00	31.50
Total	100.00	450.00	100.00	450.00
MATERIAL BALANCE AROUND THE COOKING TANK				
	Input		Output	
Component	% by mass	mass, kg	% by mass	mass, kg
Water	10.00	45.00	10.00	45.00
Sugar	3.00	13.50	3.00	13.50
Glucose syrup	80.00	360.00	80.00	360.00
Rework slurry	7.00	31.50	7.00	31.50
Total	100.00	450.00	100.00	450.00
MATERIAL BALANCE AROUND THE MIXING TANK				
	Input with flavour added		Output	
Component	% by mass	mass, kg	% by mass	mass, kg
Water	9.52	45.00	9.52	45.00
Sugar	2.86	13.50	2.86	13.50
Glucose syrup	76.19	360.00	76.19	360.00
Rework slurry	6.67	31.50	6.67	31.50
Flavour (Solid)	1.90	9.00	1.90	9.00
Flavour (Liquid)	2.86	13.50	2.86	13.50
Total	100.00	472.50	100.00	472.50
PRODUCT				
	Product		Wastes	
Component	% by mass	mass, kg	% by mass	mass, kg
Water	9.52	40.50	17.15	4.50
Sugar	2.86	13.10	1.54	0.41
Glucose syrup	76.19	342.00	68.61	18.00
Rework slurry	6.67	28.67	10.81	2.84
Flavour	1.90	8.91	0.34	0.09
Liquid flavour	2.86	13.10	1.54	0.41
Total	100.00	446.265	100.00	26.235

4.2 DISCUSSION

4.2.1 TEMPERATURE

The temperature of industrial effluent samples in this study ranged between 28⁰C and 30⁰C. The highest temperature of 30⁰C was observed for sample 2. (Table 4.1). The temperature of the effluents varies by $\pm 1^{\circ}\text{C}$. However, the temperature levels of the effluent samples are well within the FEPA range of 35⁰C to 40⁰C. And it has no effect on the environment except if the temperature exceeds 40⁰C. It will have adverse effect on the receiving water body at the same time; it will increase the level of the dissolved Oxygen.

4.2.2 pH

The pH of the industrial effluents ranges between 6.0 and 10.7. The highest value of 10.7 was measured in sample 3. The effluent had pH value of 10.7 which is slightly alkaline. The low pH reading of 6.0 in sample 2 was attributed to the decay of organic matter in the effluents. The pH of the effluent samples are within acceptable limit of FEPA range of 6 to 9, except that of sample 3 (Table 4.1 and 4.3) respectively. In most situations the concentration of H⁺ or OH⁻ is small or insignificant compared to the concentrations of other species but this does not mitigate the influence of these ions as controlling variables of the state of the water.

4.2.3 TURBIDITY

Turbidity is associated with suspended solids concentrations. It was observed that size and concentrations of particles influenced the measurement of turbidity. Turbidity of the effluents range between 7NTU to 15NTU. The nature of the solids causing the turbidity may have other health ramifications. Turbidity in natural waters reduces light transmittance and affects the species that may survive in the waters.

4.2.4 ELECTRICAL CONDUCTIVITY

The electrical conductivity of the effluents ranged from 0.00021 μ s/cm to 0.000258 μ s/cm. The value increased with sample 1 having the highest value of 0.000258 μ s/cm. This can be attributed to increased total dissolved solids, since a rapid method of obtaining an estimate of the dissolved solids, in waste water sample is by measurement of its electrical conductivity. Besides, it may be due to the influence of the metallic ions present.

4.2.5 DISSOLVED OXYGEN

Without free dissolved oxygen, there will be no survival of aquatic life forms in any water body. Streams and lakes therefore, simply become uninhabitable to most desirable aquatic life without free dissolved oxygen. At normal temperature, water is said to be saturated with oxygen at 9mg/l. This saturation value decreases rapidly with increasing water temperature. DO of the effluents ranged from 7.1mg per litre to 112mg per litre. The values exceed the FEPA maximum level of 30mg per litre.

