

**Evaluation of an alternative organic
waste disposal system in Chevron-
Escravos: A case study**

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**Dissertation submitted in partial fulfilment of the requirements for
the Degree Master of Engineering at the Potchefstroom Campus of
the North-West University, South Africa.**

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November 2008

Dedication

Firstly, to the only Almighty God for giving me life and guiding my foot steps to this achievement

In every success there is a story, this dissertation is humbly dedicated to my dear Mum Mrs. Elizabeth Bojor who is my mentor and teacher. Though do not have formal education, but knows the values and entrenched the culture of learning in me, and had also strived hard to take me this far.

I can't forget my cousin (Father) Chief Akin Lawrence for his direction, moral and financial support all these years.

Acknowledgement

My sincere appreciation goes to:

Foremost, my wife Rachael, my son Timeyin and my daughter Gbemi for their prayers, patience, support and encouragement they gave me throughout this period of my stay in South Africa.

My family members - Mrs. Nayo Arubi, Mrs. Esther Amoman and Mr. Godwin Bojor for being there on my behalf and always providing, advice and support.

I would want to use this medium to express profound gratitude to my supervisor Prof. Harry Wichers, for giving me the opportunity to work under his thorough supervision, not forgetting the constant support and guidance, inspiration, constructive criticism, and above all believing in me.

I would also like to extend my appreciation to the following wonderful people who have also contributed immensely to the accomplishment of this dissertation:

Engineer Sam Akra of Chevron Nigeria limited, Dr. Augustine Ofomaja of VUT South Africa and Mr. Awoluyi Babatayo of HSE department of Chevron Nigeria for the role they played in collecting data and materials and information, thereby making it possible to complete this exercise.

Mr. Gordon Towers of the construction and planning group (CPG) (designs) of Chevron Nigeria Limited for his encouragement and financial assistance.

Prof. Piet Stoker, for paving the opportunity for us to begin this program and providing the enabling environment and support throughout the entire program

Finally, my colleagues and co-students who in one way or the other served as inspiration to me to continue the program even at times of difficulties.

Abstract

The research presented in this dissertation focuses on the waste management techniques currently used by Chevron-Escravos Nigeria Limited (CENL), as background knowledge of the existing waste disposal system practiced by the company.

Investigation has shown that more than four tons (4tons) of organic food waste that CENL generates daily is being disposed of by using incineration and landfilling of the resulting residues. The high recoverability and economic values in form of nutrients and stored energy is not being considered.

The main dissertation problem was to develop an alternative means of promoting the economic and environmental recoverability of these huge amounts of organic wastes, by developing a disposal technique other than the current incineration and landfill methods.

The mechanism considered to achieve this objective was laid out in the customized organic waste converter or processor that provides one of the baselines for this dissertation. It also presents a procedural description of converting organic food waste to bio-feeds and feedstock of high quality.

This alternative processing and utilization of organic food waste was carried out to provide information about tradeoffs to the current practice of incineration and landfill management systems. This was done to guide decision making and to serve as a framework within which the plausibility of the proposed solution could be examined.

A comparative analysis of the two scenarios of waste to feed and waste to incineration system, the environmental impact, economic viability, and opportunity cost of recycling organic food waste produce of animal bio-feed was assessed by using:

- Life cycle analysis (LCA)
- By-products Breakeven Sale Product (BBSP) model.

The BBSP model evaluates the opportunity of recycling the organic food waste in production of animal bio-feed to waste incineration. The outcome of the dissertation indicates that incineration is an important contributor to human and environmental toxicity and global warming. The proposed solution (recycling approach) balances the socio-economic, political and environmental safety by producing renewable, clean and eco-friendly feed and by-products.

It was also concluded that there are alternative possibilities for the utilization of industrial organic food waste, where **both the energy and nutrients are completely utilized**, rather than the norms of conversion through chemical, biological, and thermal or other forms of energy (fuels), which typically utilizes only one of these (*calorific contents*) categories at a time.

The above mentioned utilization can be achieved by transforming the current waste disposal system. By introducing an alternative model for the recycling of plant and animal nutrients and the utilization of energy, renewable energy can be saved, human health and the environment can be protect and a sustainable economy can be maintained.

In summary, it was demonstrated that there is huge capital losses and environmental contamination due to the current waste management practices. Recycling of OFW for feed production would be cost effective method that contributes towards protecting the environment achieving economic sustainability.

Keywords: Waste Management; Feed Manufacturing; Incineration; Life Cycle Assessment; Waste Converter; Environmental Burden; Recycling/Reuse; Opportunity Cost; Energy And Nutrients.

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LIST OF ACRONYMS

“3R”	- Reduce, Reuse, and Recover/Recycle
BOD	- Biological Oxygen Demand
BPEO	- Best Practicable Environmental Option
CE	- Chevron-Escravos
CNL	- Chevron Nigeria Limited
COD	- Chemical Oxygen Demand
CS	- Conversion System
CT	- Conversion Technologies
EEA	- European Environmental Agency
EGASPIN	- Environmental Guidelines And Standards For The Petroleum Industry In Nigeria.
EGTL	- Escravos Gas to Liquid
EIA	- Environmental Impact Assessment
EPA	- Environmental Protection Agency
EPR	- Extended Producer Responsibility
FEPA	- Federal Environmental Protection Agency
FWD	- Food Waste Disposers
HES	- Health Environment and Safety
HW	- Household Waste
IW	- Industrial Waste
LCA	- Life Cycle Assessment
LCI	- Life Cycle Inventory
LOW	- Liquid Organic Waste

MOU	- Memorandum of Understanding
MSW	- Municipal Solid Waste
NDPR	- Nigerian Department Of Petroleum Resources
NGO	- Non Governmental organization
NIMBY	- Not-In-My-Backyard"
OM	- Organic Matter
OWC	- Organic Waste Converter
PAH	- Polycyclic Aromatic Hydrocarbon
PR	- Producer Responsibility
RCRA	- Resource Conservation and Recovery Act
Sasol	- Suid Afrikaanse Steenkool en Olie (South African Coal and Oil)
SBU	- Strategic Business Unit
SOP	- Standard Operating Procedure
SOW	- Solid Organic Waste
TWh	- Tera-Watts-hour
UNFCCC	- United Nations Framework Convention on Climate Change

CHAPTER ONE

1.0 INTRODUCTION

Chevron Nigeria Limited (CNL) is an oil and gas exploration and production company, with Chevron-Escravos as its exploration and production hub. Chevron-Escravos services several onshore and offshore flow stations and production platforms which are scattered all over the southern Niger Delta region of Delta state of Nigeria.

Chevron-Escravos production tank farm is located on an island in a swampy terrain, in the Niger Delta region of southern Nigeria. The tank farm is situated at the intersection of the Warri river and the Escravos river, adjoining the Atlantic ocean. With a population of about three to four thousand personnel in the industrial and residential estates (Chevronnews bulletin, 2006).

The intensification of oil and gas production in recent years had lead to an increase in the numbers of employed personnel resulting in an increase in the processing of food the generation of associated wastes in the estates. In chevron-Escravos tank farm alone, approximately 0.35million tons of food related wastes are disposed off annually (CNL, 2006).

Personal observation during the years of working at Chevron-Escravos Nigeria between the year 2000 and 2005, it was noticed that huge amounts of organic food wastes generated from the various canteens were piled up in the disposal bin daily, and subsequently taken away to be disposed off in the incinerator.

Due to increased environmental awareness from government, the employees, the public and the host communities, the Chevron Escravos waste facility is now facing mounting pressures to reduce environmental pollution resulting from food processing and the current wastes disposal system (REDIproj, 2006).

The organic food waste could be reused rather than being treated and disposed of as waste material. The problem is how such organic waste products could be put to economic use without adverse impacts to the environment? A decision to research organic waste management techniques in order to develop and proffer a better alternative waste disposal method that would have economic and environmental values was carried out.

There are several technological processes that have been developed to dispose off organic wastes; these are generally classified as chemical, biological, and thermal processes (Themelis, 2002).

Some of the conventional methods of waste disposal management practices are the landfill, incineration, resource recovery, recycling, bioconversion systems etc. These various techniques have their suitable applications and limitations with regards to natural resources depletion, global warming effects, air and water pollution, economics, and measure of release of toxins to the environment (Bassis, 2000 & SEPA, 2003).

A case study of organic waste management practises in Chevron-Escravos Nigeria was evaluated in terms of waste stream generation, collection, and disposal systems in order to propose a better or improved alternative organic waste disposal system, (Using the concept of Best Practise Environmental Options (BPEO)).

The BPEO procedure established with a given set of objectives will be the option that provides the most benefits and the least damage to the environment as a whole, at an acceptable cost, in the long term as well as in the short term (Herefordshire & Worcestershire, 2004).

The application of chemical treatment is typically used in the disposal of hazardous waste, and therefore does not apply to the organic food wastes considered in Chevron-Escravos. Biological treatment is the decomposition of organic waste by microorganisms. This includes the processes of aerobic digestion (in the presence of oxygen) and anaerobic digestion (in the absence of oxygen) (ERA. 2005 & Themelis, 2002).

Aerobic digestion would extremely be difficult to implement in Chevron-Escravos. These processes require an open-air forum, recommended not to be close to the local population. In the densely populated residential and industrial estates of Chevron-Escravos which is surrounded by several communities, this technology might pose health risks and odour problems to the surrounding population (Themelis, 2002).

The integrated waste management system currently practised by Chevron-Escravos includes thermal incineration and small scale landfilling. The choice of incineration as waste disposal method is obvious as the swampy terrain makes it difficult for landfill system to be practiced on commercial scale, as this would result in the possible contamination of ground water. Also being an Island, the competition for land space is very high, let alone enough for landfill purposes.

Although landfill practice is as old as mankind, it is condemned in advanced countries due to its associated environmental, safety and health risks, and more so due to its limited benefits compared to other forms of modern disposal techniques (Warner Bulletin, 2001).

Another of the available waste disposal practices that was evaluated includes a bioconversion system that generates synthetic gas for energy production (fuel and power) and fertilizer for soil regeneration. Chevron is an energy producing company burdened with large volume of natural gas production, which is basically flared (waste gas fig. 1) (ERA, 2005), using this waste disposal management method would therefore not be recommended.

The choice of incineration method to other forms of waste disposal systems in the Chevron-Escravos tank farm is obvious since other conventional methods such as landfill, and bioconversion systems are not feasible. However, the choice of recycling or resource recovery of organic food waste was forgone alternative for incineration, which served as one of the baseline of this dissertation.

Incineration has been practiced for number of years by Chevron and has had no economic benefits to Chevron or the host communities. This method has rather encouraged tension

and mistrust among the surrounding rural communities and the company, as there are no safety statistics available of how this method adversely affects people and the environment (CNL, 2006).

The current waste management process generates substantial quantities of process effluent including:

- Solid wastes and liquid wastes
- Fly ash
- Dust and smoke
- Sludge
- Toxic gases, etc.

The process effluent could affect human health and the environment adversely, therefore requires special attention due to the large volume of toxin produced and as well as legislative restrictions.

The need to have an alternative, environmental friendly, people oriented, and beneficial mode of waste management system would be highly encouraged and supported by the Nigerian regulatory bodies, company and the host communities (ERA, 2005).

Primary data were collected from reports presented by the Chevron Health, Safety and Environmental (HSE) department, and personal research on organic waste management systems (reduce, reuse, recover/recycle (“3R”) principles), with consideration to the losses of plant and animal nutrients in organic waste during current waste management methods. The identification and description of needs and problems emerging in the present waste management process were identified.

In conclusion, new possibilities for the utilization of industrial organic food waste were described, **where both the energy and nutrients are used**, rather than the norms of

conversion through chemical, biological, and thermal or other forms of energy (fuels), which typically utilizes only one of these (*calorific contents*) categories at a time.

However, the goal is to make “waste” a resource that can be utilized and not just to discard.

The primary benefits to the waste generator are the reduced waste disposal costs and compliance with increasing environmental restrictions imposed on waste and wastewater disposal including air pollution and world pollution reduction mandates.

1.1 Problem Statement

The intention of this dissertation is to develop an alternative means of disposing of these significant volumes of organic wastes with little or no consequences to the environment. The case study area is the Chevron Escravos tank farm, which houses between three to four thousand (3,000 – 4,000) people daily, excluding other locations offshore and onshore such as flow stations and production platforms (CNL, 2006).

At present it is estimated that the new Escravos Gas To Liquid project (SASOL/EGTL) would eventually contribute to an additional two thousand five hundred (2,500) workers to the existing personnel (Chevronnews bulletin, 2006). It can also be estimated that each person generates between 0.5 to 1.0kg of food waste daily, from an average of three meals (Solid Waste Audit Report, 2004).

Consequently, an approximated 1.5 to 4.0 tons of food wastes are presently generated daily. These waste products include bread, plantain, yam, cassava products, fish, bones, meat, fruits, vegetables, etc. which are presently disposed of by **incineration** via the tank farm incinerator.

Incineration has been widely used for the disposal of various waste types including household, hazardous, and medical waste. There is increasing public concern over the benefits of combusting the waste versus the health and environment risk from pollutants emitted during combustion (Warner Bulletin, 2001).

Currently, there are plans of building or expanding the incinerator plant to accommodate the increasing growth in the generation of organic waste in Escravos tank farm due to new projects and expansion of older ones.

The major concern of the present waste disposal system is its impact on community health and environmental degradation which has resulted in communal judicial activism and legislative action, resulting in an unpleasant relationship between the communities and the company. "The fact is that no matter who owns the responsibility of waste disposal, reality is that resident communities are the victim of their own apathy towards sustainable solution to the problem" (Josef F, 2004).

Some of the waste management difficulties of the existing waste stream are the significant volumes of organic wastes generated, inadequate biological stability, potentially pathogenic nature and high water content (Richard, 2002).

Apart from waste incineration at the tank farm, the methods of wastes disposal at the remote offshore and onshore locations are not monitored. With the vast ocean nearby, (being viewed as an inexhaustible depository for waste) the option of disposing of the majority of the waste into the waters surrounding the facility is highly probable.

Some of questions that could be asked and that will be addressed by this dissertation include:

- i) What could be done to the organic waste generated from the remote flow stations and platform when there are no waste incinerators at these locations?
- ii) If there are other waste disposal systems at these locations, what are they? Are they approved waste disposal system?
- iii) What are the levels of compliance with environmental waste regulations in Nigeria?
- iv) What is the probability of illegal dumping at sea as a means of avoiding ridiculously high disposal cost at these locations?

This dissertation intends to demonstrate the collection and processing technique of organic wastes from all Chevron-Escravos locations, both onshore and offshore and using the developed proposed alternative of disposal as a solution in eliminating the risks associated with incineration and other waste management techniques that are inimical to human health and environment.

The opportunity cost of still using incineration to this solution is very high to the host communities and the environment. These waste products can generate income, employment, human and infrastructural development and could be used to create good social relationship with the host communities.

This could be achieved by converting the waste products into useful economic by-products (directly or indirectly) in a number of ways. Proposed methods include the conversion and processing into feeds for livestock, or the conversion into feed ingredients (Adel, & Antonius, 2000 & Richard, 2002).

1.2 Dissertation Aims and Objectives

The primary objectives of this dissertation are:

1.2.1 To assess the current organic waste management system used in Chevron-Escravos Nigeria by:

- Identify the various wastes stream generated.
- Identify specific means to accumulate, store and transport the waste prior to disposal.
- Studying the waste disposal facilities provided for the organic waste streams and evaluating the disadvantages of this practice.

1.2.2 To propose a suitable alternative organic waste disposal systems for Chevron-Escravo's tank farm. The aim is to ensure this waste is disposed of without using incineration and landfill as disposal methods.

- 1.2.3** To provide information that can be considered in the management's decision process, to ensure that the most cost-effective disposal method can be selected for this given facility.
- 1.2.4** To evaluate the environmental benefits and associated costs of an organic waste disposal systems at the Chevron-Escravos tank farm.
- 1.2.5** To study and assess the present Socio-Economic Impact of organic waste disposal systems in the Chevron-Escravos tank farm communities.

1.3 Expected Outcomes and Deliverables

- 1.3.1** To utilize the available organic waste as resource and available technology in achieving maximum sustainable development and economic benefits through animal feed production.
- 1.3.2** To develop an alternative approach to the current waste management practises that will ensure that waste collection and disposal methods that are adopted are financially and environmentally sustainable.
- 1.3.3** To diversify the economic base of the host communities through job creation and capacity building, from organic waste utilization, thereby reducing politically-motivated youth restiveness.
- 1.3.4** To improve community–company relationship (Judicial cases) due to proper waste management system.

1.4 Dissertation Method

1.4.1 Literature Review Method

Review of available literature on waste management system and practices were undertaken to understand the information and some conventional methods used, and analyze these processes to establish detailed knowledge that would inform the basis to make recommendation.

The work of Richard, T.L. and Rosentrater, K.A. particularly provides a good baseline for the procedural and process design followed in this dissertation. Although the authors treated the subject quite rigorously, they did so from the perspective of modelling reprocessing alternatives for homogenous waste stream only - corn masa by-products.

Their work supplies a good solution to the problem and is therefore used as the basis for verification and validation in this study. As is evident from the problem statement, in section 1.1, this dissertation investigates the problem from the perspective of modelling reprocessing alternatives for heterogeneous organic waste stream.

Sources of information include but are not limited to:

Library sources include:

- Handbooks and Texts,
- Journals
- Articles and publications on waste management systems.
- Internet searches, Newspapers, magazines, and reports (NGOs proceedings, conferences, etc.).

1.4.2 Investigation Methodology

The dissertation was conducted through a literature review of similar processes, combined with a case study. Chevron-Escravos facility operating in Nigeria was chosen to be the case company.

This dissertation was carried out using three principal approaches:-

A desk top study involving consultation of official reports, articles and legal documents (Decrees) relating to solid waste management in Nigeria and Chevron SBU-NMA. This was done in order to obtain background information that would enable the construction of a conceptual model of alternative solid waste management in Chevron-Escravos Nigeria.

Verbal interviews were conducted with key stakeholders in various sectors this include:

HSE department at Chevron-Escravos

Urban development and environment agencies

Meetings with representatives of the host communities,

Personal observation during the five years of my working career at this facility and private sectors directly associated with waste management activities in Nigeria (Warri). The intention was to investigate the concept of the model in use and consider different perspectives with regards to organic waste management policy and service delivery.

Thirdly, site visits were made to observe the disposal systems at Escravos and other locations such as Warri and Lagos offices, and the immediate neighborhoods around these sites.

The main dissertation problem was to determine the means of promoting the recovery and recycling or reuse of the huge amounts of organic food waste (OFW) generated in the Chevron Escravos facilities and converting them from incinerated waste to feedstock or feed ingredients for the production of animal feed, given consideration to waste prevention and total life cycle of the product (fig. 14).

1.5 Dissertation Outline

This dissertation is structured into the following chapters:

Chapter 1: Introduction

This chapter introduces the dissertation background and the case study area. The dissertation outlook is described to provide fundamental knowledge as it's relates to the dissertation aims and objectives, problem statements and the dissertation methodology adopted.

Chapter 2: Evaluation of Some Waste Management Techniques

This chapter deals with the evaluation of several waste management techniques and applications with respect to economic and environmental impact and special emphasis is placd on organic waste disposal systems. The review of the waste management methodologies provides a broader understanding of some of the waste management systems and organic waste disposal systems in particular.

Chapter 3: Assessment of Chevron-Escravos Waste Management

The current waste management techniques and practices adopted by Chevron-Escravos in Nigeria was surveyed and analyzed to supply background knowledge in order to formulate an appropriate proposal and recommendation for an alternative management method that has economic and environmental merits over the current waste management practise.

Chapter 4: An Alternative Organic Food Waste Disposal System

A procedural description of the processes and implementation of the proposed alternative was presented, by using the knowledge gained from the waste management techniques reviewed in the chapters above to proffer solutions to the problem statements.

Chapter 1: Introduction

Chapter 5: Valuation of Alternative Waste Disposal System

This chapter evaluates the economic, safety and environmental impact of the proposed alternative compared to the current system. A description of the advantages and disadvantages of the proposed alternative is described.

Chapter 6: Result and Recommendation

The final chapter discusses the findings and benefits of the alternative disposal system in terms of economic gains. Recommendations are made on the implementation of a policy promoting recycling rather than using incineration. Limitations and the need for further research are discussed.

CHAPTER TWO

Appraisals of Some Waste Management Techniques

2.0 Introduction

The management and disposal of wastes, which are primarily of organic origin, is one of the most fundamental problems and important challenges facing mankind (Martin, 2003).

Human health relies on the quality of environmental safety, including that of air, water and food quality, etc. The modern trend in waste management has shifted from destruction to reuse/recycling (resource recovery), also considering the cost of this approach versus the use of virgin resources in the production of new products. Examples of the common methods of waste disposal management practices include landfill, incineration, resource recovery, recycling and bioconversion systems etc. (EPA, 2003).

These disposal techniques have their suitable applications and limitations regarding natural resource depletion, global warming effects, air and water pollution, and the release of toxins to the environment, etc. (Bassis, 2000).

According to Luke Bassis, 2000, "The disposal of garbage in the world is a problem that continues to grow with the development of industrialized nations and the growth in population". One of the challenges facing man since the beginning of time is finding a proper way of disposing of their trash.

For example in the 18th century, carters were paid by individuals to carry trash and discard it on the outskirts of the town in England and France, and as such disposal in open pits became routine exercise. Benjamin Franklin initiated the first municipal cleaning program in Philadelphia in 1757 (Pepper, 1996 & Bassis, 2000).

Since then we have come a long way to developing newer and better waste disposal methods as waste cannot simply be dumped into a pit or discard indiscriminately.

2.1 Waste and Waste Generation

According to Zucker, 1978, "Wastes could be defined as materials with disposal cost or as products with a negative price" This is true as long as there is no use for a material.

But as soon as there is demand or even an indication of a potential demand, the material assumes a price. Consequently, the cost of purchasing a waste residue is rarely zero, let alone a negative figure (Zucker, 1978 & Huang, 2004).

Even though, that the scope of the concepts "wastes" and "residues" is not determined by an exact technological definition. Hence, perfectly good oranges may constitute a waste under conditions of gross excess in supply over demand. Wheat bran residue from wheat flour production once treated as waste had recently become a valuable product of the flour mills as a result of the increase in demand for food fibre.

The lack of adequate processing technology is one of the reasons for treating certain material as waste. Associated gas from crude is a known example and it is generally being flared as a means of disposal. There seem to be no possibility of developing a universal waste disposal solution that is practically applicable to all types of wastes (Zucker, 1978).

Generally waste can be categorised into many different types. The most universal modes of classification are by physical, chemical and biological characteristics. Another fundamental classification is by the waste consistency. Solid wastes are waste materials that contain less than 70% water; this class includes such materials as household garbage, some industrial wastes, some mining wastes, and oilfield wastes such as drill cuttings, etc.

Liquid wastes are usually wastewater, oil, solvents, etc that contain less than 1% solids. Such wastes may contain high concentrations of dissolved salts and metals. Slurry or sludge is an intermediate class of waste, as this waste form usually contain between 3% to 25% solids, while the rest of the material is water and dissolved materials (Pepper, et al., 1996).

During human activities, wastes in the form of solid, liquid and gases are generated. Solid waste is generally divided into industrial waste (IW), household waste (HW) and

municipal waste (MW). A typical food processing plant generates 10% to 40% of the incoming raw material as waste. This often amounts to hundreds of tons of waste material daily that must either be trucked to landfills or must be treated via a costly process prior to being disposed of (Cheeseman, et al., 2007).

Organic waste from the food industry is usually characterized by a high ratio of product-specific waste such as high fibre or protein content as shown in table1. The generation of organic waste is almost unavoidable. The amount and type produced varies. The waste consists primarily of the organic residue of the processed raw materials, and will remain the same if the quality of the finished product is to remain consistent (Cheeseman, et al., 2007).

Table 1 below shows a typical household waste composition in Abuja-Nigeria.

Household Waste composition data for different districts in Abuja Nigeria						
Waste type (%)	District name and characteristics					
	Garki	Wuse	Maitama	Asokoro	Gwarimpa	Apo
Paper	13	12	13	13.6	6.9	10.1
Metal	5.6	3.3	5.3	6.7	5.4	4.9
Glass	5.5	4.4	5.32	4.1	4.1	-
Plastic	16.2	17.3	20	15.1	21.3	18.7
Food remnant	52	54.3	54.8	53	61.2	65.3
Textile	2.2	4.7	0.1	3.1	-	-
Rubber	3.4	1.5	0.19	0.7	-	0.9
Other	1.8	2.4	0.6	2.8	1.1	-
Persons/household	8	8	6	6	13	6

Source: Federal Ministry of Environment –Nigeria (2004)

As shown in the table 1 above, the amount of waste generated has increased in both quantity and diversity without adequate investment in collection, transport, treatment and disposal facilities. The lack of investment in waste management is further complicated by political, economic and social factors. The average waste generation rate in Abuja-Nigeria

is 0.55–0.58 kg per person per day (Solid Waste Audit Report, 2004). This is influenced by the time of the year, local culture, traditions and personal income (Dulac, 2001 & Cheeseman, et al., 2007).

