ESTIMATION OF ENERGY CONTENT OF MUNICIPAL SOLID WASTE.

BY

AKAEME BENJAMIN NNAMDI
MAT NO: ENG1506635

BEING A RESEARCH PROJECT PRESENTED TO THE DEPARTMENT OF CIVIL ENGINEERING IN PARTIAL FULFILLMENT OF THE REQUIREMENT FOR THE AWARD OF BACHELOR OF ENGINEERING (B.Eng.) IN CIVIL ENGINEERING

FACULTY OF ENGINEERING
UNIVERSITY OF BENIN, BENIN CITY
EDO STATE.

JANUARY, 2021

CERTIFICATION

This project with the title Estimation Energy Content of Municipal Solid Waste, submitted by Akaeme Benjamin Nnamdi with Matric Number: ENG1506635 have satisfied the regulations governing the award of Bachelor's Degree in Civil Engineering in University of Benin, Benin City, Nigeria**.**

PROJECT SUPERVISOR

NAME:……………………………………………………………………………………..

SIGNATURE AND DATE:………………………………………………………………

HEAD OF DEPARTMENT:

NAME:……………………………………………………………………………………………..

SIGNATURE AND DATE:…………………………………………………………………..

DEDICATION

I dedicate this project to God Almighty for His continues Love and Mercies over my life all these years in school and for His continuous provisions thus far. Also, to my mum and eldest brother, who have been ever supportive and caring, and for their unending prayers for me, all through my years in the University.

To all my Family/friends who in one way or the other supported me through my journey through the University of Benin

ACKNOWLEDGMENT

I express my sincere thanks to Prof Ogeneale Orie Head of Department, Civil Engineering, Faculty of Engineering, University Of Benin. I pay my deep sense of gratitude to my Project Supervisors, Prof. Nat Aniekwu, Engr. Chukwuemeka Okolie and Dr. Idowu Ilaboya who encouraged me to the highest level and to provide me the opportunity to prepare for this project.

I am immensely obliged to my parents for their elevating inspiration and encouraging prayers during the completion of this project. Last, but not the least, friends and course mates are also an important inspiration for me. So, with due regards, I express my gratitude to them.

Table of Contents

LIST OF TABLES

List of figures

ACRONYMS

WTE	-	Waste to energy
MSW	-	Municipal Solid Waste
DDT	-	dichlorodiphenyltrichloroethane
NESREA	-	National Environmental Standard and Regulations Enforcement
PAH	-	polychlorinated hiphenyte
NESREA	-	National Environmental Standards and Regulations Enforcement Agency
PCB	-	polycyclic biphenyls
N-P-K	-	Nitrogen Phosphorus & Potassium
BF	-	Biogradable Fraction
RDF	-	Refuse Derived Fuel
SDG	-	Sustainable Development Goal
MSWI	-	Municipal Solid Waste Incinerator
HCL	-	Hydrochloride
HF	-	Hydrogen fluoride
SO_2	-	Sulphur dioxide
NEHA	-	National Environmental Health Association
UNEP	-	United Nations Environmental Program

ABSTRACT

Municipal solid waste has become more challenging to manage as the population and the use for land increases, the estimation of the energy value of waste is essential to the409kj management of the solid municipal waste and the production of wealth to the community. the aim is to estimate the amount of energy by the waste produced the designated study area can produce using Dulong's formula,

In the study, the energy valued waste was collected from the faculty of engineering of the University of Benin, Benin city, Edo state. Different waste components, such as food, plastic, papers, agricultural and wood waste were collected and there elemental components such as carbon, hydrogen, oxygen, sulphur, potassium and nitrogen were analysed to get the dry weight, wet weight, Percentage of mass base, moisture content, chemical compositions, molar mass, chemical formula and the energy content

The Estimating of energy content from municipal waste was performed successfully, all objectives were accomplished, the examination of the composition of municipal waste was performed and we discovered the percentage dry mass basis of each component, the percentage mass of each of the component of solids where determined, the overall moisture content was also determined from the sample collected and the energy value was calculated to be 897.409kj, the sustainability was checked and it was discovered that it could generate about 4.01% of energy needed for the University which is a great way of converting waste to wealth.