4.2.6 CHEMICAL OXYGEN DEMAND

Chemical oxygen demand is a measure of the oxygen that certain chemicals will take from the environment. The values range from 176mg per litre to 748mg per litre. However, the values obtained exceed the maximum limit of 80mg per litre set by FEPA. If such an excess is discharged in the final effluent, micro organisms do not degrade some of the chemicals measured by this test. The COD has major influence on the trade effluent charge: higher strength equal higher charge.

4.2.7 BIOCHEMICAL OXYGEN DEMAND

Biochemical oxygen demand (BOD) is simply the rate of oxygen use. The effluent samples, generally had high BOD content with the highest value of 144mg per litre recorded in sample 2 compared to FEPA tolerance limit of 30mg per litre. Excessively high BOD concentrations were also observed in sample 1 and sample 3. The variation in the of BOD results shown in (Table 4.1). High level of BOD will reduce the level of Dissolve Oxygen (DO) and that would affect aquatic lives. It was observed that the industry partially treats effluents. This however, makes the effluent to have high biodegradable matters.

4.2.8 TOTAL ORGANIC CARBON

The test has significant advantages over the Biochemical Oxygen demand and chemical Oxygen demand tests. as it is rapidly carried out. The values ranged between 36mg per litre to 4 per litre. Total organic carbon is absorbed from the atmosphere as carbondioxide. It is readily available to the plants for the manufacture of sugar and other plant products. In addition, excess CO₂ in the soil escapes into the air and the organic matter, during its decomposition, also gives out CO₂.

4.2.9 TOTAL DISSOLVED SOLIDS AND TOTAL SUSPENDED SOLIDS

The total dissolved solids and the total suspended solids from Cadbury Nigeria Plc. effluents at the discharge point far exceed the FEPA limits of 2000mg per litre and 30mg per litre respectively (Table 4.1). This was as a result of organic matter present in the effluents. It was also observed that Cadbury Nigeria Plc does not treat their effluents to the required standards. The values range from 1692mg per litres to 2231mg per litre for Total Dissolved Solids (TDS), while Total Suspended Solids (TSS) ranges from 250mg per

litre to 581.0mg per litre. The high values obtained indicate the high potential of the leachates to cause gross organic pollution in receiving surface water bodies.

4.2.10 ODOUR

The effluents were associated with odour described as marshy, musty, and haylike. This may be due to the influence of Actinomycetes. Actinomycetes are mold like bacteria, widely distributed in the environment.

4.2.11 OIL AND GREASE

Oil and grease have direct effects on marine organisms, because they obstruct photosynthesis. The oil and grease content of the effluents ranged between 7.0mg per litre and 8.5mg per litre. The levels are however, below the maximum limit of 10mg per litre set by FEPA.

4.2.12 COLOUR

The colour was assessed visually. Because of insufficient found .The sample 1 and sample 3 were brownish in colour and sample 2 was yellowish in colour. Spectrophotometer is use for colour determination.

4.2.13 IRON

The beneficial effects of iron include: Chlorophyll synthesis, oxidation –reduction in respiration , constituent of certain enzymes and proteins. The iron content of the effluents ranged from 3.01mg per litre to 4.25mg per litre Table 4.3. The effluents had a high concentration of iron due to the fact that some of the pipes used in conveying effluents to the aeration tanks may have start rusting and depositing the iron oxide in the effluents. The iron concentration of the effluents fall within the FEPA range of 20mg per litre.

4.2.14 ZINC

Relatively nontoxic to humans and animals. Essential nutrient for life. Only at high concentrations has it been found toxic to plants. However zinc is acutely and chronically toxic to aquatic organisms. The concentrations of zinc varied from 0.025mg per litre to 1.0mg per litre. These values however, satisfy the WHO standards which stipulate 5.0mg per litre as highest level desired.

4.2.15 SULPHATE

The sulphate concentrations of the effluents samples ranged between 25mg per litre to 160mg per litre when the samples were analyzed. The values obtained are below FEPA stipulated maximum limit of 500mg per litre (Table 4.4). sulphur is absorbed by plant roots almost exclusively as the sulphate ion SO_4^{2-} . It is also an essential constituent of volatile soils of such crops; an onion and garlic gives them their characteristic fragrance.