2.1.1 Organic Wastes

Organic waste (OW) is produced wherever there is human habitation. The main forms of organic waste are household food waste, agricultural waste, human and animal waste, municipal bio-solids and wastes from some industries. Organic wastes are typically by-products of farming, industrial or municipal activities, and are usually called “wastes” because they are not the primary product (UN, 2002).

However, the goal is to make the “waste” a resource that can be utilized and not to be discarded. Major generators of food and organic materials include: restaurants, supermarkets, hotels, produce centres, food processors, school and business cafeterias, hospitals, prisons, farmers, and community events.

2.1.2 Type of wastes

Federal regulations in Nigeria classify wastes into one of the following four major different categories:

i) Inert Waste

This is waste that is physically, chemically or biologically inert. Examples include excavation spoils, landscaping trash or construction debris (Poly-SHEQ, 2006).

ii) Non-Hazardous Waste

This is waste that is within the legal limits for discharge or release into the environment. The legal limits are defined by such as Federal Ministry of Environment and Department of Petroleum Resources, Environmental Guidelines and Standards for the Petroleum Industry in Nigeria (EGASPIN). Non-hazardous wastes are those that do not create immediate threat to human health and the environment. Household garbage is included

into this category (UN, 2002 & CNL, 2006).

iii) Domestic Waste

Waste that is generated from human activities, including solid (e.g., leftover food, food containers, office waste, etc.), liquid (e.g. used cooking oils, etc.), or sanitary waste (e.g., waste from toilets, bathrooms, and kitchen drains) (CNL, 2006).

iv) Hazardous Waste

Waste material that exhibits a characteristics of hazardous waste as defined in RCRA (ignitable, corrosivity, reactivity, or toxicity), is listed specifically in RCRA 261.3 subpart D. This is designated locally or by the state as hazardous, and undesirable for handling as part of the municipal solid waste and would have to be treated as regulated hazardous waste if not from a household. Waste having chemical or physical properties exceeding legal disposal limits (EPA, 2003).

Also wastes under this category have the characteristics as defined in the Nigerian Department of Petroleum Resources (NDPR) regulations, Hazardous wastes are of two types: those that have common hazardous properties such as ignitability or reactivity and those that contain leachable toxic components. The later type of waste is also known as special wastes and is very specific in nature and it is also regulated with specific guidelines. Some examples are radioactive and medical wastes (CNL, 2006).

2.2 Waste Management Concepts

Integrated solid waste management is a practice using several alternative waste management techniques to manage and dispose of specific components of municipal solid waste stream. Alternative waste management techniques include source reduction, recycling, composting, energy recovery, landfilling, etc. (EPA, 2003).

There are several concepts about waste management which vary in practice between countries or regions. Some of the most generally used concepts are presented in this section. Waste Management comprises the process of collection, transport, processing,

recycling or disposal of waste materials resulting from human activity, in an effort to reduce their effect on human health or the environment (Nolan, 2005 & Robert, 2006).

The art of reduction and recovery of resources from waste in order to reduce its effect on the environment has been the recent focus globally. Different methods and field of expertise are required in waste management involving solid, liquid or gaseous substances (Nolan, 2005).

There are differences in waste management practises among developing and developed nations, urban and rural areas and residential, industrial, and commercial producers. It is usually the responsibility of municipal authorities to manage non-hazardous residential and institutional waste in metropolitan areas, whilst it is the responsibility of the generators to manage non-hazardous commercial and industrial wastes (Herefordshire & Worcestershire, 2004).

The waste hierarchy principle refers to the "3 Rs" **Reduce, Reuse and Recycle**, which classify waste management strategies according to their desirability in terms of waste minimization. The foundation of most waste management strategies are built on the principles of waste hierarchy. The main objective is to extract the maximum practical benefits from products and to generate the minimum amount of waste in the process (Nolan, 2005 & Robert, 2006).

The Waste Hierarchy (shown in figure 2) ranks various forms of waste treatment and disposal in order of preference. When making decisions concerning the treatment and disposal of wastes, consideration should be given first to those options that appear at the top of the hierarchy (Herefordshire & Worcestershire, 2004).

The trend of the hierarchy below the top priorities is often contested, and discussions on waste policy are intense in many countries. The order of preference of recycling and incineration has been a point of discussion in the waste hierarchy as well as where to place biological treatment such as anaerobic digestion and composting (Finnveden, 2004).

2.2.1 Waste Hierarchy.

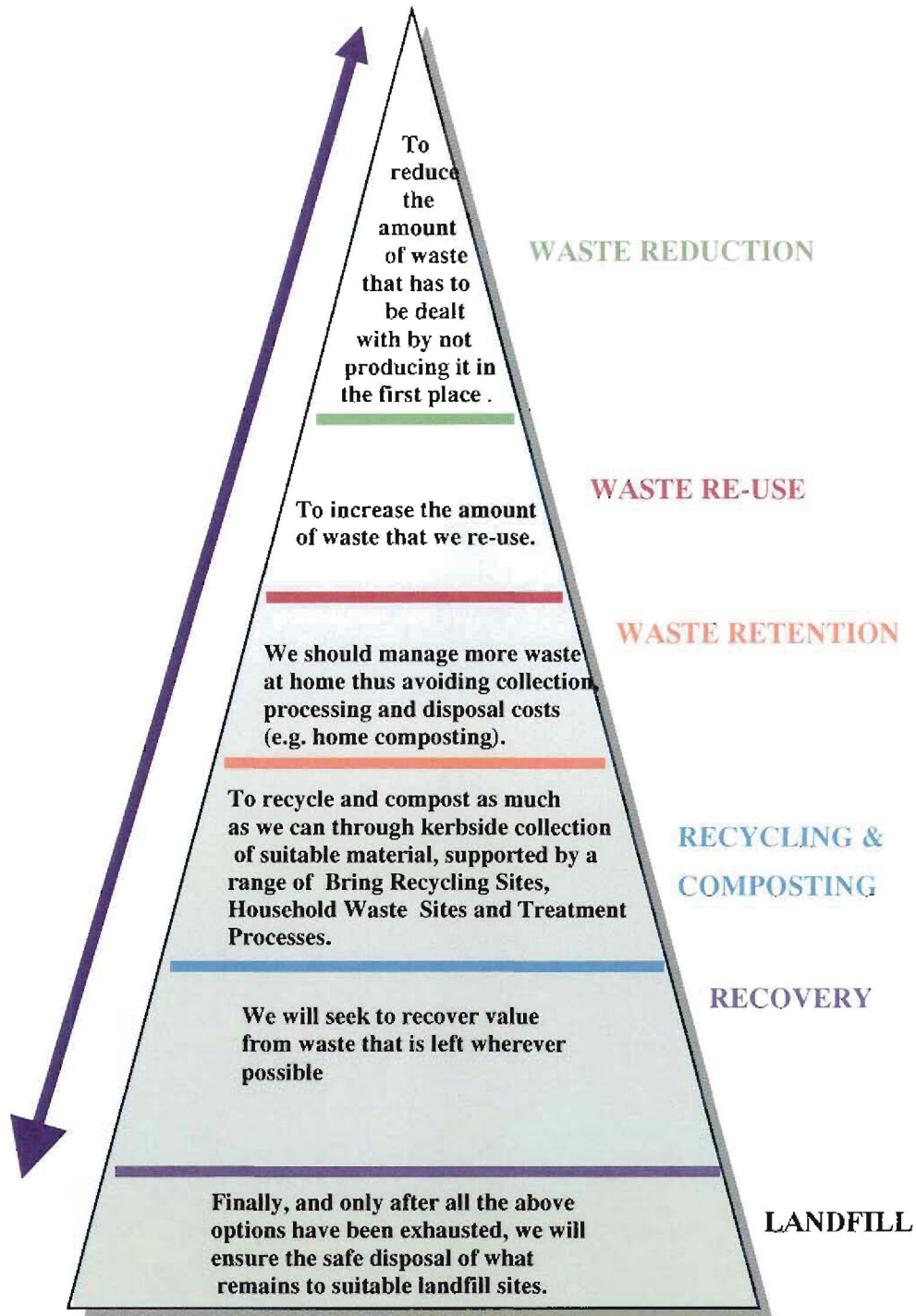


Fig. 1: Waste Hierarchy (Herefordshire & Worcestershire, 2004).

Even though, the top priority is accepted generally, strategies leading towards the reduction of waste generated are often lacking. Jacqueline McGlade, Executive director of the European Environmental Agency (McGlade, 2005) acknowledges that the EU directive targets for packaging waste have helped in achieving higher recycling rates across Europe.

However, she mentioned that “the need to tackle the ever increasing generation of waste has remained in the form of an objective rather than a specific, quantitative target, and there has been little progress on the issue” (McGlade, 2005 & Harry, 2007).

The role that Local Authorities can have in waste minimization and achieving ‘zero waste’ is shown in the diagram below:

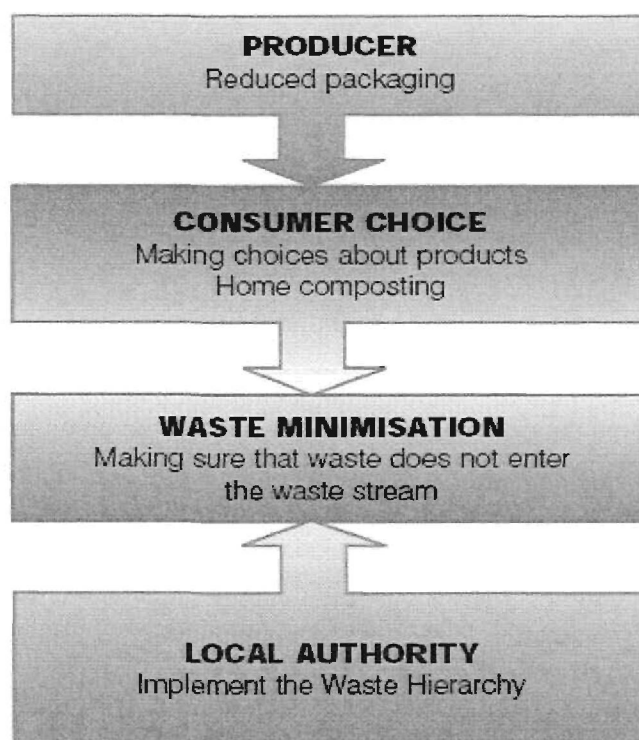


Fig. 2: Waste Minimization Strategy (Herefordshire & Worcestershire, 2004)

This Strategy views waste as a resource and aims to reduce the amount of waste which cannot be re-used, recycled or composted as far as is practicable to a minimum. The concept of ‘zero waste’ is currently being promoted in the UK by Greenpeace and Friends

of the Earth and is being formally adopted by some authorities in the UK (Zero Waste, 2005 & Herefordshire & Worcestershire, 2004).

2.2.2 Extended Producer Responsibility

Extended Producer Responsibility (EPR) is a strategy designed to promote the integration of all costs associated with products throughout their life-cycle (including end-of-life disposal costs) into the market price of the product (OECD, 2004: 89).

Extended producer responsibility is meant to impose accountability over the entire life-cycle of products and packaging introduced to the market. This means that firms which manufacture, import and/or sell products are required to be financially or physically responsible for the products after their useful life as well as during manufacture (OECD, 2004: 105).

The principle is about moving away from wasting resources. Since Producer Responsibility came into force in 1994, all producers are responsible for their products even after their use. In Sweden, Producer Responsibility is required for packaging, tyres, waste paper, motor vehicles and electronic products, etc.

The long term aim of Producer Responsibility is that it will lead to more environmentally responsible product development (Naturvårdsverket, 2006).

2.2.3 Polluter Pays Principle.

The Polluter Pays Principle is a practise where the polluter pays for the impact caused to the natural environment. It is a general requirement for waste generators to pay for appropriate waste disposal generated (Ernst, 1998 & Joseph, 2002).

2.2.4 Collection and Waste Handling Methods.

From throwing waste out of the window into the street to the organized collection of sorted waste for treatment in central facilities through recycling, incineration, digestion, composting or landfilling, waste management of household waste has made amazing progress.

The management of municipal waste creates a number of challenges as a result of decreasing availability of vacant space for landfill sites. The government at various levels has set targets to recover various percentages of the value of household organic waste by 2010 and in a progressive manner too. One potential contribution to this target is through exploiting the fact that up to 25% of this waste is "putrifiable" and can be converted to other valuable products (Gajdos, 1998).

Collection and handling methods differ among different countries and regions, and it would be impossible to describe all these methods. As an example, in Australia most urban domestic households have a 240 litre (63.4 gallons) bin that is emptied weekly by the local council. Some European countries use a proprietary collection system known as Envac. This method conveys refuse via underground conduits using a vacuum system, this system has been developed and used in Roosevelt Island since 1975 (Nolan, 2005).

The implementation and development of a sustainable waste management strategy involve the efficient use of transportation as a key factor. Presently, wherever practicable and cost effective, the transportation of waste and recycled materials should be minimized through the provision of local sites as well as compacting the waste materials to reduce the size (Herefordshire & Worcestershire, 2004 & Margaret, 2003).

The objective of Best Practicable Environmental Option (BPEO) considers transportation as a key factor in the management of waste. BPEO objectives have identifies and considers the economic and environmental cost of transporting waste.

The BPEO process also considers the relevant merits of various waste management options to help identify the 'best' option. For example, the heart of the waste management decision making framework for waste strategy 2000 was the concept of BPEO.

BPEO is defined in the 12th report of the Royal Commission on environmental pollution as:

"The outcome of a systematic and consultative decision making process which emphasizes the protection and conservation of the environment across land, air and water". As reiterated by the organization Friends of the Earth press release that focused on waste planning guidelines in December, 2004 *"that the BPEO procedure establishes, for a given set of objectives, the option that provides the most benefits or the least damage to the environment as a whole, at acceptable cost, in the long term as well as in the short term"* (Katy, 2002).

In Canadian urban centres, kerbside collection is the most common method of disposal, whereby the city collects waste and/or recyclables and/or organics on a scheduled basis. In rural areas people usually dispose off their waste at transfer stations and eventually collected and then transported to a regional landfill. There are no formal waste collection systems in many areas, especially those in less developed nations especially in Nigeria (Nolan, 2005).

Significant percentage of Garbage that resident communities generate, is picked up from houses or establishments by the sweeper and dumped at nearby community bin (termination point of primary collection) for onward transportation to notified dumping ground (termination point of secondary collection).

In some developing countries like Nigeria a process have been put in place in some areas where Garbage is picked up directly from residential homes transported directly to a dumping site. Additionally, some household garbage is transported from transfer stations to dumping site (Cheeseman, et al., 2007).

Developments in technology made it possible to use a simple collection system. Household will only be supply with two containers (one for recyclable materials and

one for residual waste). A compaction vehicle will collect waste from each household weekly (Herefordshire & Worcestershire, 2004).

Gaseous wastes originate to a large extent from gas emissions resulting from insufficient management of solid organic waste (SOW) and liquid organic waste (LOW). A specific example includes the foul-smelling odours that are mainly produced due to uncontrolled microbial degradation.

Information on exhaust gas emissions from various human activities has neither been systematically collected, or appropriately evaluated. Not only gases, but also other small particles, microorganisms, and their spores are present in the air during poor disposal methods, collection, transportation, as well as treatment and post-processing of SOW and LOW.

Developing an integrated solution for waste management problems requires public involvement. To economically and efficiently operate a waste management program, requires significant cooperation from the generators regardless of the strategies selected.

From separating recyclables from non recyclables, dropping off yard trimmings at a compost site, removing batteries from material sent to waste to energy plant, or using designated containers for collecting materials. To maintain long-term program support, the public needs to know clearly what behaviours are desired and why (EPA, 2003). These are good BPEO practices recommended.

2.3 Waste Disposal Techniques

The waste disposal strategy is to follow a minimization of waste by an approach of reuse and recycling before any possibility of elimination or treatment (fig. 2) (Sani, 2007).

Some of the various waste disposal techniques considered are as discussed below:

Conventional waste disposal systems

- Landfill
- Incineration
- Resource recovery and recycling
- Bioconversion systems

These various waste management techniques are employed to serve specific purpose depending on the type of waste being considered and legislative provisions.

2.3.1 Landfill

Globally, landfill remain the most popular (and often the cheapest) method for the disposal of municipal solid waste. The foundation of a good solid waste management system is the municipal solid waste (MSW) landfill. MSW landfills provide for the environment sound disposal of wastes that cannot be reduced, recycled, composted, combusted, or processed in another manner (EPA, 2003).

A Landfilling site is needed for disposing of residues generated from recycling, composting, combustion or other processing facilities and can be used if the alternative facilities break down. A properly designed SW landfill includes provisions for leachate management and the possible collection of landfill gas and its potential use as an energy source. Innovative planning may also facilitate the productive use of the landfill's properties after the landfill is closed (EPA, 2003).

However, recent California legislation, which requires the diversion of 50% of food and green wastes from landfills, creates additional opportunities and incentives for biomass waste utilization as a feedstock for digesters (Mingarini, 1996).

Converting these wastes into bio-energy and other valuable products creates both environmental and economic benefits. Recovery of the landfill tipping fees (currently \$25-70 per wet ton) associated with disposing of most food and green wastes will greatly enhance the economics of the anaerobic digestion technology (Mingarini, 1996).



Fig. 3: View of a landfilling site (Mingarini, 1996)

Limited knowledge is available regarding the type of substances that appears on landfills, how these substances influence water, soil, and vegetation, and how the substances interact with other compounds inside and outside living organisms. A range of heavy metals and anthropogenic substances, such as persistent organic compounds, are hidden in landfills (Mingarini, 1996).

Different chemicals are mixed with OW in the landfills, and this may cause microorganisms to mutate into unwanted forms. Therefore, it should be mandatory to evaluate how combinations of different wastes will influence the environment in the long term (Gajdos, 1998).

Landfill leachate is a latent polluting liquid, which unless returned to the environment in a cautiously controlled manner, could cause harmful effects on the groundwater and surface water surrounding a landfill site.

For example, leachate from a biodegradable landfill will contain significant concentrations of substances such as ammonical-nitrogen, which is toxic to many organisms. Run-off from a landfill that contains only soil and rubble may hold suspended solids, be turbid, and

threaten fish and other aquatic organisms. Monitoring of such leachate is therefore required. The objectives of leachate monitoring are to provide assurance that the landfill operation does not cause harm to human health or the environment (Salem et al, 2007).

Almost all wastes material would produce leachate if water is allowed to permeate through the material. The quality of leachate is determined primarily by the composition and solubility of the waste constituents. If there are changes in waste composition due to weathering or biodegradation, then leachate quality will change correspondingly, especially in municipal landfills sites. The phases in the generation of leachate specified are representative of landfills that have received non-hazardous municipal wastes (SEPA, 2003 & Salem et al, 2007).

The pre-knowledge of landfill material is vital, to eliminate methane that is generated by biodegradable wastes in landfills. Methane is a powerful greenhouse gas, many times more potent in its effects than carbon dioxide (Herefordshire & Worcestershire, 2004).

2.3.2 Incineration.

Incineration is a waste disposal technology that involves the burning of organic materials and/or substances. Incineration of waste materials converts the waste into heat, which can be used to generate electricity, gases, particulates of combustion and ash (Nolan, 2005).

This is thermal methods of waste disposal, which could be depicted as thermal gasification, and pyrolysis. Gasification method involves applying extreme heat in a near-inert environment to reduce waste, while pyrolysis is carried out in the complete absence of oxygen (Cohen, 2001).

Unfortunately, incineration degrades all organic compounds and causes emissions, which pollute the environment. Ash from waste incinerators is classified as hazardous waste in some countries and deposition fees are very high.

In Switzerland the deposition fee is US\$ 914 (1989 value) per ton of ash generated from household wastes (B. Hjortdal, the head of municipal composting plant in Falkenberg in 1989, personal communication) (Gajdos, 1998).

The Swedish Association of Waste Management disclosed that, in 1992, 4.4TWh energy was generated by incineration and used mainly for heating, while the available amount of energy, in the burned OW, was about 12 TWh. Thus, the energy transformed for use was only about one-third of the energy which was bio-chemically bound in the OW. The negative impact of incineration on the environment was not evaluated (Gajdos, 1998).

Incineration has a number of outputs such as the ash and the emission to the atmosphere of combustion product gases, and in case where flue gas cleaning is lacking or insufficient, particulate matter, heavy metals, dioxins, furans, sulphur dioxide, hydrochloric acid and PAH's are emitted.

In a study (de Bertoldi et al, 1994) from 1994, Delaware Solid Waste Authority found that modern incineration plants emitted fewer particles, hydrocarbons, SO₂, HCl, CO and NO_x than coal plants, but more than natural gas plants. According to Germany's Ministry of the Environment, modern waste combustors reduce the amount of some atmospheric pollutants by substituting power produced by coal-fired plants with power from waste-fired plants (Jenssen, & Vatn, 1991).

The gaseous and particulate emissions can be cleaned from pollutants and dispersed in the atmosphere if the incinerator is of the open variety. Incinerators that burn municipal wastes are often refer to as Municipal Solid Waste Incinerators (MSWIs) (Nolan, 2005).

Incineration functions as an alternative to land filling and biological treatment methods such as composting and anaerobic digestion. Incineration is beneficial particularly for the treatment that requires high temperature of certain waste types in niche areas such as clinical wastes and certain hazardous wastes where pathogens and toxins must be destroyed by high temperatures.

Contemporary incinerators are very different from those commonly used a few decades ago. The old-type incinerators did not include material separation to remove hazardous or recyclable materials before burning, and tended to risk the health of the plant workers and the nearby residents. Most of the incinerators did not generate electricity. Waste incineration is predominantly popular in countries such as Japan where land is a scarce resource (Kleis, et al., 2005).

Denmark and Sweden have been leaders in utilization of incineration energy for over more than a century in localized combined heat and power generation facilities supporting district heating schemes (Kleis, et al., 2005).

In 2003, waste incineration produced 3% of the electricity consumption and 8% of the total domestic heating in Denmark. A number of other European Countries rely heavily on incineration for handling of municipal waste, in particular Luxemburg, are the Netherlands, Germany and France (Kleis, et al., 2005).

The hottest ten year in the earth's history have occurred in the last 14 years. The world's carbon dioxide (CO₂) emissions are also higher than what they were. According to the intergovernmental Panel on climate change (IPCC), things are getting worse with increasing temperatures. It has been predicted that temperatures will rise by 1.4 degrees between 1990 and 2100. (Sasolnews bulletin, 2007).

Dr Bob Scholes, a systems ecologist with the Council for Scientific and Industrial Research in South Africa, studies the effects of human activities on the global ecosystems, in particular on woodlands and savannas in Africa. In an address at a recent Sasol leadership forum, he discussed how few degrees temperature change could affects ecosystems on a permanent basis.

His message was clear, "We certainly know enough to know there's problem. We also know beyond reasonable doubt that climate has changed due to human activity. What we really don't know is how people will react to this challenge" (Sasolnews bulletin, 2007).

In December 1997, negotiations regarding greenhouse gas emissions commenced in Kyoto, Japan, and on 16 February 2005, the Kyoto protocol came into force. This protocol is an agreement made under the United Nations framework convention on climate change (UNFCCC), where countries commit to reduce their emissions of carbon dioxide and five other greenhouse gases, or engage in emission trading. South Africa is one of the 175 countries that have committed to saving the environment by adopting the Kyoto protocol which Nigeria is a member nation (Sasolnews bulletin, 2007).

The atmosphere makes life as we know it possible on earth. It screens out harmful short-wavelength radiation and maintains a moderate temperature on the surface of the earth. The two atmospheric components of greatest importance in maintaining earth's temperature are carbon dioxide and water. The influence of these and certain other atmospheric gases on earth's temperature is often called the greenhouse effect.

The worldwide combustion of fossil fuels, principally coal and oil, has sharply increased the carbon dioxide level of the atmosphere, and this increase is radically affecting earth's climate (Sasolnews bulletin, 2007).

2.3.3 Resource Recovery and Recycling

Waste recovery is often viewed as a resource conservation activity. It may also offer a greater return for many products in energy saving. By 2010, at least 50% of all household waste will be recycled through materials recovery, including biological treatment (Yuan et al., 2006).redi_proj2006

Currently strict regulations on disposal of waste (Directive 99/31 and Council Decision 19 December 2002 of the European Union) almost forbid the disposal of the organic wastes to landfills and via incineration. The objective is to reduce the production of leachate and gases responsible for greenhouse effects. The treatment of bio-waste to reclaim important elements like carbon, nutrients (Nitrogen and Phosphorus), energy and heat is highly encouraged (Battistoni, et al., 2006).

An interesting option for managing organic waste streams is by diverting it from incineration and landfilling to organic waste conversion and treatment facilities is the application of food waste disposers (FWDs) for the treatment of organic food wastes (CECED, 2003).

Only recently was it acknowledged in Europe that the opportunity that FWDs offer will probably be the future of organic waste management. This technology has already been widely applied in USA, Canada, Brazil, Japan and Australia (CECED, 2003; Fatone, et al., 2003).

Although, several studies have been carried out to reveal the reliability of this approach, a part of the scientific and technical communities still believe its application to be hazardous (Fatone, 2006).

Previous studies clearly indicated that this technology caused the addition of insignificant amounts of toxic substances, while the addition of extra-loadings of pollutants like chemical oxygen demand (COD), biological oxygen demand (BOD), suspended solids, nutrients or greases and oils are sometimes consistent, but can be easily managed in existing properly designed and managed organic waste converter (OWC) systems and FWD treatment plants.

Further, the extra-load of organic material can improve the performances of the activated nutritional processes as well as the by-products (when present). The convenience of this process was demonstrated in the publication of the applications of the FWDs in the last two decades and showing the relative inconsistency of the uncertainties envisaged (Fatone, 2006).

In recent time, waste management idea has shifted to treating waste material as a resource to be exploited, rather than simply a challenge to be managed and disposed of (Soni, 2007).

The organic nutrients may be extracted and recycled or the calorific content of the waste may be converted to electricity. The process of extracting resources or value from waste is

sometimes referred to as secondary resource recovery, recycling, and other terms (Nolan, 2006 & Soni, 2007).

Due to scarcity of land for landfill purposes, waste materials are being treated as a resource especially in metropolitan area. Simply disposing of waste materials is unsustainable in the long term, as there is a finite supply of most raw materials. A number of techniques had been developed for recovering resources from waste materials, and more new technologies are continuously being developed (Nolan, 2006).

In some developing countries, there are manual labourers who rummage un-segregated municipal waste to salvage material that can be sold in the recycling market. These labourers contribute towards resource recovery in an economic way. These unrecognized workers called **waste pickers** or rag pickers, are part of the informal sector, but play a significant role in reducing the load on the Municipalities' Solid Waste Management system (Nolan, 2006).

The contributions of these waste pickers are being recognized and policies are being formulated to integrate them into the formal sector of the waste management system. Their contribution towards environmental protection has proven to be both cost effective and also appears to assist with urban poverty alleviation. However, the safety and risk associated with these activities include diseases, injury and reduced life expectancy through contact with toxic or infectious materials, and these would not be tolerated in a developed country (Nolan, 2006).

2.3.3.1 Recycling.

It requires almost the same time, energy, labour, and finance to make new products from recycling processes. Currently it has been postulated that it's often easier or cheaper for manufacturers to use virgin rather than recycled materials to make new products (Georgieva & Burazeri, 2005).

For recycling to be meaningful, manufacturers need:

- The technology to make new products from recycled materials of high quality, that meet manufacturers' specifications
- A steady supply of recovered materials at affordable cost
- Customers need to buy products that contain recycled materials and
- Consideration of disposal cost and its effect on the environment (Bassis, 2000 & Georgieva & Burazeri, 2005).

Separating glass jars, aluminium cans, and newspapers from other waste type and sending these products to a recycling centre is only the first step in the recycling process. In order to make recycling worthwhile the loop must be completed. The cans, papers, and bottles must be remade into new products that must be offered for sale and re-use in various applications.

2.3.4 Bioconversion System

Bioconversion can be used for:

- i) Biological breakdown (decomposition) of municipal solid waste with the objective to reduce the volume and the weight of the organic portion. This can be achieved by methods (a) and (b) below, which are inexpensive but still within the main goal of getting rid of the waste.
- ii) Improvement of organic matter (microbial transformation) to valuable products, by methods (c) and (d) below. Organic waste is used as renewable raw material in an ecologically, economically, and socially optimal way (Gajdos,1998).

The following are methods for bioconversion systems:

a) Bio-fertilizers are produced

b) Bio-fertilizers and biogas are produced

c) Inactivation of pathogens and seeds (sanitation)

d) Biogas as a source of renewable energy

The inaugural decade of the third millennium might well become the Era of Waste Conversion, if politics don't stand in the way. In the 1990s, the nations moved from a recycling rate of roughly 10 percent to a waste-diversion rate that approached 30 percent. Some cities pushed toward a 50 percent diversion rate. Nearly every state set waste-diversion goals or mandates. Waste-management seminars and the waste management journals exploded with discussions on recycling and composting (Gajdos, 1998).

As this exercise in waste-diversion is ongoing, the first decade of the 21st century is likely to launch a whole new set of initiatives focused on what Paul Relis, former member of California's Integrated Waste Management Board, calls "post-recycled municipal biomass." Previously, a class of entrepreneurs is pioneering the research of new ways of handling all that undifferentiated "stuff" that's hard and costly to segregate from the waste stream for mechanical recycling or composting, these efforts are commendable and multifaceted.

Conversion of biomass waste into fuels and chemical feedstock are being pioneered by some entrepreneurs like Masada Incorporation. Cellulosic plant material can be broken down by "bio-refining", using chemicals or enzymes, to release sugars. These sugars are subsequently fermented, and can be refined into ethanol a fuel or fuel-additives and bio-based industrial chemicals (Scarlett, 2000).

Masada already has a project ongoing in Middletown, New York, to convert municipal waste in this manner. In North Carolina, the DCI Group is also embarking on the construction of several ethanol plants. Agricultural products will provide much of the feedstock, but biomass refuse may also become part of the input into the process (Scarlett, 2000).

Other pioneers are rethinking the structure and management of landfills in order to develop more suitable ways to tap the latent potential and generate marketable methane gas. So-

called bioreactor landfills which speed up bio-degradation of refuse are being proposed. Proponents promoted the bioreactor landfills as yielding multidimensional benefits, which includes:

- Faster methane generation makes methane recovery more cost effective.
- This could also reduce the landfill post closure maintenance period from 30 to 60 years down to less than 15 years, since bioreactors more quickly stabilize the buried refuse (Scarlett, 2000).

The "conversion crusaders" had no lack of ideas or technologies but politics, however, may interfere with entrepreneurial dynamics in the form of both barriers and ill-considered promotional efforts. For example, Masada saw its attempt to site a bio-refinery in Birmingham, Alabama scuttled by local politics.

Public officials had initially blessed the project, but public opposition prompted a reversal of this decision. Local residents objected to potential air emissions from the facility, questioned the project's economics, and worried that the plant would result in trash imports to the community in order to provide Masada with enough feedstock to operate efficiently (Scarlett, 2000).

Biologically, all urban OW, such as that coming from gardens, food residues, paper and human excreta from households, restaurants, commerce, small industries, can be treated in bioconversion systems. These systems can also be modified for rural OWs and residues from agriculture, horticulture and forestry. Even fuel crops (plants grown for utilization as energy sources for energy) can, by similar methods, be transformed into energy-rich biogas and valuable, reproducible bio-fertilizers.

Conditions, under which the formation and or the degradation of various substances take place, are still a large field of research. Steinfeld and Zane pointed out three principal requirements:

- Nutrient balance

- Physical and chemical structure and
- Moisture content.

Also for good product hygiene, it is necessary to elevate the temperature to the required levels in the whole substrate, which means that good insulation of the equipment (bioreactor) is important (Steinfeld, & Zane, 1995).

Energy balance during aerobic bioconversion is not clearly illustrated, as suggested by Denecke, et al. systems developed where the substrate will be treated in a combined process, the substrate will undergo aerobic and anaerobic microbial transformation, respectively, and the process can go through two or three phases.

2.4 Commercial Uses of Organic Waste.

Possible uses of organic wastes include the use as fertilizer and soil amendment. OW can also be used for energy recovery (heat, liquid fuels, electricity), and production of chemicals (volatile organic acids, ammonium products, alcohols). Agriculture has traditionally used animal manures for fertilizer and improving soil physical and chemical properties. To a lesser degree municipal bio-solids and industrial organic wastes has also been utilized for these purpose.

Energy production from animal manures, crop residues, and/or other organic wastes has been utilized in agriculture to varying degrees in different parts of the world. Utilization of various organic wastes in agriculture depends on several factors, including the characteristics of the waste such as nutrient and heavy metal content, energy value, odour generation, availability and transportation costs, benefits to agriculture, and regulatory considerations.

The importance of these factors can vary by type of organic wastes, but many of the considerations for utilizing organic wastes are similar for most types of organic wastes. The emphasis of this dissertation work will focus on the conversion of organic food waste

used as feedstock for animal feed production. Many of the considerations will apply to organic food wastes only.

Converting Leftover Waste

Conversion Technologies (CTs) refer to a diverse set of new non-combustion, thermo-chemical and bio-chemical technologies which are capable of converting biomass and other organic-wastes into marketable products such technology includes:

- Gasification
- Pyrolysis
- Thermal Depolymerization
- Catalytic Cracking
- Hydrolysis/Fermentation

What Are CT Products?

Green Power and Heating Electricity derived from biomass methane, synthetic gas, steam, and bio-oils (BPA, 2004).

Green Chemicals

These are non-toxic, degradable bio-chemicals used for the production of pesticides, fertilizers, acids, solvents, lubricants, polymers, inks, adhesives, solvents, and other petroleum replacement products (BPA, 2004).

Renewable Fuels

Ethanol and bio-diesel are derived from biomass- synthesis gas, sugars and oils; Low sulfur diesel from waste plastics (BPA, 2004).

Source separation of waste and uncompromising restrictions on production, distribution and use of agrochemicals in conversion system will stimulate the development and implementation of bioconversion, and clean up our polluted environment (BPA, 2004).

2.4.1 Possible Diversion Options for Food Wastes

As an option of disposing waste in a beneficial, cost effective and environmental friendly manner, the alternative below could be exploited:

1. **Food Donations** – As a means of waste disposal, non-perishable and unspoiled perishable food can be contributed to local food banks, soup kitchens, and refugee shelters. Given that these donations assist in recycling of food and also help feed people in need of assistance, this option should be considered before looking at other alternatives.
2. **Source Reduction** – This is one of the most cost effective waste management options, as this includes waste reuse. It helps to reduce waste disposal and handling costs, and it avoids the costs of recycling, municipal composting, landfilling, and combustion. This method also conserves resources and reduces pollution, including greenhouse gases that contribute to worlds global warming.

If auditing is carefully carried out on waste streams, an establishment could determine the percentage of food and organic wastes that are present in their trash. This would assist with the identification of potential waste reduction sources that may aid an establishment to:

- Manage the quantity of food they buy
- Purchase pre-cut foods
- Explore the possibilities of ration or portion control at restaurants.

3. **Animal Feed** – Restaurant food wastes recovery as animal feed is not new. In many areas these type of waste are traditionally fed to pigs or livestock. In most cases farmers may provide storage containers and free or low-cost pick-up service on daily bases. Food wastes with high salt content are not usually accepted, because they can be harmful to livestock. This pick-up food can be converted using appropriate technology into a high-quality, dry, pelletized animal and pet feed.

4. **Rendering** – animal food, cosmetics, soap and other products can be made from Liquid fats and solid meat products and can be used as raw materials in the rendering industry.

5. **Composting** – This method requires the availability of land space. The location of end users would determine the decision to compost on or offsite. If it is to be done on site the appropriate feedstock and operational issues must be considered.

2.4.2 Benefits of Food Waste Diversion.

The major benefit of the process of recycling or reuse as show below:

a) It is beneficial to recycle rather than to incinerate or landfill. The price per ton to divert food and organic waste to a composting facility is usually much less than it is for conventional trash disposal in landfills or incinerators. For example, Slade Gorton saved an average of \$50 per ton on landfill fee through composting by diverting fish waste.

The company has furthermore saved money by reducing the removal of waste by 30%. With high recovery rates, an organization can have its regular waste collectors picked up less frequently, or use smaller collectors at the same pick-up frequency. This process would avoid Trash Collection and Disposal Fees (Megan, 2006).

b) Compliance with environmental stipulations and letting customers and colleagues know that your business is making an effort to recycle and provide for a sustainable future, it will increase customer satisfaction and confidence in business.

c) Through contribution of unused food, a business could helps to feed those in need of assistance and keep reusable material out of landfills and incinerators, For instance, the Greater Boston Food Bank distributes 13 million pounds of food to needy people annually, which worth a total wholesale value of over \$16 million (EPA, 2005).

d) Nutrients can be recovered from Food as Compost or Animal Food. The food and organic waste diverting to composting eventually produces humus or compost, which is a

valuable addition to any horticultural or landscaping project. This was exemplified by the Harvard University by composting from landscape trimmings and cafeteria food scraps used for cheap soil amendments.

e) **Jobs creation and sustenance of Local Industries:** Food waste generators typically do not need to hire new employees to manage food recovery programs. However, recycling of food waste could serve as feedstock for small scale industries. Composting industries employ four times more people on a per-ton basis than landfills.

2.5 Impact of Waste Management Practise.

A healthy environment can be achieved only when human activities respect basic biological and physical rules, for example by proper handling and management of OW (de Bertoldi, et al. 1994).

Air quality problems have no borders, and therefore there is a need to reduce harmful emissions globally. Urban areas particularly, need new technology alternatives for waste management. This includes collection, transport, and pre-processing of wet and dry wastes, which will result in efficient and hygienic upgrading of this renewable raw material to valuable and environmentally safe products.

The new, hygienic and environmentally sound infrastructure must include:

- 1) Waste management (source-separated collection, treatment, and reuse of material and energy).
- 2) Water management (proper supply and discharge, minimizing the losses of water and its pollution).
- 3) Transportation (organic fertilizers from urban to rural areas and agricultural products from rural to urban areas), and efficient systems for the utilization of renewable energy (biogas) for generation of electricity and heat or as fuel for vehicles.

Water management in most countries is not sufficient from the environmental, ecological and economical points of view. Migration to urban areas has led to problems connected with OW and water management (Goldstein, 1998).

The need to conserve and preserve the available water resources, and to safeguard their quality for use in households and for irrigation, calls for a decrease in the use of landfill as a means of waste disposal medium. The development of a new infrastructure and sanitation systems with fast collection and conversion of OW, leading to ecologically sustainable and economically efficient management of OW and wastewater, is of the highest priority (Goldstein, 1998).

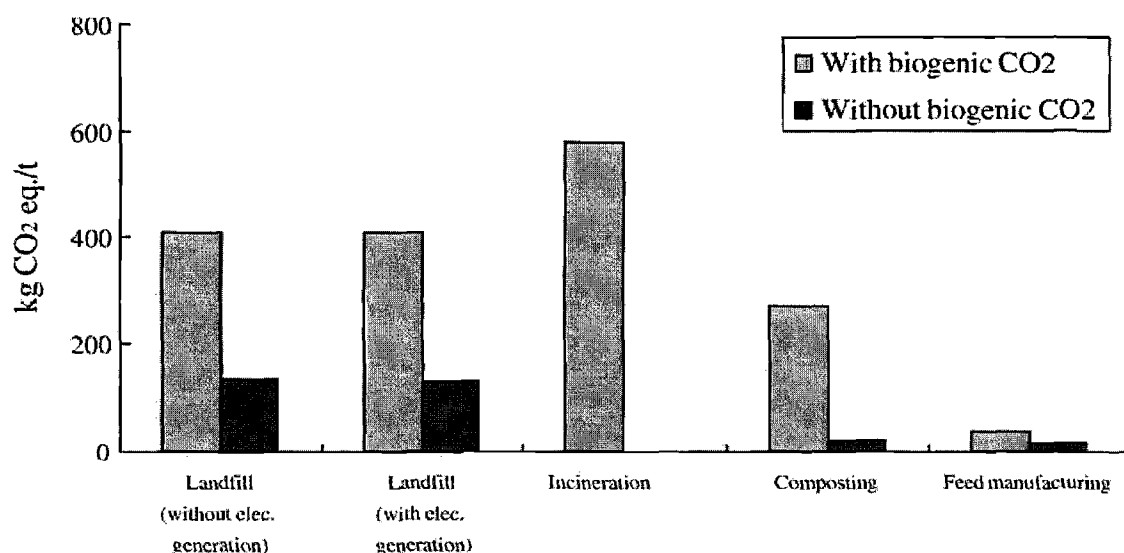


Fig. 4: Global warming impact with and without biogenic CO₂ emission (Choi et. al., 2007)

Figure 4 above shows the impact of waste management techniques to the ecosystem, especially global warming, regarding the main greenhouse gas, carbon-dioxide emission to the environment and human toxicity (Choi et. al., 2007).

When the impact category in each system is compared (i.e. CO₂ emission), it was established that landfill system is the main contributor to human toxicity and global warming (based on fossil CO₂). However, as a result of increase food waste recycling, acidification, eutrophication, and fresh water aquatic ecotoxicity impact was increased, particularly the high energy consumption and generated residue in recycling systems caused the large burden in toxicity categories (Choi et. al., 2007).

2.6 Conclusion

The review of the above waste management methods provides a broader understanding of some of the waste management and waste disposal systems in use. It is not practical to develop a universal solution applicable to the management and disposal of all waste types.

The adoption of a particular waste management system is determined by basic factors. These factors are not limited but include:

- The type waste
- Waste composition
- Legislation in place
- Awareness of environmental and health implications
- Economic cost of disposal
- Availability of resources
- Availability of technology, etc.

The evaluation of an alternative organic waste disposal system in Chevron-Escravos (CE) will requires the present waste management practices to be well understood as a case study. To propose a more suitable alternative waste disposal system and the information discussed in this chapter will have to be carefully considered. The current waste management practices are reviewed in the next section (Chapter Three) in order to propose

an alternative waste management system for the significant volume of organic food wastes generated by this facility.

CHAPTER THREE

Assessment of Chevron-Escravos Waste Management System

3.0 Introduction

This Chapter discusses the current waste management practises used by Chevron-Escravos. This chapter also discusses the waste generation, type, quantities, classification and the waste disposal routes and methodologies of the solid organic waste produce in Chevron-Escravos (CE) plant.

This chapter contains information gotten from interviews with some employees and managers, Chevron's waste management document review, site visits, and interviews with community members in order to draws an outline of the position, procedure and status of the current waste management situation in CE and the problems arising vis-à-vis best practises in terms of environmental, safety and economic benefits.

3.1 Study Area Description

The case study area selected is the Chevron Escravos oil and gas exploration and production facility. This is situated on an island in a swampy terrain in the southern part of the Niger-Delta region of Delta state of Nigeria (see Fig. 5). The area is located at the intersection of the Warri River and the Escravos River and adjoining the Atlantic Ocean.

The facility has 6 host communities and other settlements, including the Chevron Escravos tank farm industrial and residential estate. The total population in this facility is about 3,500 to 4,000 inhabitants as at 2005 personnel-on-board data. (Chevronnews bulletin, 2006).

This dissertation covers the management of organic wastes generated by the Chevron-Escravos tank farm and other Chevron offshore and onshore flow stations and production platforms in the Escravos municipal area.



Fig. 5: Arial view of Chevron-Escravos tank farm

3.2 Waste Management Process

Waste management is a requirement both from a legislative directive and from Chevron's internal policy 530 P&E (Protecting People and the Environment). Sound waste management practices generally improve environmental performance (protection and conservation) and help to avoid potential liabilities or public relation risks, including legal action and community protest against environmental pollution. SOP-701 is another waste management policy intended to comply with environmental regulatory and policy requirements (CNL, 2006).

This policy (SOP-701) outlines the waste management procedures and includes selection, operation and documentation of waste management practices for Chevron Nigeria/Mid-Africa strategic business unit (SBU). Chevron-Escravos waste management strategy

requires the facility to first take inventory of the waste types and to categorize waste according to its hazard properties. It then requires either minimization or pre-treatment prior to the final treatment or disposal in accordance with the waste hierarchy of priorities (see fig. 1 in chapter 2).

a) Wastes Inventory

The department that generates the waste is responsible for developing the waste inventory, which must provide brief information on each waste type. The information must include quantity, specific type, hazard classification, etc. An example of an inventory and management options for waste disposal options at Chevron-Escravos and other chevron facilities are as shown in Table 2 below:

Waste Inventory and Summary of Management Practices

Table 2 (SOURCE: Chevron NMA SBU – SOP 701Waste management practices. Approved 1st October 2006 Version 1.1)

Type of waste	Waste Management Methods			Note/Cautions
	Preferred Alternative 1	Alternative 2	Alternative 3	
Abrasive Blasting Media	Land reclamation	Dispose at approved dumpsite	Incorporate with cement and landfill	Dispose at dumpsite only if parameters are within limits.
Acid/caustic	Neutralize and add to wastewater			
Aerosol cans (empty)	Recycle to scrap	Dispose at approved dumpsite		DO NOT INCINERATE
Asbestos	Landfill			Inhalation hazard
Associated gas	Reuse/Recycle	Flare		Gas flaring is prohibited unless conditions in section Part 3 E3.8.8.1 are met
Batteries (lead/acid)	Drain and recycle to scrap	Incorporate with cement and landfill		Purchasing arranges scrap sale
Batteries (flashlight)	Dispose with trash			DO NOT INCINERATE

Chapter 3: Assessment of Chevron-Escravos Waste Management

Type of waste	Waste Management Methods			Note/Cautions
	Preferred Alternative 1	Alternative 2	Alternative 3	
Batteries (Ni/Cd - e.g. radio)	Return to vendor	Stabilize with cement and landfill		DO NOT INCINERATE
Contaminated fuels	Recycle to production	Use as Incinerator fuel	Recycle to off-site User / off-site treatment	Do not dispose contaminated fuels into open water.
Cooking Oil (used)	Rinse to sanitary drain.	Incinerate large quantities	Rinse to facility sump drain where oil recovery is Feasible.	Do not throw overboard.
Desiccant/mole sieve	Bury or landfill	Construction fill		
Detergents (oil cleaner/rig wash)	Rinse to process drain			
Drilling mud/cuttings	Dry, stabilize and Re-use	Injection or landfill	Offshore or Deepwater only, Overboard per DPR limits	Discharge of drilling mud and cuttings is prohibited in near-shore and inland areas
Drums (empty and cleaned)	Return to vendor	Crush and recycle to scrap	Crush and dispose in an approved dumpsite	
Filters (auto, engine, water)	Drain and recycle to scrap	Crush and recycle to scrap	Use as fill material at an approved dumpsite	
Filter media	Bury or landfill	Construction fill		
Glycol (gas dehydration)	Regenerate			
Hazardous chemicals	Recycle	Incinerate	Neutralize and rinse to waste water	Review with HES before selecting alternative, may require other pre-treatment
Hydrocarbon liquid (solvent, etc)	Recycle to production.	Use to enhance incineration		Check for chlorinated solvents.

Chapter 3: Assessment of Chevron-Escravos Waste Management

Type of waste	Waste Management Methods			Note/Cautions
	Preferred Alternative 1	Alternative 2	Alternative 3	
Incinerator ash	Dispose at approved dumpsite	Screen and stabilize with cement before disposal		Inhalation Hazard Dispose at dumpsite only if parameters are within limits.
Laboratory waste	Recycle	Neutralize and add to waste water	Neutralize and mix in cement	Use in cement if incompatible with waste water
Lumber and packing	Re-use	Donate to community	Incinerate	Incinerate if oil soaked
Medical Waste (Infectious)	Incinerate			Segregate from other trash; package to protect from sharps.
Naturally Occurring Radioactive Materials (NORM)	Encapsulation/ Re-injection			Report/alert DPR within 24 hours when NORM is present above regulated levels.
Oily rags and sorbents	Incinerate			Launder soiled clothes
Oily sludge	Offsite TDU	Incinerate		
Paint and related material	Re-use	Incinerate	Dry and landfill container	
PCB				Review with HES before selecting alternative
Produced formation water	Re-injection	Offshore or deepwater only, overboard per DPR limits		Discharge of Produced water into inland and near-shore areas is prohibited .
Radioactive waste	Return to contractor	"Leave" down-hole	Encapsulate with cement	Review with HES before selecting alternative
Refractory	Double wrap and dispose at approved landfill			Review MSDS with HES before selecting alternative.
Refrigerant/Freon	Recover and reuse			Avoid release or vent

Type of waste	Waste Management Methods			Note/Cautions
	Preferred Alternative 1	Alternative 2	Alternative 3	
Rubbish/garbage	Incinerate	Dispose at an approved dumpsite		Wash and segregate containers for recycling/scrap
Scrap metal / warehouse junk	Recycle to scrap			
Sewage	Sewage treatment plant	Septic tank		
Storm Water	Discharge into adjacent water per DPR requirements			
Tires	Re-cap/reuse	Cut into pieces and incinerate		Avoid using burning pit
Used oil	Recycle to production	Incinerate		
X-ray chemicals (medical)	Neutralize and add to sanitary sewer	Neutralize and mix in cement		Review with HES before selecting alternative

b) Waste Characterization

Table 2 shows a typical waste detailed sheet indicating waste generated at Chevron-Escravos, including detailed description of each type of waste and its waste management practices.

It is the responsibility of the Supervisor of the waste generating facility to determine or verify waste characterization. Waste detail sheets indicate the kind of analysis to request from the laboratory to assist in waste characterization in order to determine its disposability. Health Environment and Safety (HES) department can help characterize new or unusual wastes.

c) Waste Segregation

Waste segregation is critical to the implementation of the above mentioned waste

management procedures. Wastes that are not properly segregated may be returned to the generator – as per policy (SOP-701) (CNL, 2006).

Wastes are to be segregated according to categories at the source/location of generation. In Escravos, waste bins are identified by their colours. Combustible waste to be incinerated or disposed of with other domestic waste must be placed into the BLUE coloured bins, metal wastes must be placed into the YELLOW coloured bins, and bottles must be placed into GREEN coloured bins (CNL, 2006).