4.2.16 CALCIUM

The calcium content of the effluents ranged from 0.22mg per litre to 1.08mg per litre. The values fall below the Federal Environmental Protection Agency maximum level of 200mg per litre. Calcium appears to be essential for the growth of meristems and particularly for the proper growth and functioning of root tips and is absorbed by higher plants.

4.2.17 CHLORIDE

The chloride level of the effluents ranged between 44mg per litre to 25mg per litre. The chloride level in the effluents were quite lower than that of the FEPA maximum limit of 600mg per litre. Chloride is absorbed by plant as the Cl^- ion through the roots,

and as chloride or chlorine gas by aerial plant parts. The uptake rate depends primarily on the concentration in the nutrient or soil solution, and on the quantities in the atmosphere.

4.2.18 MAGNESIUM

The magnesium content of the effluents used in this study ranged from 0.2mg per litre to 19.8 mg per litre. The values obtained are well below the FEPA maximum desirable level of 200mg per litre for magnesium, (Table 4.3). High magnesium and calcium concentrations result to hardness of water and magnesium has been known to be essential for plant growth and development.

4.2.19 PHOSPHATE

Phosphate, whether present in organic form in wastewater, by biological action, all phosphate, in nature will eventually revert to inorganic forms to be again used by plants in making high energy material, hence its suitability for irrigation in a phosphate deficient soil. The phosphate content of the effluents during the period of this study ranged between 5.0 mg per litre to 8.5 per litre. The phosphate content of sample 2 and sample 3 were higher than that of sample 1 (Tables 4.2 and 4.4 respectively). This may be due to the presence of some phosphate chemicals used in their processes. Phosphate is readily mobilized in plants and can be translocated in an upward or downward direction. Excessive supply of phosphate over the amount required by the crop sometimes decreases crop yield.

CHAPTER FIVE

5.0 CONCLUSIONS AND RECOMMENDATIONS

5.1 CONCLUSIONS

Tables 4.1, 4.2 and 4.3 respectively depict the water polluting nature of the effluents from Cadbury Nigeria Plc. When compared with FEPA Guidelines and Standards. The effluents contain several pollutants far in excess of FEPA's limits. In fact, they were continuously discharging organic pollutants, micro pollutants and pathogens into the aquatic environment.

Industrial effluents have grossly polluted virtually all streams flowing through industrial estates in Lagos. Vivid examples are Shasha and Iya-Alaro streams which are perpetually coloured, smelling, murky and devoid of aquatic life.

The effluents of Cadbury Nigeria Plc may not generate any public outrage due to the presence level of pollutants in the wastewater. However, because of the possibility of accumulation of some of the pollutants especially biodegradable matters and trace metals in the wastewaters, steps should be taken to reduce the net quantity present.

The food processing industry should also take necessary action to control its waste especially biodegradable matter and trace metals. Even though the industry has environmental control units as well as a modern effluent treatment plants, it should encourage and intensify its research and monitoring techniques relevant to environmental problems in the industry. Emphasis should not be placed only on the installation of control equipment with adequate design and characteristics but also on its efficiency and maintenance.

Resource limitations relate to the available laboratory equipment, analytical facilities and funds.

Finally, with growing environmental consciousness on the part of the populace, glamouring for better environmental responsibilities from the industries and, the increasing agitation and resentment of industries for multiple taxes, levies and governmental enforcement on the industries; it is certain that the nation will achieve long expected environmental friendly behaviour and a sustainable and safe environment for all now and for future generations.

5.2 RECOMMENDATIONS

Environmentally sound management of waste/effluents is among the environmental issues of major concern in maintaining the quality of the earth natural resources and especially in achieving environmentally sound and sustainable development.

This however goes beyond mere safe disposal of effluents or recovery of wastes that are generated and seek to address the root course of the problem by attempting to change unsuitable patterns of production and consumption. This implies the application of the integrated life cycle management concept which provides opportunity to reconcile development in all its ramifications with environmental protection.

The following are recommended from the conclusion reached.