3.3 Waste Management System

3.3.1 Food Waste Generation

The tank farm houses between three to four thousand (3,000 – 4,000) personnel on board daily, if each person generates between 0.5kg – 1kg of food waste every day, then the facility has to dispose of approximately 1.5 to 4.0 ton of food waste daily.

In this dissertation, the functional unit is defined as the management of the average amount of food waste produced per personnel on board per day.

Estimated volume of food waste generated at Chevron-Escravos, shows that in 1992, an approximated 1.85tons of OFW were generated per day (see fig.6) and there was an astronomical increase of over 2.17tons per day to over 4.02tons in 2007, which culminated to about 1,467tons of OFW per annum.

This increase was brought about by the growth in numbers of employee due to new projects such as the Escravos Gas Plant project (EGP I and II), the Sasol/Chevron Gas to Liquid (EGTL I) and hosts of other servicing companies.

This food waste is produced from Chevron-Escravos tank farm's leftovers, food waste at the canteens and kitchen (fig 6 below). These huge volumes of food wastes were incinerated. Domestic wastewater was not included. This would be food residues from dish washing which are drained into the adjoining sea through the storm water drainage.

The amount of OFW that is generated by the production platforms in the remote creeks and offshore areas are yet to be established. It is estimated that this addition would result to a total of over 2,500tons annually (CNL, 2006).

The amount of waste that is produced over a given amount of time, say per day, per week, etc, is referred to as the generation rate.

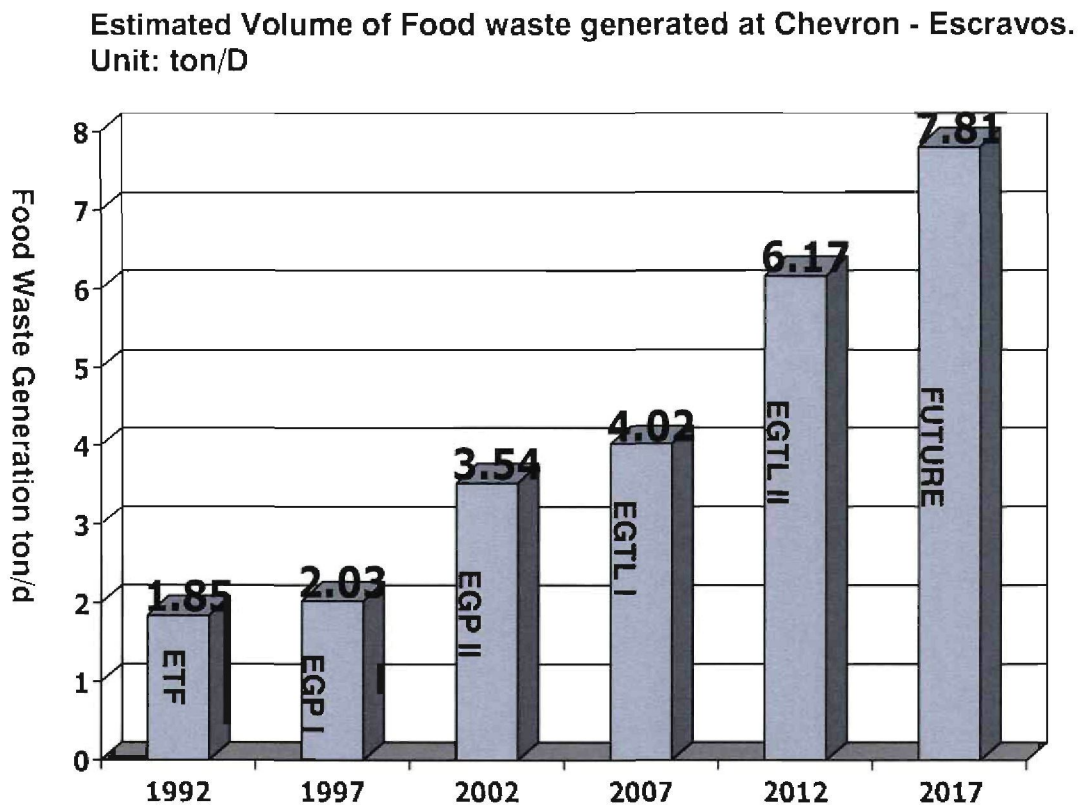


Fig. 6: Estimated Volume of Food waste generation (Chevron news bulletin, 2007).

LEGEND:

- ETF - Escravos Oil & Gas Tank Farm
- EGP - Escravos Gas Plant project
- EGTL - Escravos Gas To Liquid project

Estimated organic food wastes typically generated at the Chevron-Escravos facilities on daily basis are as shown in the figure above:

Over the past ten years, Chevron-Escravos organic food waste has experienced a fast growth in generation in the process of exploration and production of oil and gas as a result of increasing world demand for energy. Consequently, this demand has led to the initiation of new projects and expansion of old ones. As a result, there is an accelerated increase in the population of personnel and the organic waste generation to over 200%.

Accordingly, the total organic waste has increased from less than 2.0tons in 1992 to over 4.0tons per day in 2007, See fig.6 above, - a graph showing food waste generation growth over the last ten years and future projections.

3.3.2 Waste composition

Table 3 provides composition data for solid wastes generated in Chevron-Escravos production facilities per month. The main organic components are food wastes, such as rice, cassava base meals, vegetables, fruits, fish and meat, hamburgers, pizzas sandwiches, etc.

The composition of the waste is heterogeneous comprising of both organic and inorganic materials and it is collected and segregated into its components. The bulk of the inorganic waste is potentially recyclable materials, while the degradable materials are disposed of by incineration as shown in bold italics (Table 2 and 3).

3.3.2.1 Domestic Waste

Waste that is generated from human activities, including solid (e.g., leftover food, food containers, office waste, etc.), liquid (e.g. used cooking oils, etc.), or sanitary waste (e.g., waste from toilets, bathrooms, and kitchen drains). The emphasis on these organic wastes composition is in the food waste which include leftover food, used cooking oil, kitchen drains. These wastes comprise over 80% of the total organic waste generated.

Table 3: WASTE MANIFEST (Source: Chevron Escravos waste manifest, January 2007)

Date	Waste Stream	Waste Source	Waste Type	Waste Classification	Waste qty.	Waste vol.	Waste vol. unit	Waste weight (kg)	Location	Waste disposal method
1/1/07	Empty Drums	Meren 1	Metal	Hazardous	6				North Offshore	Crushing
1/1/07	Domestic Waste	Logistics	Rubbish	Non-Hazardous	1	2.2	M ³		Escravos Terminal	Incineration
1/1/07	Incinerator Ash	HES WMGT	Special	Hazardous	1	1.1	M ³		Escravos Terminal	Landfilling
2/1/07	Domestic Waste	Logistics	Rubbish	Non-Hazardous	6	13.2	M ³		Escravos Terminal	Incineration
2/1/07	Bio-medical waste	Escravos Clinic	Special	Hazardous	1			0.8	Escravos Terminal	Incineration
3/1/07	Domestic Waste	Logistics	Rubbish	Non-Hazardous	9	19.8	M ³		Escravos Terminal	Incineration
3/1/07	Expired Sliced Bee foot	ESS	Rubbish	Non-Hazardous				300	Escravos Terminal	Incineration
3/1/07	Expired Evaporated Milk	ESS	Rubbish	Non-Hazardous				400	Escravos Terminal	Neutralization
3/1/07	Cajun Seasoning	ESS	Rubbish	Non-Hazardous				200	Escravos Terminal	Neutralization
3/1/07	Chilly Sauce	ESS	Rubbish	Non-Hazardous				150	Escravos Terminal	Incineration
4/1/07	Burnt Fluorescent Tubes	Okan GGCP	Special	Hazardous	250				South Offshore	Crushing
4/1/07	Empty Drums	Meren 1	Metal	Hazardous	6				North Offshore	Crushing
4/1/07	Bio-medical waste	Escravos Clinic	Special	Hazardous	1			2	Escravos Terminal	Incineration
4/1/07	Waste Oil	Gulf Fleet	Liquid	Hazardous	1	10	Bbl		Escravos Terminal	Recycling
4/1/07	Oily Sludge & Water	Opuekeba	Sludge	Hazardous	1	4.5	MT		Swamp	Offsite

Chapter 3: Assessment of Chevron-Escravos Waste Management

Date	Waste Stream	Waste Source	Waste Type	Waste Classification	Waste qty.	Waste vol.	Waste vol. unit	Waste weight (kg)	Location	Waste disposal method
5/1/07	Empty Drums	LMP	Metal	Hazardous	4				Escravos Terminal	Crushing
5/1/07	Domestic Waste	Logistics	Rubbish	Non-Hazardous	9	19.8	M ³		Escravos Terminal	Incineration
5/1/07	Waste Oil	Shop Mtce.	Liquid	Hazardous	1	15	Bbl		Escravos Terminal	Recycling
6/1/07	Bio-medical waste	Escravos Clinic	Special	Hazardous	1			1	Escravos Terminal	Incineration
6/1/07	Domestic Waste	Logistics	Rubbish	Non-Hazardous	9	19.8	M ³		Escravos Terminal	Incineration
7/1/07	Bio-medical waste	Escravos Clinic	Special	Hazardous	1			0.5	Escravos Terminal	Incineration
7/1/07	Wood Logs	CPG	Rubbish	Non-Hazardous	6	13.2	M ³		Escravos Terminal	Open Burning.
7/1/07	Chemical Deformer	South Warehouse	Liquid	Hazardous	12				Escravos Terminal	
7/1/07	Waste Oil	Jill McCall	Liquid	Hazardous	4	5.24	Bbl		Escravos Terminal	Recycling
8/1/07	Incinerator Ash	HES - WMGT	Special	Hazardous	4	4.4	M ³		Escravos Terminal	Landfilling
8/1/07	Domestic Waste	Logistics	Rubbish	Non-Hazardous	7	15.4	M ³		Escravos Terminal	Incineration
8/1/07	Bio-medical waste	Escravos Clinic	Special	Hazardous	1			1.5	Escravos Terminal	Incineration
8/1/07	Chemical Flo-troll	South Warehouse	Solid	Hazardous	2			2700	Escravos Terminal	Landfilling
8/1/07	Oily Sludge & Water	Opuekeba	Sludge	Hazardous	5	22.5	MT		Swamp	Offsite
9/1/07	Domestic Waste	Logistics	Rubbish	Non-Hazardous	8	17.6	M ³		Escravos Terminal	Incineration
9/1/07	Bio-medical waste	Escravos Clinic	Special	Hazardous	1			0.5	Escravos Terminal	Incineration

Date	Waste Stream	Waste Source	Waste Type	Waste Classification	Waste qty.	Waste vol.	Waste vol. unit	Waste weight (kg)	Location	Waste disposal method
10/1/07	Domestic Waste	Logistics	Rubbish	Non-Hazardous	9	19.8	m ³		Escravos Terminal	Incineration
11/1/07	Bio-medical waste	Escravos Clinic	Special	Hazardous	1			0.6	Escravos Terminal	Incineration
11/1/07	Domestic Waste	Logistics	Rubbish	Non-Hazardous	8	17.6	m ³		Escravos Terminal	Incineration
11/1/07	Used Batteries	Shop Mfce.	Special	Hazardous	28				Escravos Terminal	Recycling
12/1/07	Junk Barge	Logistics	Metal	Non-Hazardous	1				Escravos Terminal	Recycling
12/1/07	Bio-medical waste	Escravos Clinic	Special	Hazardous	1			1	Escravos Terminal	Incineration
12/1/07	Empty Drums	MWIP	Metal	Hazardous	18				North Offshore	Crushing
12/1/2007	Empty Drums	Meren P/P Am.	Metal	Hazardous	6				North Offshore	Crushing
12/1/07	Waste Oil	Independent	Liquid	Hazardous	1	10	Bbl		Escravos Terminal	Recycling
12/1/07	Waste Oil	Trident IV	Liquid	Hazardous	1	20	Bbl		Escravos Terminal	Recycling
13/1/07	Waste Oil	Surfer	Liquid	Hazardous	1	2.5	Bbl		Escravos Terminal	Recycling
13/1/07	Waste Oil	PAAN	Liquid	Hazardous	1	11.9	Bbl		Escravos Terminal	Recycling
13/1/07	Waste Oil	Comex	Liquid	Hazardous	1	25	Bbl		Escravos Terminal	Recycling
13/1/07	Bio-medical waste	Escravos Clinic	Special	Hazardous	1			1.1	Escravos Terminal	Incineration
14/1/07	Bio-medical waste	Escravos Clinic	Special	Hazardous	1			1.6	Escravos Terminal	Incineration
14/1/07	Waste Oil	FSO	Liquid	Hazardous	4	40	Bbl		South Offshore	Recycling

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Date	Waste Stream	Waste Source	Waste Type	Waste Classification	Waste qty.	Waste vol.	Waste vol. unit	Waste weight (kg)	Location	Waste disposal method
14/1/07	Wood Logs	Logistics	Rubbish	Non-Hazardous	4				Escravos Terminal	Open Burning.
14/1/07	Empty Drums	Meren 1	Metal	Non-Hazardous	12				North Offshore	Crushing
15/1/07	Domestic Waste	Logistics	Rubbish	Non-Hazardous	9	19.8	m ³		Escravos Terminal	Incineration
15/1/07	Bio-medical waste	Escravos Clinic	Special	Hazardous	1			1.1	Escravos Terminal	Incineration
15/1/07	Incinerator Ash	HES-WMGT	Special	Special	4	4.4	m ³		Escravos Terminal	Re-bag
15/1/07	Crushed Plastics	Logistics	Plastics	Non-Hazardous	10			285	Escravos Terminal	Crushed
16/1/07	Bio-medical waste	Escravos Clinic	Special	Hazardous	1			3.9	Escravos Terminal	Incineration
16/1/07	Domestic Waste	Logistics	Rubbish	Non-Hazardous	8	17.6	m ³		Escravos Terminal	Incineration
16/1/07	Waste Oil	Masley Tide	Liquid	Hazardous	1	10	Bbl		Escravos Terminal	Recycling
16/1/07	Waste Deformer Chemical	Esc. (South) Whse	Liquid	Hazardous	12	600	Liters		Escravos Terminal	Recycling
16/1/07	Waste XCAL EC1126A	Nalco BP	Liquid	Hazardous	1	385	Gallions		Escravos Terminal	Landfilling
17/1/07	Bio-medical waste	Escravos Clinic	Special	Hazardous	1			0.6	Escravos Terminal	Incineration
17/1/07	Domestic Waste	Logistics	Rubbish	Non-Hazardous	8	17.6	m ³		Escravos Terminal	Incineration
17/1/07	Empty Drums	Meren 1	Metal	Non-Hazardous	9				North Offshore	Crushing
17/1/07	Waste Oil	Hercules Boat	Liquid	Hazardous	1	1.31			Escravos Terminal	Recycling
17/1/07	Oily Pads	Opuekaba	Pads	Hazardous	3			13.5mt	Onshore - Swamp	Open Burning.

Chapter 3: Assessment of Chevron-Escravos Waste Management

Date	Waste Stream	Waste Source	Waste Type	Waste Classification	Waste qty.	Waste vol.	Waste vol. unit	Waste weight (kg)	Location	Waste disposal method
18/1/07	Domestic Waste	Logistics	Rubbish	Non-Hazardous	10	22	m ³		Escravos Terminal	Incineration
18/1/07	Bio-medical waste	Escravos Clinic	Special	Special	1			0.6	Escravos Terminal	Incineration
18/1/07	Crushed Plastics	Logistics	Plastics	Non-Hazardous	4			720	Escravos Terminal	Crushing
19/1/07	Domestic Waste	Logistics	Rubbish	Non-Hazardous	12	26.4	m ³		Escravos Terminal	Incineration
19/1/07	Bio-medical waste	Escravos Clinic	Special	Hazardous	1			0.5	Escravos Terminal	Incineration
19/1/07	Empty Drums	LMP	Metal	Non-Hazardous	4				Escravos Terminal	Crushing
20/1/07	Domestic Waste	Logistics	Rubbish	Non-Hazardous	12	26.4	m ³		Escravos Terminal	Incineration
20/1/07	Bio-medical waste	Escravos Clinic	Special	Hazardous	1			0.9	Escravos Terminal	Incineration
20/1/07	Empty Drums	Utonana	Metal	Non-Hazardous	4				Onshore - Swamp	Crushing
20/1/07	Crushed Plastics	Logistics	Plastics	Non-Hazardous	6			48	Escravos Terminal	Crushing
20/1/07	Crushed Plastics	Logistics	Plastics	Non-Hazardous	1			160	Escravos Terminal	Crushing
20/1/07	Waste Oil	Lourdes Tide	Liquid	Hazardous	4	5.24	Bbl		Escravos Terminal	Recycling
20/1/07	Waste Chemical (LP1001 XCAL)	NALCO BP	Liquid	Hazardous	1	170	Bbl		Escravos Terminal	Recycling
21/1/07	Wood Logs/Absorbent	Logistics		Hazardous	4	8.8	m ³		Escravos Terminal	Open Burning.

Chapter 3: Assessment of Chevron-Escravos Waste Management

Date	Waste Stream	Waste Source	Waste Type	Waste Classification	Waste qty.	Waste vol.	Waste vol. unit	Waste weight (kg)	Location	Waste disposal method
21/1/07	Empty Drums	Tapa	Metal	Non-Hazardous	5				South Offshore	Crushing
21/1/07	Empty Drums	Meren I	Metal	Non-Hazardous	5				North Offshore	Crushing
21/1/07	Bio-medical waste	Escravos Clinic	Special	Hazardous	2			5.4	Escravos Terminal	Incineration
21/1/07	Waste Oil	M.E.R. Engineering	Liquid	Hazardous	3	3.93	Bbl		Escravos Terminal	Recycling
22/1/07	Domestic Waste	Logistics	Rubbish	Non-Hazardous	8	17.6	m ³		Escravos Terminal	Incineration
22/1/07	Bio-medical waste	Escravos Clinic	Special	Hazardous	1			0.2	Escravos Terminal	Incineration
22/1/07	Confidential Documents	Port Harcourt	Rubbish	Non-Hazardous	2				Port Harcourt	Incineration
22/1/07	Waste Oil	Robertkiri	Liquid	Hazardous	1	10	Bbl		Port Harcourt	Recycling
22/1/07	Oily Sludge & Water	Idama	Liquid	Hazardous	2	2.62	Bbl		Port Harcourt	Recycling
23/1/07	Domestic Waste	Logistics	Rubbish	Non-Hazardous	10	17.6	m ³		Escravos Terminal	Incineration
23/1/07	Bio-medical waste	Escravos Clinic	Special	Hazardous	1			0.2	Escravos Terminal	Incineration
23/1/07	Waste Oil	Charlie Cobb	Liquid	Hazardous	4	5.24	Bbl		Escravos Terminal	Recycling
24/1/07	Domestic Waste	Logistics	Rubbish	Non-Hazardous	7	15.4	m ³		Escravos Terminal	Incineration
24/1/07	Bio-medical waste	Escravos Clinic	Special	Hazardous	1			0.6	Escravos Terminal	Incineration
24/1/07	Waste Oil	Dibi	Liquid	Hazardous	2	2.62	Bbl		Onshore - Swamp	Recycling
25/1/07	Domestic Waste	Logistics	Rubbish	Non-Hazardous	8	17.6	m ³		Escravos Terminal	Incineration

Chapter 3: Assessment of Chevron-Escravos Waste Management

Date	Waste Stream	Waste Source	Waste Type	Waste Classification	Waste qty.	Waste vol.	Waste vol. unit	Waste weight (kg)	Location	Waste disposal method
25/1/07	Crushed Plastics	Logistics	Plastics	Non-Hazardous	3			600	Escravos Terminal	Crushing
25/1/07	Oily Sludge & Water	Abiteye	Liquid	Non-Hazardous	6			27mt	Onshore - Swamp	Offsite
25/1/07	Oily Sludge & Water	Olero	Liquid	Non-Hazardous	2			9mt	Onshore - Swamp	Offsite
25/1/07	Oily Sludge & Water	Dehydration	Liquid	Non-Hazardous	3			13.5mt	Escravos Terminal	Offsite
26/1/07	Domestic Waste	Logistics	Rubbish	Non-Hazardous	8	17.6	m ³		Escravos Terminal	Incineration
26/1/07	Waste Oil	Terminal Maintenance	Liquid	Hazardous	8	10.48	Bbl		Escravos Terminal	Recycling
27/1/07	Domestic Waste	Logistics	Rubbish	Non-Hazardous	9	19.8	m ³		Escravos Terminal	Incineration
28/1/07	Wood logs	Logistics	Rubbish	Non-Hazardous	4				Escravos Terminal	Open Burning.
28/1/07	Waste Oil	ED Kyle	Liquid	Hazardous	1	6.35	Bbl		Escravos Terminal	Recycling
28/1/2007	Waste Oil	Pan African	Liquid	Hazardous	1	10	Bbl		Escravos Terminal	Recycling
29/1/07	Domestic Waste	Logistics	Rubbish	Non-Hazardous	6	13.2	m ³		Escravos Terminal	Incineration
29/1/07	Incinerator Ash	HES-WMGT	Special	Hazardous	4	4.4	m ³		Escravos Terminal	Landfilling
29/1/07	Empty Drums	LMP	Metal	Non-Hazardous	56				Escravos Terminal	Crushing
29/1/07	Waste Oil	LMP	Liquid	Hazardous	7	9.17	Bbl		Escravos Terminal	Recycling
29/1/07	Waste Paint	LMP	Liquid	Hazardous	1	205	Liters		Escravos Terminal	Recycling
29/1/09	Waste(B1581)Chemical)	LMP	Liquid	Hazardous	1	205	Liters		Escravos Terminal	Recycling

Chapter 3: Assessment of Chevron-Escravos Waste Management

Date	Waste Stream	Waste Source	Waste Type	Waste Classification	Waste qty.	Waste vol.	Waste vol. unit	Waste weight (kg)	Location	Waste disposal method
30/1/07	Empty Drums	LMP	Metal	Non-Hazardous	32				Escravos Terminal	Recycling
30/1/07	<i>Domestic Waste</i>	<i>Logistics</i>	<i>Rubbish</i>	<i>Non-Hazardous</i>	6	17.6	m ³		<i>Escravos Terminal</i>	<i>Incineration</i>
30/1/07	Confidential Documents	Port Harcourt	Rubbish	Non-Hazardous	1			30	Escravos Terminal	Incineration
30/1/07	Asbsorbent Pads	Lady Whiskey	Pads	Non-Hazardous	1				Escravos Terminal	Recycling
31/1/07	<i>Domestic Waste</i>	<i>Logistics</i>	<i>Rubbish</i>	<i>Non-Hazardous</i>	8	17.6	m ³		<i>Escravos Terminal</i>	<i>Incineration</i>
31/1/07	Metal Junk	Logistics	Metal	Non-Hazardous	1				Escravos Terminal	Recycling
31/1/07	Waste Oil	Masley Tide	Liquid	Hazardous	1	1.31	Bbl		Escravos Terminal	Recycling

3.3.3 Resource Recovery and Recycling.

At present however, organic food waste makes up the highest percentage of the domestic waste stream, and is usually disposed of by incineration despite its high recoverability. Theoretically, studies have indicated that the recovery rate of organic waste in the chevron-Escravos facilities could be as high as 93% of the total annual quantity, while the actual recovery rate now is just only 0% (organic waste disposal method as shown in table 3) of the total annual amount.

3.3.4 Waste Collection and Transport.

The Chevron-Escravos operations is a swamp base (offshore), which include flow stations, gas stations, compressor stations, drilling rigs, logistic centres (house boats) and the Escravos terminal. Waste collection and disposal is problematic as collected waste represents only a fraction of the total waste generated. There is no reliable statistics or data on collection efficiency.

There is generally no distinction between service provider's (contractors) waste streams and Chevron's waste streams. The waste streams are usually mixed together prior to disposal. Collected OW is left in open waste bins for several hours to decomposed, with associated odour problems.

The entire system of waste collection, treatment/disposal is the responsibility of Chevron. With the ocean nearby being viewed as an inexhaustible depository for waste, the option of simply throwing the majority of the organic waste into the waters surrounding the facility would not be unlikely, due to the remoteness in the creeks and the ridiculously high disposal and transport cost at these locations.

3.3.5 Waste Treatment and Disposal System

In table 3, it is indicated that all garbage and rubbish (organic wastes) are treated or disposed of by incineration as shown in fig. 7 below. Garbage burnt in incinerators is known to impact the quality of air, soil, and water. This is not different in the case of the

Chapter 3: Assessment of Chevron-Escravos Waste Management

Escravos incinerator plant. There is no emission monitoring in place, the only physical indication is the effect of acid rain on the surrounding communities.

The host communities near incinerators have not been enlightened enough to object to its operation, but only indication of possible fears of emissions and environmental effects.



Fig. 7: Chevron-Escravos incinerator, showing organic waste being loaded for combustion.

3.3.6 Employee HSE Awareness and Attitude

An important strategy adopted by Chevron Nigeria/Mid-Africa SBU, was the active encouragement of staff and contractors in the development and implementation of the health, environmental safety strategies. For example, the use of safety and environmental champions was practised by Chevron-Escravos HSE department. Empowering of the workers is achieved through direct implementation of a range of environmental management initiatives that incorporate waste, water, food, energy and transport. These included awareness campaigns on issues such as recycling and waste segregation procedures at source. Providing labelled bins for different waste types thereby, contributing towards successful waste management practices.

Employees were further provided with skills and development through training in waste management. Thereby empowering them to make suggestion and change on environmental management processes and procedures.

3.3.7 Waste Management Documentation

Accurate records that track the quantity of wastes generated and the disposal methods are used. Waste generating facilities must utilize the Waste Tracking Log (Appendix A). The log includes the date and Type(s) and Quantity of waste generated and transferred for handling/disposal.

This documentation is the basis for reviewing waste inventory and waste identification, which is designed for waste reduction efforts. Copies of this log are kept in the facility. The HES department will review the Log during compliance inspections.

It is the responsibility of the Supervisor of the waste generating facility to ensure that all records of waste transferred are logged and the waste shipments are accompanied by a Waste Manifest (Appendix B).

The Supervisor of the waste generating facility ensures that waste transferred from his facility is manifested and the form is handed over to the Carrier (Vessel, Barge or Truck)

captain or driver for transfer to the waste receiver. Information on the Waste Manifest Form (Date, Waste Description, Waste Volume or Weight, etc.) should also be kept in a Waste Log Book at the Waste generating facility and at the Waste Management Unit of HES (CNL, 2006).

3.4 Waste Disposal Management Facilities

The following tables 4a and 4b lists all waste management facilities at Chevron Nigeria Ltd. It indicates which facilities are operated at each location and which facilities or services are still under design/construction.

Table 4a (SOURCE: Chevron NMA SBU – SOP 701 Waste management practices. October 2006 Version 1.1)

COMPLETED		
S/N	Waste Treatment Facilities	Location
1	Scrap metal recyclers	all locations
2	Battery recyclers	all locations
3	Tire recyclers	all locations
4	Sewage treatment plant	(Lekki)
5	Sewage hauling contractors	(Lekki)
6	Septic Tanks	(Escravos)
7	Incinerator	(Escravos)
8	Approved Waste Disposal Site	(Warri)
9	Produced Water Injection	(Escravos – inland)
10	Third party thermal treatment facility for oily sludge/waste	(Port Harcourt)

Table 4b

IN DESIGN/CONSTRUCTION		
S/N	Waste Treatment Facilities	Location
1	Sewage Treatment Plant	(Escravos)
2	Medical clinic incinerator	(Warri/Lekki/Escravos)
3	Government approved landfill	(Warri/Lekki)
4	Drill Mud/Cuttings Slurry Fracture Injection Well	(Escravos)
5	Produced water - offshore disposal	(Escravos terminal)

3.5 Impact of Present Waste Disposal System.

The Chevron open organic (canteen) bins and dumping sites become an eye sore, cause foul smell, become breeding places for harmful bacteria and attracts disease carrying vectors such as flies, mosquitoes, birds, rodents, etc, before they are transported and disposed off at the incinerator.

The prime concern arising out of the present waste disposal system is its impact on the community's health and the environment as well as economic losses. No matter who owns the responsibility of garbage disposal, the reality is that resident communities are the victim of their own apathy towards sustainable solution to the problem. The opportunity cost of incinerating the organic garbage to its conversion to economic products is very high.

Apart from land being costly and a being finite resource on this island, judicial protest by the communities and regulatory agency on the use of land near water bodies for waste disposal (landfilling), is forcing Chevron in Escravos to move towards enforcement of organic waste segregation and conversion. Initiative toward waste minimization and recycling instead of incinerating all organic wastes generated is encouraged.

The residues from the incinerator (toxic-ash) are disposed of at Chevron-Escravos by land-filling. Considering the fact that the area is a swampy terrain, the possibility of contaminating underground water is high, and consequent effects on aquatic life.

3.6 Conclusion

The existing organic food waste (OFW) management practiced in Chevron-Escravos is basically by the use of incinerator and landfills treatment plants. The OFW is not recycled, reused or treated biologically.

The existing waste management systems used could result in environmental degradation and also leads to insufficient qualitative use of OFW and associated economic losses. There is a need to implement an alternative disposal method that will be environmentally friendly and as well as economically viable.

The next step is to adopt an alternative waste disposal technique that would be suitable to convert the organic food wastes in an economically viable and environmentally friendly manner; these process and procedure are discussed in the next chapter.

CHAPTER FOUR

An Alternative Organic Food Waste Disposal System

4.0 Introduction.

In today's society, there is huge demand for nutritional food and suitable health values; this is characterized by high costs and often less availability. Consequently, there is considerable emphasis on the recovery, recycling and upgrading of wastes to convalesce the nutritive values (Martin, 1998).

This is particularly applicable to the food and food processing industry in which wastes, effluents, residues, and by-products can be recovered and can often be upgraded to higher value and useful by-products (Laufenberg, et al., 2003).

The proposed legislation to develop alternative disposal methods may be challenging to meet. The Federal legislation on environmental protection in Nigeria, decree Number 58 of 1988, established the Federal Environmental Protection Agency (FEPA). One of the specific roles of FEPA with respect to solid waste management was to develop alternative waste disposal methods, other than the current waste management regulations which were designed for landfills and incineration methods only (Onibokun, 1999).

Many technologies that have the prospect of achieving the desired goals are in the preliminary stage of development and application. These new technologies are not ready to be scaled-up to handle the size of organic food waste stream in Nigeria.

However, this dissertation work intends to show that there are some processes that could be used to dispose off the large daily volume of organic food waste generated by Chevron. The success of this proposed solution will be quantified in terms of environmental benefits by comparing with other forms of disposal systems. There are though some measurements that could be used to gauge the technology's successes as well.

4.1 Dissertation Invent

This chapter focuses on the research and design of the procedural solution to the problem statement with a view of achieving the proposed objectives. The possibility of organic food waste conversion is attended to. This dissertation also focussed on the management of such waste given consideration to the nutritional properties and energy values hidden in this waste type.

A novel waste management approach will be introduced in an attempt to prevent the production of green house gases which poses health hazards and contribute towards global warming. This is synonymous with domestic and industrial organic food waste disposal systems.

This new waste management mechanism exploits the Waste Conversion System, using the mechanical Organic Food Waste Converter machine (OFWC systems). The Waste Converter processes 100% of kitchen and restaurant food waste, including meat, in an environmental and user friendly manner.

This eliminates the need to landfill or incinerate organic food waste in large quantities, in addition to high operational and capital costs of disposal.

This innovation is designed to achieve the goal of Zero Waste by eliminating organic food waste from the Chevron-Escravos waste streams and converting this waste to animal feed and feed stock. This could result in the saving of millions of dollars with little or no environmental impact.

The proposed waste converter is not a worm farm. It processes all types of organic food or kitchen wastes, including those used in worm farm and would likely replace the worm farm. With this new innovation, the former concepts regarding organic composting would now need to be updated to reflect the availability of this organic waste conversion system.

While other forms of waste disposal system and innovative conversion approaches have clearly demonstrated applicability, one traditional approach that should not be overlooked is the direct use of food processing residues as livestock feed. Although this direct application is crude and biochemically unstable and associated with various unhygienic side effects.

Product safety, sensorial quality, and suitable packaging

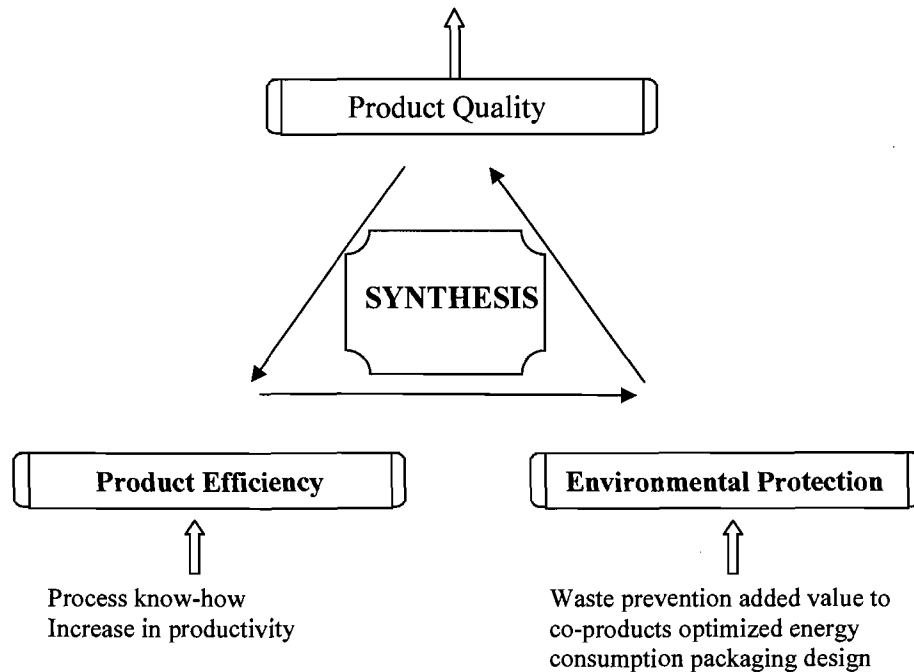


Fig. 8: The holistic concept of feed production (Herefordshire & Worcestershire, 2004).

The application of the bio-mechanical OFWC eliminates the risks associated with direct use and makes automation possible. The economic value of organic residuals is higher in feeding applications, **where both the energy and nutrients are used**, than in conversions to fuel, fertilizers, manures, biogas, etc, which typically utilizes only one of these categories at a time (stored energy).

The procedure was approached through the following methodology:

- ❖ **Potentials of organic food waste recovery**
- ❖ **Organic Food Waste Conversion Process**
- ❖ **Organic food waste conversion techniques**
- ❖ **Process Limitation**
- ❖ **Social-Economic and environmental impact**
- ❖ **Company – communities benefits**

4.1.1 Potentials of Organic Food Waste (OFW) Recovery.

In general, organic food wastes from the food processing industry have some common characteristics (Litchfield, 1995).

- a) Large amounts of organic materials such as proteins, carbohydrates, and lipids,
- b) Large amounts of suspended solids depending on the source,
- c) High biochemical oxygen demand (BOD) or chemical oxygen demand (COD),
- d) High nitrogen concentration,
- e) High suspended oil or grease contents, and
- f) High amount of minerals and vitamins
- g) High variations in pH.

The flow of organic waste stream in Chevron-Escravos has a significant potential and implications for both pollution control and economic efficiency in terms of energy and nutritive values.

One of the driving forces for the rapid development of this new industry (waste conversion) is the increasing environmental concerns, arising in many agricultural, industrial and municipal sectors of the community regarding the ineffective and oftentimes

improper, unconventional methods in which agricultural food and urban wastes are managed (Ayer, et. al., 1996).

The recovery potential at Chevron-Escravos would be approached through the following sub-problems:

1. What is the *theoretical recovery* rate of organic food waste generated currently?
2. What is the *actual recovery* rate of organic food waste generated currently?
3. What is the *recovery potential* of organic food waste generated currently?

The theoretical recovery rate illustrates how much (in percentages) of the total annual amounts of organic food wastes could be recovered as material or as energy by the existing solid waste infrastructure. The theoretical recovery rate is 100% if all organic food waste could be recovered.

The actual recovery rate of OFW illustrates how much (in percentages) of the total annual amount of OFW is actually recovered by the existing solid waste management infrastructure.

The recovery potential illustrates how much (in percentages) of the OFW could be recovered in the total amount of organic waste.

The recovery potential is the difference between the theoretical and actual recovery rates, and the sum of achievable and theoretical recovery potentials (Hamalainen, 2007).

The achievable recovery potential is the share (in percentages) of the amount of OFW recoverable by the existing solid waste infrastructure, but not recovered, in the total annual amount of organic waste.

The theoretical recovery potential is the share (in percentages) of the amount of OFW non-recoverable by the existing solid waste infrastructure in the total annual amount of organic waste (Hamalainen, 2007).

At present however, organic food waste is mostly disposed off at the incinerator despite its high recoverability. Theoretically, studies showed that recovery rate of organic waste in the chevron Escravos facilities is high, 93% of the total annual amount, while the actual recovery rate presently is only 0% of the total annual amount (see table 2 and 3).

These are shown in the data collected for the dissertation from the January year 2007 waste manifest summary; refer to table 4, and Waste Inventory and Summary of Management Practices. Refer to table 2.

4.1.2 Organic Food Waste Conversion Process.

Development of Conversion Model

Presently, large volumes of organic food wastes from pre-cooked, leftover after meal are dumped in disposal bins, which are responsible for foul odor & health hazards and finally disposed off by incineration (table 3).

This incineration practice is as shown in the waste incineration process flow diagram (fig. 9) below

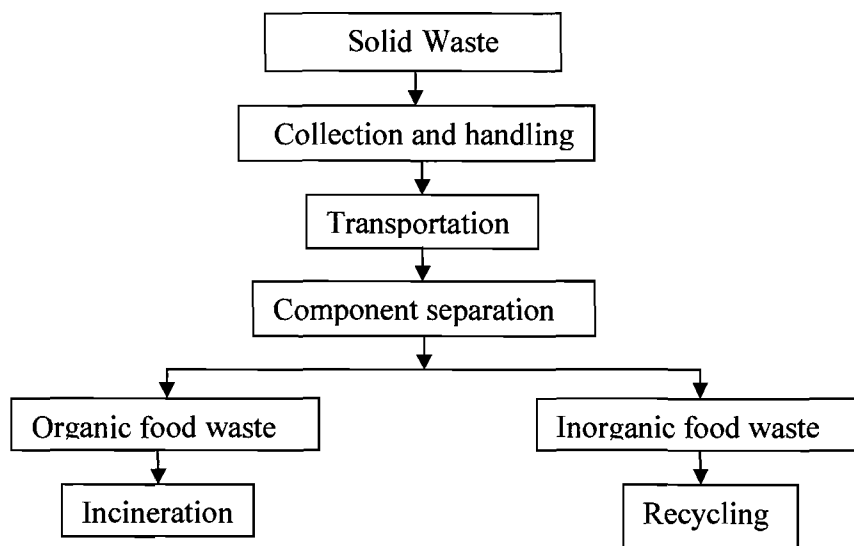


Fig. 9: Waste Incineration Process Flow Diagram

Increasing production of organic food waste has resulted in large quantities of organic residuals, requiring environmentally and economic sound management. The food wastes were mostly leftover food and plate scrapings of various compositions (Table 5) and contained approximately 40 to 51% moisture content (Myer, et.al, 1999).

Table 5 Example of Food Waste Composition (Cheeseman, et al., 2007)

Carbohydrates	Crude Protein	Crude Fat	Vit./minerals	Others
Bread, Cassava products, yam, plantain, potatoes, rice,	Meat, fish, beans, eggs, milk,	Cooking oil, meat fat, butter,	Additives, vegetables, fruits,	Bones, blood meals, egg shell, spices,

Food waste used in this study was a mixture of “restaurant (kitchen) food waste” (wasted food not offered for consumption) and “plate waste” (wasted food after being offered for consumption); for simplicity, the term food waste will be used in this work.

These wastes stream composition (Table 5) are suitable for use as livestock feed material, thus eliminating landfilling and incineration costs. Potential processes and procedures model for developing livestock feed is illustrated in figure 10 below, this include:

- a. Collection and Transport
- b. Segregation,
- c. Pulverization,
- d. Dehydration,
- e. Pelletizing or Extruding,
- f. Component Blending and Recipe Formulation

a. Waste Collection and Transport

Fast collection of organic waste is a prerequisite for an end product of good quality using this process (OWC). Minimizing transport between production of waste and the treatment

site will decrease pollution, contamination and increase the possibility to keep the OW fit for pre-processing.

This preserves the quality of the collected waste, especially those with high water content and high amounts of readily decomposable compounds. Collected OW can easily decompose by unwanted processes in dustbins, with the associated odor problems. For efficient collection, the use of close vessel is necessary to eliminate vector carriers and rodents (Gajdos, 1998).

b. Segregation (Pre-processing)

The aim of pre-processing is collecting and pre-sorting or segregation into various nutritive components of the solid organic food waste, such as carbohydrate components, protein components, fibre, fat or lipid, minerals, vitamins, etc. Processing and separating the pre-sorted waste into separate bins for efficient conversion and combination is important.

c. Pulverization

To achieve a homogenized and stabilized product, the waste materials have to be disintegrated in order to have uniform structure before the conversion commences. The energy required for grinding or shredding is well used, since the grinded material is more easily handled, mixed, moistened, and saves space before, during and after processing. Grinding can also accelerate homogenization rate and permit more uniform product (Gajdos, 2000).

This product is in a slurry and semi-slurry state depending on the moisture content and the constituents

d. Dehydration

Steinford and Zane pointed out three principal requirements: nutrient balance, structure and moisture content. Most organic wastes are food waste and therefore require dehydration before they can be biologically stable and used as feed.

Dehydration is essential for stabilization, and for the reduction of transportation and storage costs. However, the cost implication of this process is very high, and if feasible wet feeding, should be considered first under strict hygienic condition.

Dehydration of organic waste components byproduct slurries is not as process intensive as either extrusion or pelletizing, but it does have substantial energy costs, because the slurry has such a high moisture content (between 40-51% (w.b.) (Richard, et al., 2002).

To achieve a microbiologically stable feed product, substantial amounts of water must be removed from the byproduct stream. The semi moist byproduct blend is set at a drying temperature of 150 to 200⁰C, and final product temperature of 110 to 120⁰C is achieved.

For this model, the final moisture content of the organic waste byproducts is set at minimum of 10% (w.b.), a moisture stable level to prevent spoilage. After dewatering, OFW residues are transported via a conveyor belt to a surge bin, the resulting feed can either be bagged or left in bulk form, which is similar to both the extrusion and pelletizing options (Richard, 2002).

The percentage of each component (c_i) could be computed using the relation (Zhuang, et al):

$$c_i (\%) = \frac{M_i}{M} \times 100\% \quad \dots\dots\dots\text{eqn (1)}$$

Where M_i is the weight of a certain component (kg) such as protein and M is the total weight of the waste sample (kg).

The moisture content of each component $C_{i(\text{water})}$ and of the waste sample $C_{(\text{water})}$ could also be determined using the relation (Zhuang, et al):

$$C_{i(\text{water})} = \frac{1}{m} \sum_{j=1}^m \frac{M_{j,\text{wet}} - M_{j,\text{dry}}}{M_{j,\text{wet}}} \times 100\% \quad \dots\dots\dots\text{eqn (2)}$$

And

$$C_{water} = \sum_{i=1}^n C_{i(water)} \times \frac{C_i}{100} \times 100\% \quad \dots\dots\dots\text{eqn (3)}$$

where $M_{j,wet}$ and $M_{j,dry}$ are the initial mass of each component and the mass of each component after drying respectively; n and m are the number of all components and the number of times of water content determination, respectively (Zhuang, et al).

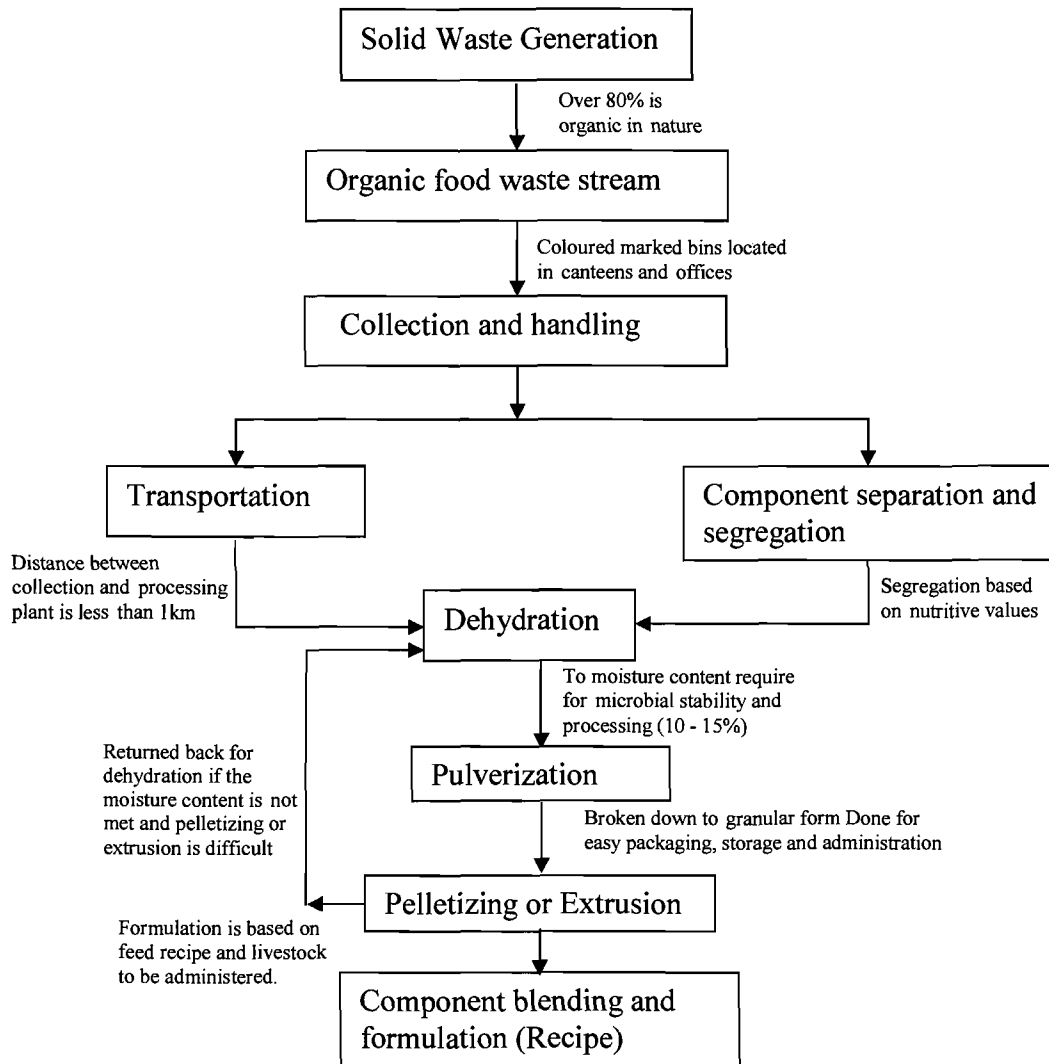


Fig. 10: Alternative Waste Processing Flow Diagram.

e. Pelletizing or Extrusion System

Pelletizing

Producing feed materials from a pellet mill processing line is very similar to extrusion processing vis-à-vis equipment required. As with extrusion, pellet mill processing of feed-stocks is confined to a limited moisture content range and, thus, the OFW byproduct slurry must be dehydrated to achieve less than 25% m.c.(w.b.) prior to processing.

The major difference between pellet mill and extrusion processing, other than using a pellet mill instead of an extruder, is that the pelletized feed discharges directly from the pellet mill into the dryer/cooler, and does not require an air lift to transport the material. Once again, the resulting dry feed can either be bagged or left in bulk form (Richard, 2002).

Extrusion System

Extrusion processing of OFW byproducts is very process intensive. A major constraint with this type of processing, however, is the moisture content range which is amenable to extrusion (i.e. the raw OFW byproduct stream must be dehydrated to reduce the moisture content to approximately 25% (w.b.) for the extruder to process this material).

The OFW residues are transported via a belt conveyor to a scale/surge bin above a mixer, the feed is transported to a bucket elevator, and then placed in another holding/surge bin.

The material is then metered out of the bin, using a screw conveyor, into a pre-conditioner. Steam and water are added so that the material is properly prepared for extrusion. After exiting the extruder, the feed material is pneumatically conveyed to a dryer/cooler, where water is removed until the feed product is at an appropriate moisture content level. The processed feed is eventually cooled to room temperature.

It is generally recommended that feed materials have final moisture content below 15% (w.b.), because this moisture level is microbiologically stable (Beauchat, 1981; Richard, 2002).

At this point, there are two possible alternatives that could be implemented: the processed feed can either be delivered in bag form or in bulk form to the user. If a bagged form is chosen, the feed will then exit the surge bin into a bagging scale, and then will enter an automatic bagging and palletizing system. Then, a forklift will place the bagged and palletized feed onto a delivery truck. If, however, a bulk feed is desired, the surge bin will empty directly into a bulk feed delivery truck (Richard, 2002).

Note that the choice of either processes (pelletizing or extrusion) are determined by the desirability of the end product, the packaging methods and feed application techniques.

4.1.3 Organic Food Waste Conversion Techniques.

The technology is now available to convert food wastes into dry, stable products that could be incorporated into many modern feed production programs (Myer, 1999).

Organic waste converters (OWC) used in organic food waste processing has made the production of feedstock from organic matter easy and simple as illustrated in figure 10 above.

The food waste processor (FWP) units on the other hand which are mainly used to dispose off organic waste generated in the kitchen during the preparation of food. The FWPs macerate organic waste and dispose it into the sewage system using water as a transport medium.