- i Periodic assessment, data collation and analysis, and systematic reporting to appropriate agencies are highly recommended.
- ii Mathematical models can be generated for predicting the level of pollutants at different portions of the industry. These models can be formulated after repeated sampling and analysis of effluent.

iii Reducing BOD, COD, TSS and water use. The food processing plants contribute large Biological Oxygen demand (BOD) and Chemical Oxygen Demand (COD) loads, as well as Total Suspended Solids (TSS) and Trace Metals to wastewater. The most effective waste load reduction practice is keeping by-products out of the water stream. Employees can use dry cleanup methods to remove by-products before wet clean up. Keeping by-products off the machines and floor greatly reduced BOD, COD and TSS loading into the effluents water stream. Some of the most effective dry cleanup methods include scraping raw materials (Enzymatic Hydrolyzed) of conveyor belts, and other areas to keep food industry by products off the floor; and sweepings squeezing or shovelling materials off the floor before wet clean up.

iv Water pollution prevention and control is necessary by the application of the 'polluter pays' principle to the sources where appropriate. Also it involves strict compliance to the standards of effluent discharge for receiving streams; use of new technologies, product and process change, effluent reuse, recycling and recovering, treatment and environmentally safe disposal for pollution minimization. In addition, mandatory environmental impact assessment of major water resources development project is necessary.

v Development and application of clean technology; which involves treatment of agro industrial discharges, industrial wastewater for safe reuse in agriculture and aquaculture, development of biotechnology for waste treatment and development of

appropriate methods for waste pollution control considering traditional and indigenous practices.

vii Finally, the improvement on waste quality including associated resources is only achieved if the various regulatory measures put in place by FEPA are vigorously enforced. Ensuring compliance by polluters with FEPA regulation requires comprehensive monitoring programmes of waste in the country by FEPA. But FEPA requires strengthening of its capacity and capability in order to carry out its onerous tasks. The National Reference Laboratory in Surulere, Lagos should be equipped to International Standards and staffed adequately with competent personnel.

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APPENDIX 1

Cadbury Nigeria Plc SAMPLE (1)

$$\text{Total Suspended Solid (TSS)} = \frac{\text{mg weight gain in No.1} - \text{mg weight gain in No.2} \times 1000}{\text{Volume of sample (ml)}}$$

$$= \frac{100-50}{100} \times 1000 = 500\text{mg/l}$$

$$\text{Total dissolved solid} : = \frac{\text{mg of residue}}{\text{Volume of sample(ml)}} \times 1000 = \text{mg/l}$$

$$= \frac{223.1}{100} \times 1000 = 2231\text{mg/l}$$

$$\text{Total solids} : = \text{total suspended solid} + \text{total dissolved solids} = \text{mg/l}$$

$$= 500\text{mg/l} + 2231\text{mg/l} = 2731\text{mg/l}$$

$$\text{Total organic carbon} : = \frac{(\text{Blank} - \text{titre})N \times 8000}{100 \text{ vol. of sample}} = \text{mg/l}$$

$$= \frac{(90 - 88.8) \times 0.5 \times 8000}{100} = 48\text{mg/l}$$

$$\text{Chemical Oxygen Demand} : = \frac{(V_1 - V_2)N \times 800}{x} = \text{mg/l}$$

$$= \frac{(110 - 55) \times 0.1 \times 800}{20} = 220\text{mg/l}$$

$$\text{Oil and Grease} : = \frac{(A - B) \times 1000}{\text{Sample}} = \text{mg/l}$$

$$= \frac{(25 - 24.15) \times 1000}{100} = 8.5\text{mg/l}$$

Chloride: = $\frac{\text{Blank} - \text{volume of silver nitrate for sample} \times 1000}{\text{Vol. of waste water sample (ml)}} = \text{mg/l}$

$$= \frac{8.8 - 4.4 \times 1000}{100} = 44 \text{mg/l}$$

APPENDIX II

$$\text{Total suspended solid:} = \frac{\text{mg weight gain in No.1} - \text{mg weight gain in No.2} \times 1000}{\text{mg/l}}$$

$$= \frac{50 - 25 \times 1000}{100} = 250 \text{mg/l}$$

$$\text{Total Dissolved solids :} = \frac{\text{mg of residue} \times 1000}{\text{Vol. of sample (ml)}} = \text{mg/l}$$