But due to the perceived potential of environmental and technical problems associated with an increased market penetration of FWPs in the future, the potential environmental problems deemed worthy of consideration included an increase in energy usage, water consumption and greenhouse gas emissions. The possibility for sewage pipe blockages

and the scale of additional loads to sewage treatment plants causing technical problems were also of interest (Francesco, 2006).

The potential of the organic waste converter (OWC) is unique, as it has the technical capabilities of performing the procedures of waste pulverization, dehydration, blending, pelletizing/extruding, and packaging it is actually all in one unit as shown in Figure 11.



Space Requirement : 3M x 4M for OWC
Capacity : Segregated Organic Waste
25kg / 50kg / 125kg per batch (10 to 15 minutes)
Power : 4 HP / 8 HP / 13.5 HP

Fig. 11: Organic Waste Converter Machine (karmayog, 2006).

4.1.3.1 Implementation Procedure (OWC)

Production without harming the environment is a basic requirement of modern conversion system, for sustainable development of food and fiber production (Gajdos, 1998).

The OWC operates via the following principles as illustrated in figure 11:

Chapter 4: An Alternative Organic Food Waste *Disposal* System.

1. Here the wastes are collected, cleaned and segregated into its various nutritive components, such as carbohydrate, protein, fiber, minerals, vitamin, etc.
2. Each waste component is process at a time, by introducing it into the OWC.
3. The specification for each composition of component is set at the control panel to manage the process variables such as temperature, pressure, volume, flow rate, moisture content etc.

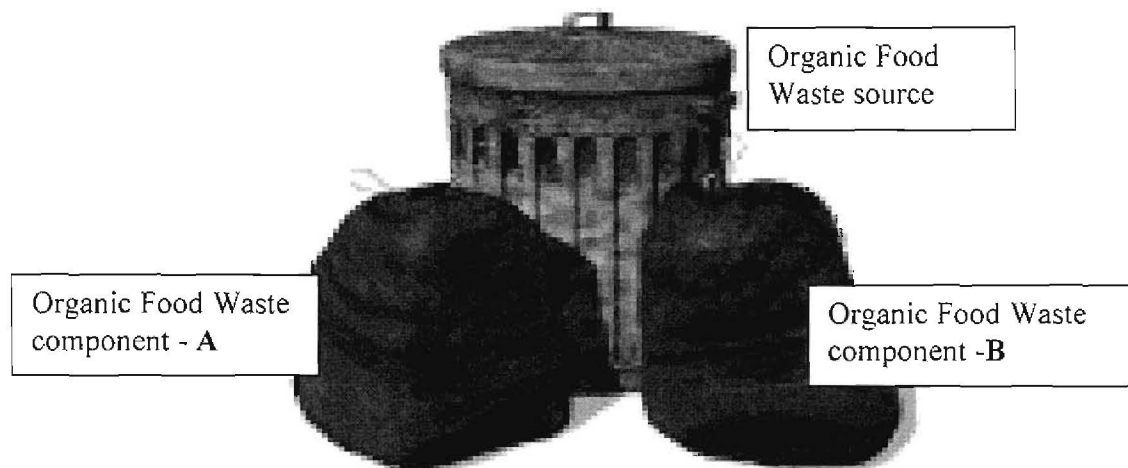


Fig. 12: Waste component segregation system

4. A sample product is taken for test of consistency and conformance.
5. The final product is then run and collected and bagged separately in each case.

The Organic Waste Converter homogenizes organic wastes with appropriate additive & bio-culture depending of the user demand. The output from the device is uniform coloured coarse powder in appearance and is without any bad odour. The treated organic material overcome the major cause of nuisance to resident community related bad odours and negative visual impacts and at the same time formulated into good quality organic feed (karmayog, 2006).

4.1.3.2 Feed Formulation and Blending Process (*Post-processing*)

After the waste is segregated into its various nutrition components and with the desired moisture content (Fig. 13), formulation involves blending the various components together to achieve a given feed recipe.

Organic food waste byproducts are seldom stabilized after the short processing time. Various measures therefore got to be taken to decrease any microbial activity and prevent the chemical processes involved in decomposition of organic matter.

Preserving methods should be developed to maintain good quality of OFW bio-products and avoid emissions and contact with water.

After implementing the conversion of the organic food waste as described in section 4.1.3.1 above, various animal or poultry feed could be formulated, knowing the specifications and formula required in each recipe.

To increase the concentration of food wastes and to reduce the moisture content in the final dried product used, the initial dried product can be blended with additional minced fresh food wastes and dried.

Blending with less expensive agricultural byproduct (e.g. Grain dust, soy hull, wheat bran) to achieve a given formulation can also enhance the nutritional properties of end product and increase the shelf-life of the final feed product due to a decreased moisture content.

After the Processed conditions have been met (the output from device is uniform coloured coarse powder in appearance without any bad smell), a given formulation (recipe) is taken, e.g. pig feed. The composition (recipe) is made up from each of the processed components (carbohydrate, fat, protein, mineral, vitamins, fibre, etc.) and then blended together to achieve the desired feed or feedstock.

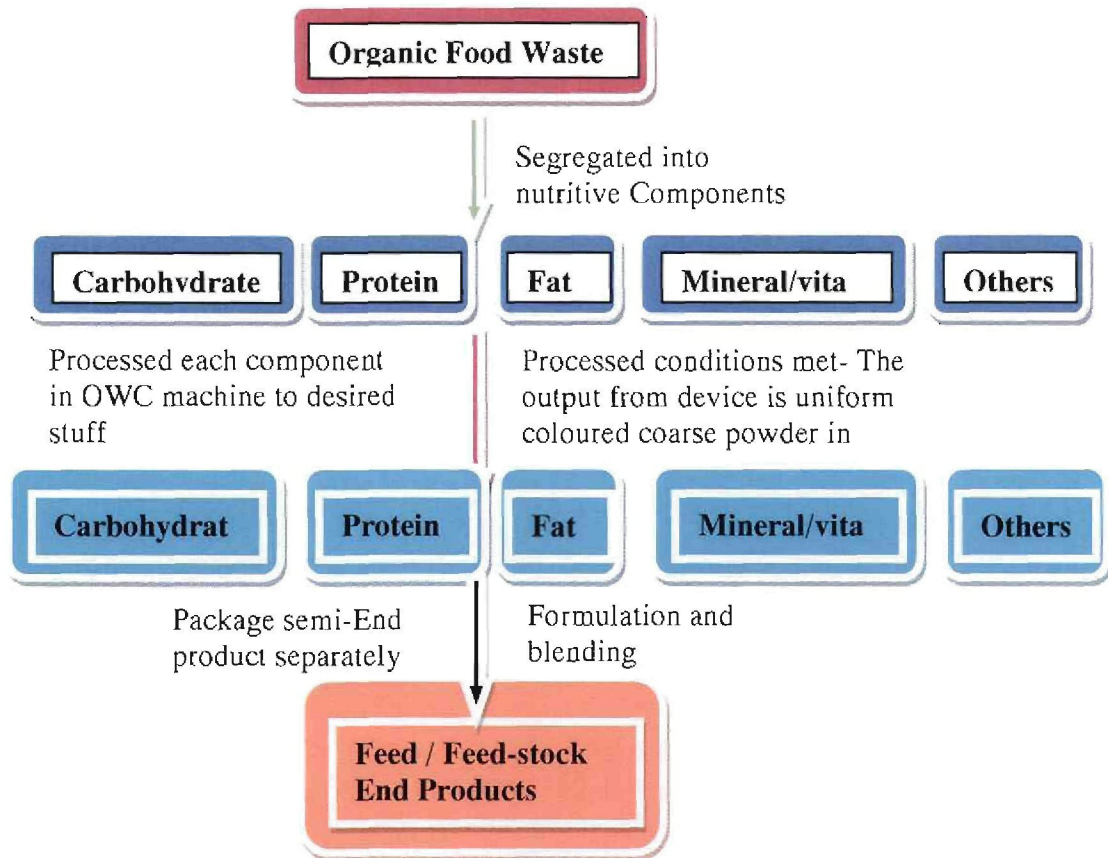


Fig. 13: Waste Conversion Procedure

This feed could be fed to animals and in turn serve as a source of protein to human. The waste product from this animal (droppings) is use as manure to fertilize the soil for fruits and vegetables growth that is also consumed by human. The food wastes or remnants from human are collected and recycled again as illustrated in figure 14 process loops.

The final feed products is introduced again into the OWC machine and blend with appropriate additives to obtain final desired forms such as, granular, powdered, pellets, etc. for definite feeding purpose and administration.

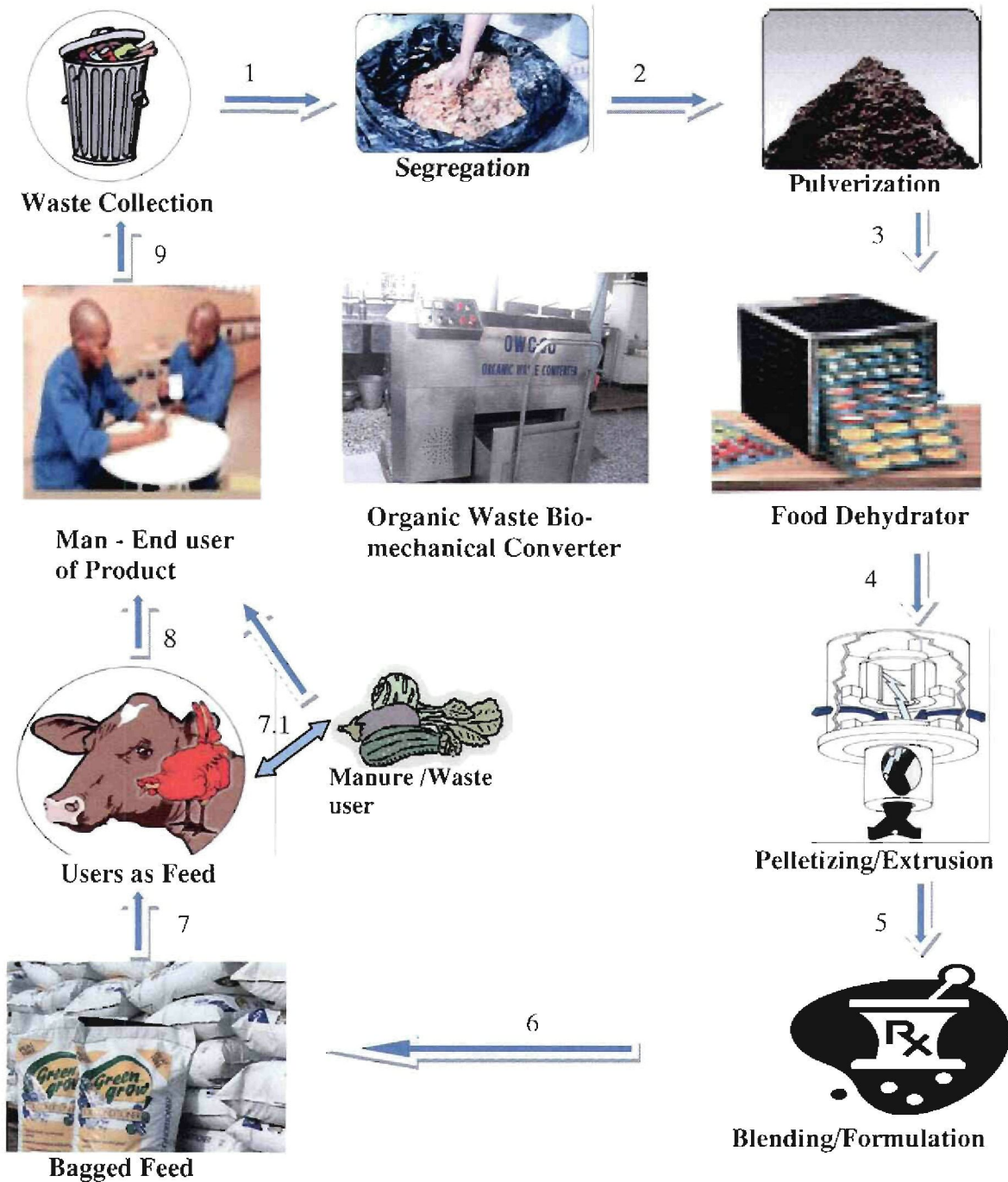


Fig. 14: Life Cycle of Feed Production Process (Loop)

Edible food wastes containing meat or in contact with meat must be heated (boiled) at 100°C for at least 30 min before processing (Swine Health Protection Act, 1980; USA)

The application of organic waste feed products of various qualities may be used for different purposes, such as for different animal and poultry types. The formulation (recipe) changes base on biological, chemical and physical properties, for different stages of animal development.

The biological and growth control of animal pathogens can be enhanced using organic feed remediation or as additives for feed combinations for feedstock in feed production (Gajdos., 1998).

4.1.3.3 Processing and Handling Capacity.

Industrial OWC as shown in figure 11 comes in variety of specifications such as:

- Space requirement: 3m x 4m
- Capacity: segregated organic waste processing capacity of 25kg/50kg/125kg per batch per 10 to 15 minutes of processing time.
- Power rating: 4HP/8HP/13.5HP

The variable characteristics include size of facility, plant location, availability of raw materials, type and composition of food waste supplies, and ability to ship processed products.

Feed production rates can range from less than 800 to over 4000 Kg/day culminating to over 200tons to 8 million tons per year. Organic food waste residues losses from dish washing which are drained into the adjoining sea and domestic wastewater from food processing, ranges from 5.0 to 8.0% of the original OFW mass.

The handling capacity could be modeled economically for adequate flexibility to accommodate a wide range of OFW byproduct processing rates.

This OWC machine could cover broad range of waste processing as possible, depending on user. This can be done by first understanding the nature of waste to be treated, and then

procedural application of the waste material in a sequential form. This will yield high potential OW byproducts level and possible waste production fractions.

Additionally, a planned benefit is that this model can be applied to similar byproduct utilization scenarios for other food processing residual streams. The blending, extrusion, and pelletizing options require the addition of a dry carrier material to facilitate dehydration and nutritional values, such as rice bran, maize husk, soybean meal etc, was used in this analysis because of their high protein value and common use in the feed industry (Rosentrater, 2001).

4.1.4 Process Limitations

In most cases, wastes are often widely dotted around in offshore and onshore areas and may be quite remote from the point of utilization or processing. Thus, the cost of collection and transportation to a central processing plant could be involving.

- 1) The viability of big-regeneration of wastes for feeds requires the solution of many difficulties that can be divided into two groups: techno-economic factors and health problems.
- 2) Waste values are emphasized commercially rather than its biological significance. In other words, how much money is a certain waste material worth in a specific application as feed rather than converting to other forms of energy?

Apparently, these values are determined not only by strictly nutritional qualities such as nutrient composition, digestibility, presence of anti-nutritional factors, palatability, and tolerance, but also by usage characteristics such as handiness, consistency, effect of the feed on the acceptability of the by-products (e.g. effect on egg yolk colouration or on the milk taste, etc.), aesthetic obstacles, or plain traditionalism. For these and other reasons, the value of wastes as feed is often considerably less than the value that would be assigned to them by a computer programmed for least-cost feed formulation (Berk, 1978 & Battistoni, 2006).

Administration of feed for rearing of farm animals requires a high degree of uniformity in feeds. Most organic food waste stream residues lack such uniformity as a result of seasonal variations, differences in agro-technical methods of processing, dietary change and diversity of sources. The OWC is a modern feed mill technology and can cope with variability of ingredient composition within certain limits, by making up feeds with required additives.

The following process limiting factors must be noted:

a. Techno-Economic Factors.

Animal feed production could be the most profitable means of small scale utilization of organic food waste in rural communities. This method may represent the highest immediate cash return because, there is enormous but stable demand for feed, and the technologies involved are not too sophisticated to implement (Berk, 1978).

Also feed marketing is relatively easy; as it is easier to introduce an unconventional **feed** than that of an unconventional **food**. Unfortunately, there are some limiting economic factors that may lessen the apparent profitability of the feed production approach, such as collection cost, conversion (Berk, 1978).

b. Health Factors.

The subject of health factors in feed production from organic food waste should be examined from two facets:

1. Issues related to the effect of the feed on the health of the animals. These include primary toxicology, parasitology, microbiology, etc.
2. Factors relating to the wholesomeness of the final animal dairy products. These include health related issues pertaining to animal products like meat, eggs, milk, etc. This could be treated as subject matter for secondary toxicology, microbiology, etc.

Primary safety evaluation is simple to perform. Routine feeding trials could show the presence or absence of acute toxicity or the danger of outbreak of contagious diseases. Effects of diseases that could be detected only after many generations are generally of no consequence. Other than in the case of animals raised for reproduction purposes (Rosentrater, 2001 & Berk, 1978).

Whenever it is expected to use an organic food waste material as feed ingredient or feedstock of the diet for only a certain portion of the life span of the animal, health hazards should be evaluated in relation to animals of corresponding age. It is not advisable to use certain feed ingredient for newborn animal without justification of proof of toxicity. Such feed should rather be considered as a fattening or finishing ration instead (Park et al., 2002 & Berk, 1978).

The subject of secondary safety or transmitted health hazards is still more complicated. The basic philosophy and methodology of evaluation are being debated and no accepted standards are available to date (Rosentrater, 2001 & Berk, 1978).

Controlled tests for residues transmitted from animal feeds in farm animals, may give an insight to useful information concerning safety or nutritional value for man. The following health and safety factors must be considered in the evaluation of organic waste as feed:

- Pesticide residues,
- Toxic metabolites,
- Pathogens,
- Heavy metals,
- Drug residues, and
- Foreign bodies (e.g., metal, glass), etc. (Berk, 1978).

4.1.5 Socio-Economic and Environmental Impacts.

Advancement in waste management technology may have wider implications for the local economy of the communities. The Chevron Escravos Community Development and Economic Strategy identified several Business Clusters within its boundary that needed to

be developed. This development will assist with the diversification of the economy of the rural communities away from an over-dependence on the oil and gas industries.

Business Clusters could be formed by companies interacting with each host community in other to contribute to their specific economic and social demands and services. One of the identified business clusters is Environmental Technologies, with the focus on agricultural economy. This could specifically include waste management utilization.

This Business Cluster could include poultry farming, piggery, fish farming, and the sale of agricultural feed. This can be achieved by employing the required expertise in these various fields and providing local based centre of technological expertise, which could be made available to the communities and be harnessed by companies who train the local communities regarding new applications that would influence employment and development.

This Local Environmental Technology (LET) cluster development could be applied to organic waste management to create efficiencies, improve environmental conditions and create new employment opportunities to bring about sustainable development in the host communities (Herefordshire & Worcestershire, 2004).

4.1.6 Company – Communities Benefits

4.1.6.1 Economic Advantages

- a) Recovered materials use less energy in the OWC facility plant compared to that needed for products produced from virgin raw materials. A resultant saving of energy in terms of electricity or fuel could be achieved.
- b) Reuse of recycled material may reduce importation costs in food material, as most of the food such as meat, fish, eggs, etc, could be produced from the agricultural based community. The case of Chevron Escravos which is situated on Island in a swampy terrain without road connection to the city, food and other products are presently either transported through sea or air which is an expensive venture (Kaseva, 1999).

Summary of Economic Benefits of an Alternative OFW Disposal System

- Reduction of landfill disposal fee penalties on incinerated waste residues
- Reduction of waste transportation costs
- Increased revenue for sale of recyclables
- Generation of income from waste to contribute towards the wealth of the host communities
- Extension of the life of landfill facilities
- Minimize or delay the purchase incinerators and construction of new landfill facilities
- Cost savings passed on to rate or taxpayers
- Additional benefits include the ability to recycle the process wastewater and to sell value-added waste from agricultural economic residue as manures.

4.1.6.2 Environmental Advantages.

- Recycling practices reduce the amount of waste to be disposed through incineration, thus reduces global warming impacts, and the toxin emissions to the environment resulting from land-filling and incineration.
- Recycling could conserve the healthy relationship between the host communities and the operating company.
- Extension of landfill life and reduction of incinerated wastes
- Reduction in waste transport equals lower vehicle emissions, energy use, traffic noise and congestion
- Mitigation of landfill and incineration pollution

- Improvement in recycling compliance, current and future
- Reclamation of the waste stream reduces future needs for raw materials and related energy costs to process into finished goods.

4.1.6.3 Socio-economic Advantages

- Recovery of materials from organic waste, when properly organized could generate sources of livelihood for unskilled workers in the host communities. This may further inculcate the concept 'Waste to Wealth' when people begin to perceive waste materials as recyclables not rubbish.
- The waste to wealth concept could be developed, and this philosophy in extension, could be learn to the larger society.
- The company could meet some of its social corporate responsibility through this process.

4.1.6.4 Ecological advantages

- Recycling aids conservation of natural resources e.g. water, plant, minerals, trees, etc. For example a smaller amount of it water is needed if the production is from recycled raw materials than if it is from virgin raw materials (Kaseva, 1999).
- The waste products from the animal and poultry (droppings) fed using this feed could be used as compost material to produce manure or fertilizer for increase soil characteristics to grow plants and vegetables (Kaseva, 1999).

4.2 Conclusion

It has been illustrated that animal feed production via utilization of OFW in small scale rural communities could be a profitable means of waste disposal. This approach has been part of traditional agriculture for centuries, but not without some health related issues such

Chapter 4: An Alternative Organic Food Waste *Disposal* System.

as odour, Foot-and-mouth disease (FMD), etc, as a result of unprocessed direct feed application.

The proposed alternative organic waste disposal system has provided a wealth of information indicating the feasibility of the processes and also identifying the pitfalls.

The process technologies involved may sometimes be of a larger-scale and require organization intervention, but are not out of reach for rural communities.

Considering the enormous economic and environmental benefits of organic food waste as illustrated, it would be necessary to compare the present waste management practice of incineration and alternative recycling or resource recovery of organic food waste in an environmentally and economically manner. This is necessary in order to make an assessment (trade-off) for managers' decision-making processes, so that the most cost-effective disposal method could be chosen for this facility. This process is analysed in the next chapter (5).

CHAPTER FIVE

Evaluation of an Alternative Waste Disposal System

5.0 Introduction

There is a global move towards developing agricultural production systems which are sustainable. This involves inter alia the more efficient utilization of inputs, particularly nutrients, water and energy, and the reduction and recycling of waste products (Sims, 1996).

Ideally it is expected that all the organic waste material be converted to useful byproducts by recycling of the nutrients, or composting organic matter for replenishment of soil, or generation of useful energy. Consequently waste disposal costs would be avoided, environmental pollution would be reduced, and the word "waste" in this context would become resources or redundant (Sims, 1996).

For many developing countries and eastern bloc countries, the intent is primarily to produce enough from the land to provide food and clothing to enable their populations to survive on the short term. Reduction of pollution and waste is a low priority. There are however good examples in subsistence farming systems where waste products are well utilized because resources are scarce.

Recently an increasing number of papers have been submitted on Agriculture, Ecosystems and Environment regarding the utilization of organic wastes. This reflects the expanding interest in sustainable farming systems.

This submission has brought together a miscellany that there are several papers on the topic from various interests covering a wide range of methods for utilizing organic waste materials as a result of primary agricultural processes. The objective is to convert organic wastes into co-products and at the same time consider the environmental impact of such management practices (Sims, 1996).

The present organic waste disposal system at Chevron-Escravos does not consider such an innovative waste management process where organic waste is utilized in terms of Agricultural economy, Ecosystems and the Environment.

Before any waste disposal alternative is adopted for a specific waste stream on an industrial-scale, each technically-viable option must be considered for its feasibility, with special consideration given to the economics and environmental impact of such choice (Clarke, 2000).

The choices being considered in this study include the application of incineration versus recycling or the reuse methods of organic food wastes as a means of waste disposal technique.

The dissertation problem was advanced through the following:

- **Opportunity cost of recycling of organic food waste to incineration**
- **Environmental impact of both systems [using LCA]**

5.1 Opportunity Cost of Recycling Organic Food Waste to Incineration.

Environmental Economics

There is much debate over whether recycling is economically feasible. Advocates of recycling argue that judging the process on financial issues alone is not enough. They claim that the environmental benefits, energy savings, waste reduction and raw material conservation must also be considered in order to make such non-fiscal benefits economically relevant. Advocates have also pushed for legislative action to increase the demand for recycled materials (Lyons & Burford, 1993).

Opponents counter that it is not reasonable if recycling is more costly than any other disposal methods or manufacture from new virgin production. Any government incentive that to support recycling the opponents claim would be a waste of resources. This was reiterated in John Tierney's article in 1996 for the New York Times, estimating that New

York's recycling program would cost \$3000 dollars per ton of recyclates if the public were paid for the time spent on sorting and cleaning (John, 1996).

In John Tierney's article "Recycling is Garbage", he is highly critical of recycling and states that the simplest and cheapest option is usually to bury garbage in an environmentally safe landfill. He claims that "recycling may be the most wasteful activity in modern America" a waste of time and money, a waste of human and natural resources (John, 1996).

In their article Richard A. Denison and John F. Ruston, (members of the Environmental Defence Fund), claim that John Tierney's article is "gravely inaccurate" and that Tierney unquestioningly repeats the claims of a group of consultants that have strong ideological objections to recycling (Richard, 1996).

Michael Munger, the Chair of Political Science at Duke University corroborated Tierney's claim by arguing that the financial costs of recycling some materials outweigh the environmental benefits, and that the benefits do not compensate for the extra effort recycling requires (John, 1996).

Though recycling would make economic sense in a densely populated area where virgin materials are scarce and disposal costs high, legislated recycling in other situations would only bring unnecessary economic hardship (Lyons & Burford, 1993).

From these debates it has become clear that certain requirements must be met in order for recycling to be economically feasible and environmentally effective. These include an adequate source of recyclates, a system to extract those recyclates from the waste stream, nearby facility capable of reprocessing the recyclates and a potential demand for the recycled products.

The last two requirements are often overlooked. Without both an industrial market for production using the collected materials and a consumer market for the manufactured goods, recycling would not be feasible (Lyons & Burford, 1993).

It is important to determining the environmental effect of recycling, in order to decide whether the recycling of a certain material has environmental benefit. The environmental impact of recycling must be determined and then be compared to the effect of virgin production. Also the environmental impact of waste collection must be identified beforehand.

If a waste collection vehicle has to cover an entire city to collect material to be recycled, this will have an environmental effect in terms of CO₂ emission. Water is also needed to wash and clean the recyclates, energy is needed to drive the sorting apparatus.

These are the environmental costs of transporting the recyclates to the reprocessing plant and the subsequent shipping of the reprocessed materials to new manufacturers all these may lead to CO₂ emission (Lyons & Burford, 1993).

The direct benefits of waste recycling must also be factored into the environmental calculation, such as; helps to conserve natural resources, which is especially important with non- renewable resources such as aluminium and other metals. Waste which would otherwise end up incinerated or stored in landfills and lead to greenhouse-gas emissions is diverted and environmental damaging process of mining or harvesting new virgin materials is avoided (John, 1996).

Once the environmental costs from virgin production and recycling are known, the two processes can be compared economically. It will be difficult to determine which is most beneficial, as there will often be many calculations involved in the total cost estimation.

Ultimately, the final choice may come down to a trade-off; virgin production may use more energy, for example, while recycling requires a larger supply of water. Despite these complexities, a study conducted by the Technical University of Denmark found that in 83% of cases, recycling is the most efficient method to dispose off organic food waste (Lyons & Burford, 1993).

The United States Environment protection agency has also concluded in favour of recycling, saying that recycling efforts reduced that country's carbon emissions by a net 49 metric tons in 2005.

In the UK, the Waste and Resources Action Program stated that Britain's recycling efforts reduce CO₂ emissions by 10-15 tons a year

5.1.1 Economic Model

Scope of Model

The overall intention of this model is to evaluate the Opportunity Cost of Recycling of Organic Food Waste versus the Incineration method of disposal by using the By-product Breakeven Sales Price (BBSP).

The economics of producing value-added by-products feed and feed ingredients material using organic waste converter and processing alternatives are of interest.

Model Parameters and Assumptions

The basis of this model is that an organic waste production facility already exists. The intent in constructing this model is to provide the facility planner or manager with a tool that can be used to help in deciding on the optimum organic waste management options.

This model examines the costs associated with installing and operating a processing line in the existing production plant. It also examines the costs associated with incinerating the organic waste byproduct stream to provide baseline results that can be compared to the results of the resource recovery or recycling method which is the opportunity forgone.

For each waste disposal options, equipment and building facilities were sized to adequately meet processing requirements. Only operational costs and installation were determined. Service life of 15 years ($n = 15$) was adopted. The model accounted for annual fixed costs, annual variable costs and annual benefits for each option. (Richard & Rosentrater, 2001).

This model does not account for annual variable costs incurred, such as electricity, gasoline, dryer fuel, labor, raw ingredients (blending agents), water, maintenance, etc. Annual benefits included the sale of byproduct feed materials, cost of CO₂ emission saved and the annualized salvage value of equipment and structures. Table 6 itemizes all annual costs and benefits included in the model. More detail regarding this model, as well as a full reference list, is found in Richard & Rosentrater, 2001.

5.1.1.1 Economic Analysis.

A general balance sheet (Table 6) was implemented as a model to account for all annualized fixed and some variable costs, as well as all annual benefits, for each waste management option.

Table 6: General balance sheet of Economic model (Source: CNL HSE department, 2008 & Richard & Rosentrater, 2001).

Model Input Variables	Incineration^a /yr	Recycling/reprocessing option^b /yr
Delivery radius (km; mi) ^a	100m-1km	100m-1km
Electricity price (\$/kW h) ^b	N/A	N/A
Gasoline price (\$/l; \$/gal) ^b	N/A	N/A
Interest rate (decimal) ^b	17%	17%
Incineration penalty fee (\$/ton) ^b	N/A	N/A
Organic waste generation rate (tons/yr) ^a	4,380 tons	4,380 tons
Annual Fixed Costs (\$) ^c		
Initial capital investment	USD 1,637,724	USD 51,400
Buildings	N/A	N/A
Equipment		
Other (spouting, wiring, engineering, etc.)	USD 150,000	USD 1,800

Chapter 5: Valuation of Alternative Waste Disposal System.

Total initial capital investment	USD 1,787,724	USD 24,800
Depreciation	20%	20%
Insurance	4%	4%
Interest	17%	17%
Overhead	N/A	
Taxes	N/A	
Annual Variable Costs (\$) ^d		
Delivery truck insurance	USD 3200	USD 3200
Energy (boiler fuel for steam generation)	N/A	N/A
Energy (dryer fuel)	N/A	N/A
Energy (electricity)	N/A	N/A
Fork lift truck operation	USD 3,600	USD 3,600
Labour	USD 24,000	USD 24,000
Maintenance and repairs	USD 28,966	USD 4,120
Miscellaneous supplies	N/A	N/A
Other variable costs	N/A	N/A
Pallet repairs and replacement	USD 1,200	USD 1,200
Water	N/A	N/A
Annual Benefits (\$)		
Environmental gains over current disposal methods (CO2 Saved)	None	USD11,031
Equipment salvage value	N/A	N/A
Annual equivalent salvage value	N/A	N/A

a - Input variables intrinsic to model

b - User-specified input variables.

c - Values are dependent on processing option and production rate.

d - Values are dependent on processing option, production rate, and delivery distance.

Chapter 5: Valuation of Alternative Waste Disposal System.

The essence of this model was to compare the costs of incineration of organic food waste with the economics of producing value added byproduct feed material using OWC as an alternative to waste disposal system in Chevron-Escravos tank farm. Specifically, the objective of this economic model was to determine byproduct feed sales price that is required to reach the breakeven point each year of plant operation, and then to compare this result with the cost of incineration economically.

By determining these values, the required byproduct feed sales price needed to reach the annual breakeven point could be determined via eqn. (4). The analysis of opportunity cost of the economic parameters of the alternative option and incineration are presented in Table 6. (Rosentrater, 2001& Richard, 2002):

$$BBSP = \frac{\sum AFC + \sum AVC - \sum AB}{\sum AMBP} \dots\dots\dots \text{eqtn. (4)}$$

Where BBSP is the byproduct break even sales price (\$/tons), AFC is the annualized fixed costs (\$/yr), AVC is the annualized variable costs (\$/yr), AB is the annualized benefits (\$/yr), and AMBP is the annual feed and byproduct production rate (tons/yr).

Feed production estimation.

$$\sum AFC = \text{USD}78000$$

$$\sum AVC = \text{USD}36120$$

$$\sum AB = \text{USD}11031$$

$$\sum AMBP = \text{USD}1822$$

80% of organic waste (4,380 tons) was assumed to be organic food waste = 3504tons
 Minus moisture content of organic food waste (3504 tons) 48% = 1682tons
 Solid organic feed and byproduct rate = USD 1822.

Chapter 5: Valuation of Alternative Waste Disposal System.

$$\text{BBSP} = \frac{103089}{1822} = \underline{56.6 \text{ tons/yr.}}$$

$$\text{BBSP} = \underline{56.6 \text{ tons/yr.}}$$

The sales price for this tonnage could be estimated, for example the cost of a bag (25kg) of poultry feed in Nigeria is about US\$10.0 per 0.025 ton. (25kg). Therefore, 56.6tonnes/yr would amount to

$$\frac{56.6}{0.025} = 2,264\text{bags/annum}$$

Using a cost of USD 10 per bag, we then have USD 10 x 2264 = **USD 22,640 annually.**

5.1.2 Cost of CO₂ Emission Saved

There is a need to illustrate the cost of carbon dioxide to guide public investment decisions. The man made emissions resulting from the current incinerator waste disposal system has economic losses and environmental effects. The 10tons chevron-Escravos incinerator used in organic food wastes disposal is an environmental burden and a contributor to the effect of global warming due to the huge emission of CO₂.

A modeling analysis in 2002 indicated an international carbon price in the range of US\$4-7 per ton of carbon dioxide emitted (AGO, 2002).

One ton of waste incinerated is equivalent to 2MWh of energy used in district heating and 0.67MWh of electricity produced. According to the statistics of the Danish Energy Agency the calorific value in 2003 was on average 10.5 MJ/kg. Therefore, 4 tons of waste substitutes 1 ton of oil or 1.6 tons of coal (Ramboll, 2006).

The amount of carbon dioxide emission saved in terms of international carbon tax price could be determined from the expression:

$\text{CO}_2 \text{ emission (tons)} = \text{Energy consumption (KWh)} \times \text{emission factor (KgCO}_2\text{/KWh)} \times 0.001$ (DEFRA, 1995).

Where:

Energy consumption (KWh) = each ton of waste burned

Emission factor (KgCO₂/KWh) = 0.537 (using average emissions factor)

The average Organic food wastes burnt = 4,380 tons/yr

According to Ramboll, 2006, 1 tonne of waste can generate approximately 0.67 MWh of electricity.

Therefore 2934600 KWh of energy could be generated from the incineration 4380tons of waste annually. This gives a total CO₂ equivalent of 1575880KgCO₂ (2934600KWh x 0.537) emitted annually.

This gives an interpretation of 1575.880tons CO₂ emitted annually.

From an economic point of view, a total of **USD11,031** is realizable annually using international carbon price of US\$7 per ton of carbon dioxide emitted (AGO, 2002).

Using the proposed alternative waste disposal system, a total of **USD22,640** and **USD11,031** could be generated annually from feed production and cost of CO₂ emission saved respectively.

Economic gain of the proposed disposal method amounts to a total income of at least **USD34, 431** realizable annually.

5.2 Environmental Impact of Both Systems

5.2.1 Life Cycle Assessment

Life Cycle Assessment (LCA) is a well established technique of environmental assessment and is guided by the International Standard Organization 14040 series of standards. These standards establish a flexible framework in which LCAs can be conducted in a reliable and practical manner (Aye, 2005).

According to this standard, LCA consists of the following phases:

Goal and Scope Definition, Inventory, Impact Assessment and Interpretation

- **Goal and scope definition:**

This defines the purpose of study, functional unit for comparison and system boundaries (McDougal et al., 2001).

- **Inventory:**

Identifies inputs and outputs for each process or material, calculates the flows of materials, energy and emissions (Goedkoop, 1995).

- **Impact assessment and interpretation:**

Results of inventory are analyzed by the relevance impact categories (Goedkoop, 1995).

The process of evaluating the effects that a product has on the environment over its entire life cycle is known as Life cycle analysis (LCA) (UNEP, 1996).

Life cycle analysis measures costs and benefits more accurately. The assessment fully examines the impact of a product or service from the mining of raw materials,

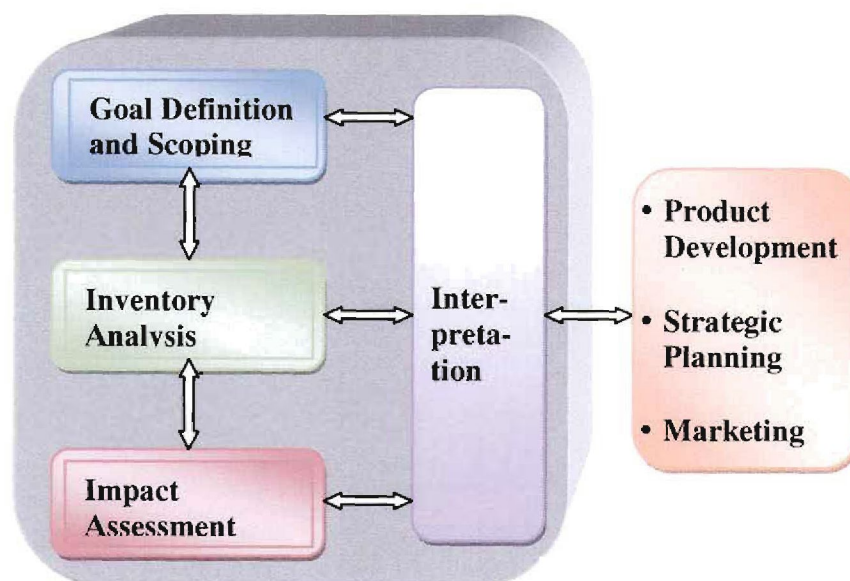


Fig. 15: Life Cycle Assessment Framework (Source: SFS - EN ISO14040.)

manufacture, distribution, use, re-use or recycling, and final disposal. The assessment evaluates raw material energy used, releases to air and water as well as solid waste emissions (Powell & Turner, 1996, 99).

Given an evaluation method, the total environmental costs and benefits of the product can be calculated. Despite its complexity compared to than other environmental tools, LCA provides objective data that is not dependent on ideology. The life cycle assessment framework is as modelled in figure 15 above.

5.2.1.1 Goal and Scope Definition

One of the aims of this evaluation is to quantitatively assess the environmental effect of present incineration of organic food waste disposal system in Chevron-Escravos and compare this with the alternative options of OFW recycling, reuse, and conversion to animal feeds.

The environmental impact categories considered in this study are:

- **Air acidification**
- **Eutrophication**
- **Human and eco-toxicity**

a) **Functional Unit**

In LCA, the “functional unit” (fu) is the definition of the functional outputs of the product system. The key essence of the functional unit is to provide a reference to which the inputs and outputs can be related (ISO 14040, 1999 & Sven, 2004)

For this dissertation, the functional unit is defined as the management of the average amounts of food waste generated per person working per day in Chevron-Escravos. An estimate of between 0.5kg to 1.0kg of food waste is generated per person daily, from an average of three daily meals. Consequently, an approximated 1.5 to 4.0tons of food wastes is generated daily (see fig. 6). This amounts to about 540 to 1440 tons (wet) per annum.

b) Constructed Scenarios

This analysis compares two scenarios constructed (Fig. 16) for handling waste from Chevron-Escravos wastes stream. The current operation of incineration was used as the baseline (business as usual (BAU)) scenario for comparison.

c) System Boundaries.

Cradle: Chevron-Escravos waste collection bins at the canteens.

Grave: when waste becomes inert landfill material (or) the waste is converted into air and/or water emission or waste is converted to secondary materials which have resale values in this case animal feed.

Breadth: second level effects on system, such as building of capital equipment are ignored (for fuel and electricity life cycle, the pre combustion effects are included in the model) (Aye, 2005).

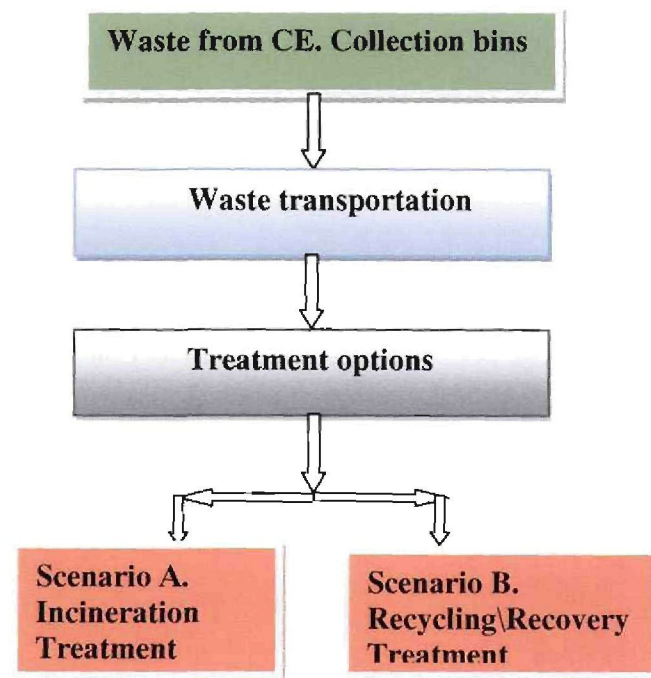


Fig. 16: Waste Treatment Scenarios

d) Outline of Options Modeled

The following two waste management options were modeled:

Option 1: Meet the modern recovery targets. This option meets the Waste recovery targets through a combination of recycling and conversion system. No thermal treatment is considered and all organic food waste was used in an OWC, for feed manufacturing.

Option 2: An “Incineration All” scenario: This option considered 100% of the organic food wastes recovered in the case study area is sent to an incinerator. This option is able to meet the waste disposal option, but does not conform to the waste recovery targets.

General Assumptions

The majority of input data used to conduct the LCA for the different options was kept consistent. The general assumptions used were as follows:

- The percentages of materials that make up OFW were kept consistent for all waste management options. However, it should be noted that the composition of OFW could change significantly in the future.
- Recycled material is attributed to waste treatment methods using data for production of virgin material of the same kind.
- The average distance travelled by vehicle used to collect recyclables from the waste dump was estimated to be about 367km per year.
- It was assumed that on the whole the population of the case study area did not increase over the time period (2005–2008). The total numbers of collection bins, and waste sacks would remain the same.
- As there is currently no large scale landfill treatment facility in the case study area, and also the generation, collection and treatment plant are on the same facilities, the results of the LCA modeling would be consistent.

5.2.1.2 Life Cycle Inventory Modeling and Impact Assessment

The LCI of each system consists not only of the impacts from the energy consumption of the system, treatment process, and residue disposal, but also of the saving from product displacement and environmental emissions from disposal of solid residues or wastes, by-products were considered as a part of each system.

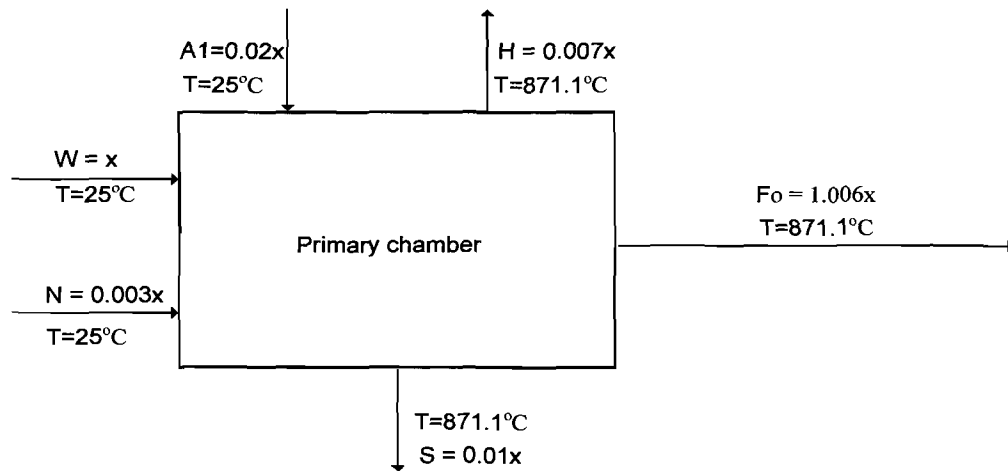
To obtain the process impacts of food waste treatment, two main treatment processes were compared: incineration and feed manufacturing. All operating parameters were taken from existing facilities of Chevron-Escravos (CE), such as energy consumption, and equipment. There is no landfill for food waste and therefore no operating parameters for this process in CE.

Detailed process descriptions and emissions of each process are the following:

a) Incineration

The incinerator is an industrial incinerator of 10t/d capacity, food waste combustion is assumed to be between 73-85% of the total organic wastes.

This incinerator like similar other installation (fig. 18) is equipped with a series of general incineration processes, e.g. heat recovery facility, so called advanced air pollution control devices (semi dry reactor for acidic pollutants, fabric filter for particles, and selective catalytic reduction for NO_x and dioxins), wastewater treatment system, etc. The recovered heat in this case is not used on-site but cooled with water to produce steam and vented to the atmosphere (wasted energy).



Where N – natural gas, W – organic wastes & A_1 – air

Fig. 17: Schematics of Incineration System

b) Feed Production System.

Food waste can be used as feed stock for farming or feed ingredients, by implementing a number of mechanical and biological operations. Such usage is hindered by problems like decay, odour during transportation, storage and contamination. The selected feed manufacturing facility is the dry-type processor (OWC), which consists of only a few mechanical operations, e.g. segregation, shredding, dewatering, and drying process including odour treatment.

Considering the characteristics of the process, it can be assumed that there are no air emissions from the process. Leachate generated by food waste was only at dump bin site and because leachate generation is known to strongly depend on precipitation and decomposition. The generated leachate is not harmful and the collection of waste is regularly done daily.

The surveyed facility and data that was collected, indicates that a relatively large amount of wastewater (35 -45%), with a high concentration of nutrients is generated. In this

process (OWC) the moisture is removed via dehydration with moisture removal efficiency of 85 - 90%. The electricity consumption for this process (feed manufacturing) is assumed to be supplied by Chevron-Escravos via the flared gas.

To consider the displacement effect of the product, it was assumed that the final product or byproduct could replace commercial feed or soybean as an ingredient of feed. This could reduce the resource consumption and emissions caused by the production of commercial feed from virgin resources and soybean cultivation.

To obtain the LCI for fuel and electricity, it is assumed that these energy sources are free. The case study facility (CE) is an energy producing company which flares natural gas, some of the gas flared is used as fuel for the generation of electricity.

This implies that the electricity consumed by this waste management process could reduce gas flaring, as well as conserve the environment.

In this dissertation, the collection and transportation of waste was excluded from the system boundary. The impacts of water consumption, chemicals usage as well as the construction and demolition of facilities were ignored. This was done due to the relatively small impact of these activities compared to the treatment process (Eriksson et al., 2005; Conssonni et al., 2005).

5.2.2 Environmental Effect Categories

All predicted environmental burdens were classified and characterized into five impact categories due to gap in data generation and acquisition.

The impact assessment categories reviewed are the following:

5.2.2.1 Air Acidification

Some of the principal effects of air acidification include lake acidification and forest decline. The two primary acidifying species are compounds of sulphur and nitrogen which are found in the Flue gas, characteristics of the incinerator (see table 7).

a) **Incineration Emission Process (CE)**

It is apparent from the process model of the alternative waste management option shown in figure 19, that there would be little or no significant air acidification in option 2 since no acid gases are produced. Unlike the process of incineration (fig. 18) in option 1 which emits flue gases such as fly ash, smoke, and other toxins (Table 7).

These contaminants eventually condense in the atmosphere and on the water surface to form various types of acids depending on the contact and chemical reaction. The health impacts associated with incinerator derived chemicals from flue gases are as shown in table 8 below.

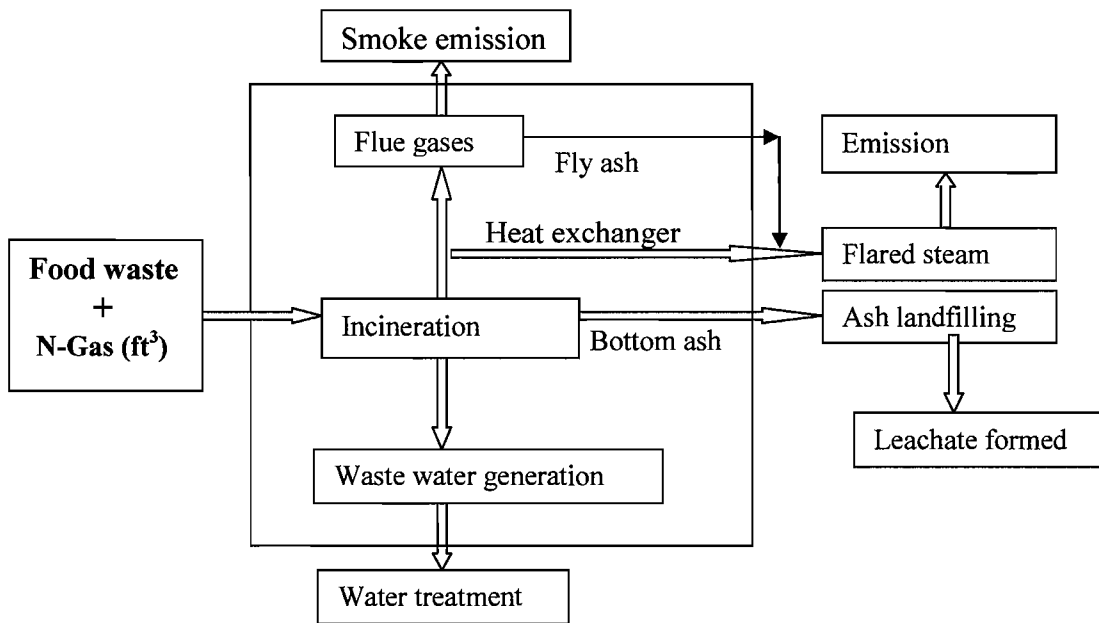


Fig.18: Current Incineration and Emission Process (Option 1)

CE. Flue gas characteristics from incineration

Flue Gas components	Attribute
Ash	0.3x
HCl	0.089x
HF	0.0372x
SO ₂	0.0007x
NO _x	0.0011x
Dioxins	0.0544x
O ₂	0.0406x
CO	0.0258x
N ₂	0.4568x
Metals	0.0169x

Table 7: Source: HSE department, Chevron Nigeria Limited.