$$= \frac{0.1692 \times 1000 \times 1000}{100} = 1692 \text{mg/l}$$

$$\text{Total solids:} = \text{Total suspended solid} + \text{Total dissolved solid}$$

$$= 250 + 1692 = 1942 \text{ mg/l}$$

$$\text{Total Organic Carbon:} = \frac{(\text{Blank} - \text{Titre})N \times 8000}{100} = \text{mg/l}$$

$$= \frac{(90 - 89.1) \times 0.5 \times 8000}{100} = 36 \text{mg/l}$$

$$\text{Dissolved Oxygen:} = \frac{\text{Vol. of thiosuophate (ml)} \times 101.6}{\text{Vol. titrated (ml)}} = \text{mg/l}$$

$$= \frac{11.0 \times 101.6}{100} = 11.2 \text{mg/l}$$

$$\text{Chemical Oxygen Demand:} = \frac{(V_1 - V_2)N \times 800}{X} = \text{mg/l}$$

$$= \frac{(374 - 187) \times 0.1 \times 800}{20} = 748 \text{mg/l}$$

$$\text{Biochemical Oxygen Demand:} = \frac{(\text{DO}_0 - \text{DO}_5 - B) \times 100}{\% \text{ of the sample}} = \text{mg/l}$$

$$= \frac{7.2 \times 100}{5} = 144 \text{mg/l}$$

$$\text{Oil and Grease:} = \frac{(A - B) \times 1000}{\text{Sample}} = \text{mg/l}$$

$$= \frac{(25.00 - 24.15) \times 1000}{100} = 8.5 \text{mg/l}$$

$$\text{Chloride:} = \frac{\text{Blank} - \text{vol. of silver nitrate for sample} \times 1000}{\text{Vol. of waste water sample (ml)}}$$

$$= \frac{49.90 - 24.80 \times 1000}{100} = 251 \text{mg/l}$$

APPENDIX III

$$\begin{aligned}\text{Total suspended solid:} &= \frac{\text{mg weight gain in No.1} - \text{mg weight gain in No.2} \times 1000}{\text{Volume of sample (m}_1\text{)}} \\ &= \text{mg/l} \\ &= \frac{116.20 - 58.1 \times 1000}{100} = 581 \text{mg/l}\end{aligned}$$

$$\begin{aligned}\text{Total Dissolved Solids:} &= \frac{\text{mg of residue} \times 1000}{\text{Vol. of sample (ml)}} = \text{mg/l} \\ &= \frac{0.1999 \times 1000 \times 1000}{100} = 1999 \text{mg/l}\end{aligned}$$

$$\begin{aligned}\text{Total solids:} &= \text{Total suspended solid} + \text{Total dissolved solid} \\ &= 581 + 1999 = 2580 \text{mg/l}\end{aligned}$$

$$\begin{aligned}\text{Total Organic Carbon:} &= \frac{(\text{Blank} - \text{Titre})N \times 8000}{100 \text{ volume of sample}} = \text{mg/l} \\ &= \frac{(9.0 - 8.0) \times 0.5 \times 8000}{100} = 40 \text{mg/l}\end{aligned}$$

$$\begin{aligned}\text{Chemical Oxygen Demand:} &= \frac{(V_1 - V_2)N \times 800}{X} = \text{mg/l} \\ &= \frac{(88 - 44) \times 0.1 \times 800}{20} = 176 \text{mg/l}\end{aligned}$$

$$\begin{aligned}\text{Biochemical Oxygen Demand:} &= \frac{(\text{DO}_0 - \text{DO}_5 - B) \times 100}{\% \text{ of the sample}} = \text{mg/l} \\ &= \frac{(6.3 - 3.3) \times 100}{5} = 60 \text{mg/l}\end{aligned}$$

$$\text{Oil and Grease:} = \frac{(A - B) \times 1000}{\text{Sample}} = \text{mg/l}$$

$$= \frac{(25.00 - 24.25) \times 1000}{100} = 0.75 \text{mg/l}$$

Chloride: = $\frac{\text{Blank} - \text{vol. of silver nitrate for sample} \times 1000}{\text{Vol. of waste water sample (ml)}}$

$$= \frac{8.8 - 4.4 \times 1000}{100} = 44 \text{mg/l}$$