Table 8: Health effects associated with incinerator derived chemicals

Toxins	Health Threats
SO _x	Respiratory tract irritation
HCl	Tissue and respiratory tract irritation
PM	Respiratory problems
Dioxins	Developmental & reproduction problems (unborn and infants most susceptible)
Heavy Metals	Lung, gastric, esophageal cancer, etc.

Source: United States Environmental Protection Agency (EPA).

b) Organic Waste Alternative Technology

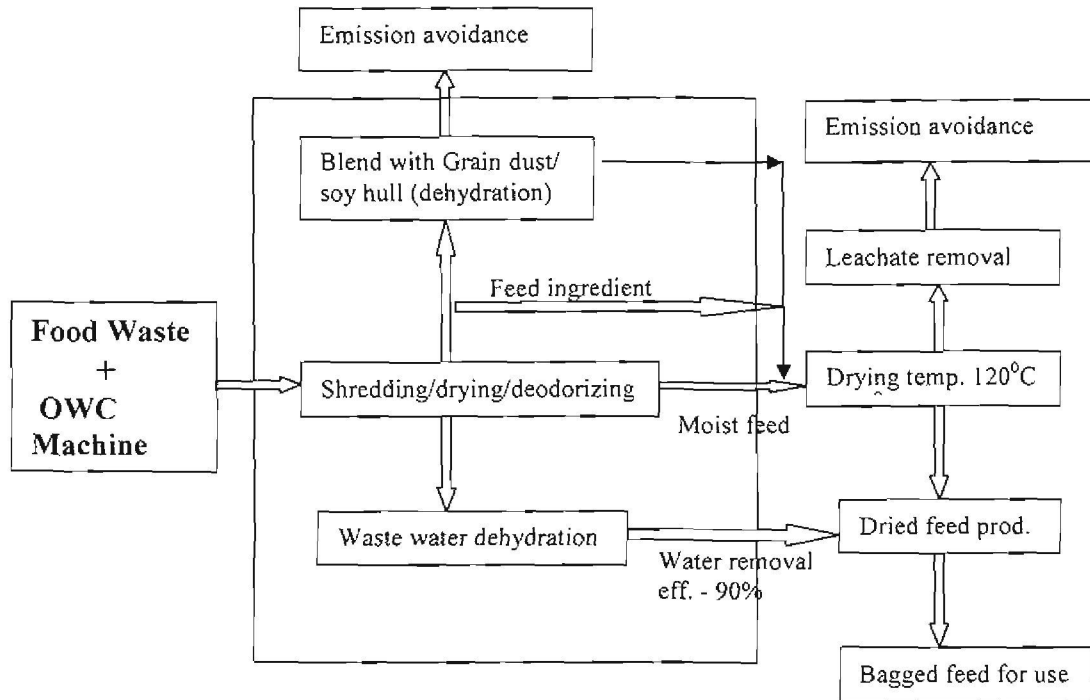


Fig. 19: Feed Manufacturing Emission Free Process (Option 2)

Table 9: Environmental Impact of Each System

Category	Unit (eq./t)	Incineration	Feed Manufacturing
Global warming	g CO ₂	High	n/a
Human toxicity	g 1,4-DCB	High	Less
Acidification	g SO ₂	High	n/a
Eutrophication	g PO	Medium	n/a
Ecotoxicity	g 1,4-DCB	High	Less

c) Global Warming.

This is largely caused by the depletion of the ozone layer through the combustion and production greenhouse gases. Resource depletion has cause the diminishing availability of natural resources such as fossil, virgin materials and mineral resources.

Greenhouse effect permits solar radiation to penetrate the earth's atmosphere but absorbs the infrared radiation returning to space. Water vapor, methane and carbon dioxide are the gases responsible for this effect. Depletion of ozone layer, Man-made emissions of CFCs, CO₂ and other chemicals used in refrigeration, aerosols and cleansing agents are thought to cause destruction of ozone in the stratosphere, letting through more of the harmful ultra-violet radiation.

The option 1 described above is a major contributor of the ozone depletion, unlike the proposed alternative option 2.

5.2.2.2 Eutrophication (water)

The fortification of mineral salts and nutrients in marine or lake waters from natural processes and man-made activities is known as the Eutrophication effect. Contributors to eutrophication process include such as farming, incineration fly ash. Materials in this impact category are mainly substances which contain nitrogen and phosphorus, e.g. NO_x, Sox -emissions contribute to Eutrophication and acidification as shown in table 7.

5.2.2.3 Human Toxicity and Eco-Toxicity.

The wet organic waste conversion leads to production of waste water as waste product which is toxic if not treated (Leachate). OWC actually dehydrate this waste water along with the byproducts produced. But the toxins in fly ash and smoke from incinerator could cause eye and respiratory disease.

5.3 Conclusion

The large scale generation of organic food waste has reached a state that a warning signal is flicking as reflected from the running out or shortage of food globally. One of the best ways to manage this acute problem is by recycling organic food waste to produce feed for animal production.

As food waste forms the major components of organic solid waste, which contributes to over 80% of the total organic waste, recycling this waste is the best option to mitigate this enormous waste. This dissertation demonstrate the opportunity cost of feed production from recycling method to incineration, the current practice of organic food waste management in Chevron-Escravos.

With the huge loss of capital on the current practice, it is envisaged that the organic food waste recycling method can result in a huge savings. Recycling OFW for feed production is a cost effective method that also helps in protecting the environment and achieves economic sustainability.

The modeling conducted for the case study area was successful in demonstrating that there are many positive environmental and economic benefits in choosing an integrated feed manufacturing (resource recovery) waste management approach, instead of the current practice of incineration in Chevron-Escravos.

With the aid of the economic and environmental modeling shown above, the results could aid those in the waste management industry in making environmental and economical viable decisions.

The dissertation would also play key role for government and private sectors in investment decision making for establishment of small, medium and micro enterprise (SMME) for rural and urban organic food waste management and would also guide in selecting suitable waste disposal system.

CHAPTER SIX

Conclusion and Recommendation

6.0 Environmental Impact of Each System

LCI results obtained from each scenario in Fig. 16 are presented in Table 7, and the environmental impact characterizing the results of Table 7 are shown in Table 8.

In the global warming category, feed manufacturing showed the least impact (amount of kg of CO₂ eq. per treatment of 1.0ton of food waste). This is the result of the selected facility being based on the dry-type process which does not involve any operation related with release of toxic gasses (global warming).

However, incineration produced a large burden on global warming (higher than that of feed manufacturing). This seems reasonable because combustion itself is a sort of conversion of organic carbon to CO₂.

i) Conservation of Waste Material through Recycling.

When organic food waste products are recycled, less virgin material is used for production of commercial feed. The virgin material could be used for human consumption, rather than being used for other purposes, e.g. for fuel production (bio-diesel), which has led to global food crisis.

The results presented here should therefore not be taken as an argument for a “waste maximization” policy but as guide in decision making process. The order of preference for the treatment options is that recycling of food waste is more economical and environmental friendly than incineration.

ii) Global Warming

Results for environmental impact of each system affecting global warming are shown in table 9 and fig.18 as well as fig. 19 respectively, for the base scenario. In this case, the order of preference is that recycling is better than incineration.

The emissions contributing to global warming from incineration are in no way comparable to that from feed production. This is because all the fossil carbon is released during incineration, in the hypothetical infinite time perspective used here for food waste treatment methods; there is no direct residue that needs to be disposed of.

The Swedish Association of Waste Management showed that, in 1992, 4.4TWh energy was generated by incineration and used mainly for heating, while the available amount of energy, in the burnt OW, was about 12TWh. Thus, the energy transformed for use was only about one-third of the energy which was bio-chemically bound in the OW. The negative impact of incineration on the environment was not evaluated (Gajdos, 1998).

Also in Table 9, the emissions of greenhouse gases are expressed as CO₂-equivalents. The potential saving that can be made in terms of CO₂ emission when going from incineration to recycling is in thousand tons CO₂-equivalents (see section 5.1.2.1).

If the issue of monetary value of CO₂ emission tax is compare for both methodss, as regards environmental tax as explained above, and these taxes and fees is represented in the value of the damages done to the environment, the results can be seen as a minimum for feed production unlike that for incineration.

6.1 Policy Implications and Recommendations

6.1.1 Policy Implementation

The policy implementation of the proposition presented here depends on the intent of the policy maker. The intent here as a starting point is that the desire of the policy makers should be based on eliminate the combustion of the vital resources in form of organic food waste and reduce the total emissions of gases contributing to global warming (normally the aim of a policy is a mixture of different environmental, social and economic aspects).

This policy framework promoting recycling of organic food waste materials could be extended and advocated to replacing virgin agricultural produce for feed manufacturing could consequently reduce cost and emissions of greenhouse gases.

In the system elaborated here, the energy used in heat for incineration of organic wastes could be put back into animal feed production. The organic food waste byproducts can replace conventional animal feed or as a substitute. A policy promoting OWC may be successful for OFW materials regarding cost saving and emissions of greenhouse gases.

The application of this methodology could also be extended to the following areas such as Industrial Canteen and restaurants, Temples, Clubs & Resorts, Hotels, Hospitals, Food Processing Industries, Slaughter Houses, Markets, Large Housing Complex, Institutional Campus, etc. It may, in fact, serve as a model for similar organic wastes from other related establishments which operate in similar fashion as chevron in the Niger Delta area of Nigeria such as NNPC, ExxonMobil, Elf, Shell, Agip oil, Adax, etc.

6.1.2 Recommendations

Some of the recommendations suggested amongst others are:

- ii) That all organic food waste generated should be diverted from incineration and landfill to feed manufacturing using OWC system.
- ii) To create awareness and training of the utilization and processing of organic waste
- iii) That independent environmental measuring device is placed at strategic locations to monitor the incineration effluents created by the incinerator in order to develop adequate data relating to impact level of this process on the environment and on humans.
- iv) That legislation should be put in place to prevent the incineration of non hazardous organic food waste in all industries.
- v) That industries be set up to process the huge organic food wastes generated from all the onshore and offshore processing and production platform throughout the Niger Delta areas of Nigeria.

The disposal losses due to incineration could be economically significant as a result of the large volume losses in organic food waste yield, leading to waste processing and disposal costs, potential environmental pollution, and subsequent legal penalties. Solutions to environmental problems caused by overuse of natural resources, requires that we drastically reduce (and prevent) generation of waste, and find effective ways to recycle what is left (Ballard, 1995).

Doing so is fundamental to sustainable development. In addition it would assist with conserving natural resources, and reducing the dependence on decreasing landfill capacity. Reductions in the emission of toxins resulting from incineration, energy consumption, pollution and carbon dioxide emission to the atmosphere could also be positive consequences (Bhargava, & Tettelbach, 1997).

The primary benefits to the end users will be the conversion of waste to wealth; that is, utilizing the economic value of organic waste in feed product and its applications, **where both the energy and nutrients are exploited**. Rather than in conversions of organic waste to industrial fuel, fertilizers, manures, biogas, etc, which typically utilizes only one of these categories at a time (stored energy). Reduction in waste disposal costs and compliance with increasing environmental restrictions imposed on waste and wastewater disposal including air pollution reduction mandates.

The 2,340 bags of feed production per annum, at a cost of over US\$ 23,400 could be used in developing the host communities and moving the source of livelihood away from a petroleum dependent mono-economy, where people are living in abject poverty, with less than US\$1.0 per day.

It would also help to restore job diversification, and create agricultural economy such that waste products could be put to useful economic agricultural products directly or indirectly in several ways such as feeds for *pig farm, aqua culture, poultry, and compost manure from animal waste for rice and vegetable farm, & other cash crops, etc.*

These could provide infrastructure which could address increasing concerns over domestic security, kidnapping of expatriate (hostage taking), communal conflicts, ethnic rivalry and youth restiveness. Presently, there is an outright shortage of food globally; this dearth in food has been linked to several factors amongst climate change, global warming, lack of recycling, overuse of resources, etc.

6.2 Conclusion.

The primary aim of this dissertation was to assess the current waste management practises in Chevron-Escravos and which were found to be basically incineration and landfill system **(see section 3)**.

The prime concern of this system is its impact on community health and the environment in general. Economic losses are also important. These issues can be addressed through the development of suitable alternative organic waste disposal techniques that has little or no consequences to the environment and also cost effective **(see section 4)**.

This proposed alternative technique was compared economically, socio-politically and environmentally with the current disposal method in order to provide a guide for management decision making process **(see section 5)**.

Some of the benefits of this dissertation is that a resource once treated as waste is used to achieve sustainable development and brought economic benefits through conversion to various productions of animal feed **(see section 4.4 and 6.2)**.

Consequently, the expected outcomes and deliverables of the system is the utilization and development of by-products from these wastes which could be used to diversify the mono-economy of the host community from oil and gas dependent to agricultural base and allied commerce and trade **(see section 4.3 and 4.4)**.

The resultant of this would be capacity building and creation of jobs which would in the long run improve community-company relationship in reduction of politically motivated youth restiveness; kidnapping, etc. **(see section 6.2)**.

The results have demonstrated that the combination of material recovery at the source with the utilization of the organic fraction is the optimum solution for small local communities. The decision-makers would find this solution satisfying both in environmental and economic criteria. However, this model should not be used as an ultimate decision-making instrument but could serve mostly as an aid or/as a complementary tool to other modelling tools.

LCAs can be used to test the waste hierarchy and identify situations where the hierarchy is not valid. The results suggest, however, that the waste hierarchy is valid as a rule of thumb. Finally, these analyses showed that all OFW (residues, by-products) can be treated biologically and mechanically to produce economic returns, which can pay for the treatment, plant maintenance and conserve animal nutrients and energy, and help to control pollution.

The flexibility of the OWC units increases the ability to use OFW as a renewable raw material. By choosing this suitable technology, the process will not only be more environmentally friendly than current waste management practices in use, such as incineration or landfilling, but also consumer friendly and more profitable.

The proposed alternative integrated waste management system in Chevron-Escravos (Island) is a representative example of proper use of a simplified model with the easiest developed technology for economic and environmental management systems.

It is eminent that recycling of organic food waste materials is in general favorable according to this dissertation regarding overall energy usage, emissions of gases contributing to global warming and the total economic weighted outcome. However, recycling may still be favorable with respect to toxicological impact and these results still show benefits for recycling with regard to total weighted results.

The fundamental deliverable for organic food waste conversion systems is energy-efficient production of hygienically safe products (animal feed) of high and reproducible quality, without infectious pathogens.

In summary, the production of animal feed provides one of the most logical routes for utilizing (disposal) a substantial portion of the enormous potential material represented by organic food waste residues. Therefore suggestions and recommendations for setting up and operating a recovery or recycling pilot plant to extract the organic values from residual organic waste as final disposal technique could be achieved.

The aims and objectives of this dissertation have been achieved given consideration to waste utilization and total life cycle of the product and by-products. Summation of this is that treating a certain material as waste is the lack of adequate technology for upgrading and converting it. One of the practical consequences of this situation is the impossibility of developing a universal solution, applicable to all types of wastes. The dissertation has been able to develop adequate technology that could be used to achieve organic food waste utilization as an alternative waste disposal method.

6.3 Limitations and Need for Further studies.

It is important to note that not all relevant environmental impact is included in this dissertation. This is of relevance, for example, the toxicological impact categories are plagued with data gaps.

For example, when discussing additives in feed production and pollution in incineration and the whole range of different possible micro-pollutants that may occur in mixed wastes. These data gap indicates that conclusions on an overall level should be drawn with caution.

This is one reason why the focus here is on total energy and nutritive values of waste, emissions of greenhouse gases, in terms of economics and environmental trade-offs.

It should, however, be noted that many of the results presented here are fairly robust in the sense that they do not change much with changing assumptions in different scenarios.

It is also interesting to note that many of these results are similar to the results obtained in previous studies. For example Finnveden and Ekvall, reviewed several studies on recycling versus incineration of paper packaging materials and noted that the use of total

Chapter 6: Results and Discussion

energy and emissions of gases contributing to global warming were lower in the cases where bio-fuel was the competing energy source, thus similar results to that is used in this dissertation.

Better data on actual behavior would be of interest in order to reduce the dependence on assumptions. Since the interesting questions relate to future situations, data relevant for change-orientated strategic studies are needed, but to a large extent lacking.

Glossary:

Anaerobic Digestion (AD) – A waste treatment process where biodegradable material is supported to break down in the absence of oxygen, it produces methane and soil improver.

Best Practicable Environmental Option (BPEO) – a process carried out by the Planning Authority to determine the option that provides the most benefits or least damage to the environment as a whole, at acceptable cost, over the longer term as well as the short term for waste management.

Best Value – The Local Government Act 1999 places a duty on Local Authorities to deliver services by the most effective, economic and efficient means available.

Best Value Performance Indicators – a number of key indicators used to monitor Local Authority performance.

Biodegradable Waste - waste that will decompose over time through the action of bacteria, fungi or algae, with or without oxygen.

Bulky Waste – generally any household item which does not fit, or cannot be fitted, into a typical domestic dustbin.

Centralized Composting – large-scale composting site which handles garden waste from Household Waste Sites and green waste household collection schemes. Shredded waste is placed in elongated heaps, called windrows, normally outdoors. The windrows are turned mechanically to periodically aerate the composting waste. The process takes at least twelve weeks, at the end of which the compost represents about half the weight of the input material.

Clinical Waste – also known as healthcare waste, it is waste arising from medical, nursing, dental, veterinary, pharmaceutical or similar practices, which may present risks of infection.

Glossary

Commercial Waste – waste arising from premises which are used wholly or mainly for trade or business, sport, recreation or entertainment. The full definition can be found in the Controlled Waste Regulations 1992.

Compostable – materials which are suitable for composting e.g. garden waste, vegetable peelings and tea bags.

Composting – an aerobic (in the presence of air) biological process in which organic wastes, such as garden and kitchen waste, are converted into a material which can be applied to land to improve soil structure and enrich the nutrient content.

Curtilage collection – a collection of recyclables or household waste from the boundary of a property.

DEFRA – Department for the Environment, Food and Rural Affairs.

Energy from Waste – the combustion of waste under controlled conditions in which the heat released is recovered to provide hot water and steam (usually) for electricity generation.

Environment Agency (EA) – established in April 1996, combining the functions of the former local waste regulation authorities intended to promote a more integrated approach to waste management and consistency in waste regulation. The Agency also conducts national surveys of waste arising and waste facilities.

FEPA – federal environmental protection agency

Gasification – a process where waste is heated by a low-oxygen atmosphere to generate a low heat content gas for burning in an engine or turbine.

Home Composting – compost can be made at home using a traditional compost heap, a purpose designed container or a wormery.

Household Waste – this includes waste from household collection rounds, waste from services such as street sweepings, bulky waste collection, litter collection, hazardous

Glossary

household waste collection and separate garden waste collection, waste from Household Waste Sites and wastes separately collected for recycling or composting through bring or drop-off schemes and kerbside schemes.

Household Waste Sites – sometimes described as Civic Amenity Sites, these are places provided by the Unitary and County Councils where the public can dispose of their own household waste, free of charge. The waste they receive generally consists of bulky items such as beds, cookers and garden waste as well as materials intended for recycling.

Incineration – more properly known as mass burn incineration, is the controlled burning of waste, either to reduce its volume or its toxicity. Energy recovery from incineration can be made by utilizing the calorific value of paper, plastic, etcetera to produce heat or power. Current flue-gas emission standards are very high. Ash residues still tend to be disposed of to landfill.

Integrated Waste Management – involves a number of key elements, including: Recognizing each step in the waste management process as part of a whole; involving all key players in the decision making process, and utilizing a mixture of waste management options within the locally determined sustainable waste management system.

Kerbside Collection – any regular collection of recyclables from households where materials are placed at kerbside for collection.

Landfill with Energy Recovery – a landfill site which harnesses the methane generated within the site and turns this into electricity through generators.

Landfill Sites – are areas of land in which waste is deposited. Landfill sites are often located in disused quarries or mines. In areas where there are limited or no ready-made voids, the practice of land-raising is sometimes carried out, where waste is deposited above ground and the landscape is contoured.

Landfill Tax – introduced in October 1996, this tax is levied on landfill operators with the explicit environmental objective of reducing the reliance on landfill as a means of disposal.

Municipal Waste – is household waste and any other wastes collected or managed by either a Waste Disposal Authority or a Waste Collection Authority in carrying out their duties. It is mainly comprised of “dustbin” waste and waste received at the Household Waste Sites, but also includes street cleansing waste, waste resulting from the clearance of fly-tipped material and any commercial and industrial waste for which the Waste Collection Authority takes responsibility.

Proximity Principle – the proximity principle (as applied to wastes) is that wastes should be treated or disposed off as near to their place of origin as possible so as to minimise the distance that they are moved.

Pyrolysis – a process where waste is heated to high temperature in the absence of oxygen to produce a secondary fuel product.

Recovery – getting value from waste that remains after recycling, composting etcetera by converting it into energy or using it in product manufacturing.

Recyclables/Recyclate – materials that can be recycled.

Recycling – involves the reprocessing of wastes, either into the same product or a different one.

Residual Waste – the elements of the waste stream that remain after recyclable or compostable materials have been separated or removed.

Sustainable Development – development which is sustainable is that which can meet the needs of the present without compromising the ability of future generations to meet their own needs.

Transfer Loading Station – a facility to which waste is delivered before being compacted and transported onward for treatment or disposal.

Unitary Authority – a Local Authority which, amongst other things, has the responsibility of being both a Waste Collection Authority and a Waste Disposal Authority.

Unitary Development Plan: prepared by a Unitary Authority to guide the determination of planning applications for all development, including waste management facilities.

Waste – is the wide ranging term encompassing most unwanted materials and is defined by the Environmental Protection Act 1990. Waste includes any scrap material, effluent or unwanted surplus substances or articles that require to be disposed of because the material is broken, worn out, contaminated or otherwise spoiled. Explosives and radioactive wastes are excluded.

Waste Arising – the amount of waste generated in a given locality over a period of time.

Waste Development Framework – a statutory framework document for the country that facilitates the provision of sites for waste management facilities that will be required to meet various municipal needs.

Waste Disposal Authority (WDA) – government statutory establishment monitoring system, the WDA Amongst other functions, it is legally responsible for the safe disposal of household waste collected by the WCAs, and the provision of Household Waste Sites.

Waste Hierarchy – a framework for managing waste giving an order of preference for the treatment methods to be used.

Waste Minimization – reduction of the quantity of waste arising and requiring processing or disposal.

Waste Reduction – “waste reduction” is action to prevent wastes being produced. Reducing or minimizing waste, saves not only on collection and disposal costs, but also on the cost of raw materials and their use together with production costs.

Waste Retention – dealing with waste at home, i.e. home composting.

Waste Reuse – reusing material or items such as old furniture, clothes, food, etc. by either selling or donating them to others through special collection services, charity shops, car boot sales etc.

Glossary

Waste Stream – wastes generated from different sources.

Annexure

Annexure A

FACILITY NAME: _____

	Date	Waste Type	Quantity (kg,m³,drums, tanks etc)	Name of Vessel	Disposal Method	Disposal Location	Initials
1							
2							
3							
4							
5							
6							
7							
8							
9							
10							
11							
12							
13							
14							
15							

Name of Supervisor _____

Signature _____ **Date** _____

Annexure B

CNL WASTE MANAGEMENT PRACTICES

<i>Waste Manifest Form</i>					
Waste Generating Facility:					
Carrier (Vessel, Barge, or Truck):					
Destination:					
Date:					
Item	Waste Description	MSDS		Waste Volume or Weight	For S & E Use only. Check the appropriate Handling/Disposal Method Used
		Yes	No		
		<input type="checkbox"/>	<input type="checkbox"/>		Recycle
		<input type="checkbox"/>	<input type="checkbox"/>		Reuse
		<input type="checkbox"/>	<input type="checkbox"/>		Neutralize
		<input type="checkbox"/>	<input type="checkbox"/>		Process through sewage system
		<input type="checkbox"/>	<input type="checkbox"/>		Send to waste disposal site <input type="checkbox"/>
		<input type="checkbox"/>	<input type="checkbox"/>		Recycle to scrap
		<input type="checkbox"/>	<input type="checkbox"/>		Return to vendor
This is to certify that the above named materials are properly packed for transport to the disposal site:			This is to certify that the above materials are received at the specified disposal site:		
Facility Supervisor:			Lead Environmental Engineer:		
Signature: _____			Signature: _____		
Waste Disposed by:			Date:		
Signature: _____			Date: _____		

Copy S & E, Originating Facility, Boat Captain/Driver

References:

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