Chapter One

INTRODUCTION

1.1. Background of the study

The municipal solid waste rate is continuously increasing due to rapid urban population growth and technological developments. The collection and elimination of municipal solid waste (MSW) causes serious environmental problems, however, which makes its management one of the critical challenges facing the world (Nordi et al., 2017).

In the early part of the 20th century, most waste came from kitchen and consisted mainly of food scraps and local ashes. Only about fifteen percent of it is now composed of what most people think of as real garbage, which is likely to decompose and decay. Since World War (II) and at an accelerated rate convenience packaging has become the hallmark of rapid sanitary food preparation. Packaging has reduced the quantity of garbage and ashes as paper, metal, glass and plastics have become the new components.

The nature of urban waste understandably varies with country, city, suburb and season and can be determined precisely only by analysis in each particular case. It also varies with time as living patterns alter. However, the personal income has been found to have the most significant effect on waste generation. According to the World Bank data, per capita waste generation ranges between 0.4 and 0.6 kg/day for low income countries between 0.5 and 0.9kg/day for middle income countries and between 0.7 and 1.8 kg/day for industrialized countries. Based on a comprehensive study encompassing nationwide survey and analysis of the solid waste sector in Nigeria, the above waste is also applicable to be observed in Nigeria cities. It is also observed that high income household generated higher quantities of waste than the lower income group.

Waste management policy in Nigeria is hardly based on the waste treatment hierarchy of source reduction, recycling, treatment and ultimate disposal. Mostly, the last option for the management of waste (ultimate disposal) is what is commonly practiced by households in Nigeria. Both biodegradable and non-biodegradable fractions of the waste generated end up in the refuse dump sites since waste are hardly segregated. For the Nigerian economy to gain the benefits of alternative sources to energy there is need to invest in waste management using appropriate technology.

As part of sustainable waste management strategy, most western countries are reducing the amount of biodegradable waste that go to landfills. For example, the European Council Directive (1991/31/EU) on landfill of wastes mandates member states to reduce the amount of biodegradable municipal waste deposited at landfill to 35% over fifteen-year period starting since 1999. It is estimated that 50 - 60% of the municipal solid waste generated in Nigeria is organic, this has been attributed to our cultural heritage in foods and lack of preserving facilities. One of the challenges of landfilling biodegradable waste is the emission of greenhouse gases such as carbon dioxide and methane which contribute to global warming.

Energy generation is pivotal to economic, social and intellectual development of any nation. The drive towards meeting the global energy demand has created immense challenges with 90% of energy generated from fossil fuels having attendant risks to human health and the environment. (Cheng and Hu, 2010).

Municipal solid wastes, collected continuously from cities, have recently thought as one of the important renewable energy resources. Recovering energy from municipal solid waste is feasible by means of a number of energy generation processes such as combustion, pyrolysis and gasification. Design and operation of the mentioned energy systems based on municipal solid waste are highly related to heating value of the used municipal solid waste materials.

Thus, determining heating value of municipal solid waste is a key work to perform the efficient design and operation of the waste to energy conversion-based technologies.

Most developing countries have huge challenges in the use of white incinerator plants due to the large investments and operating costs, but more importantly is the absence of profound knowledge on waste generation and composition which form the bedrock in the choice and design of WtE (waste to energy) plant. According to World bank technical guideline for WtE plant, 1999, the major preconditions factors to WtE plant before the financial implication assessment are: i) A mature and well-functioning waste management facility operated for a number of years, ii) disposal of solid waste at a controlled and well operated landfill iii) The supply of combustible waste at a stable volume which at least 90% of daily capacity of the WtE facilities iv) The average lower calorific value must not fall below 6 MJ/kg.

Although, Nigeria is richly endowed with various energy resources: crude oil, natural gas, coal, biomass, solar, wind, hydro resources, yet her development has been negatively impacted by the gap of energy demand and supply to both formal and informal sectors of the country (Oyedepo, 2012). The nation currently generates about 3,920 MW with per capita power capacity of 28.57 W which is not enough to meet even the domestic consumption demand (Oyedepo, 2012, Ibikunle et al., 2019). Most tertiary institution's energy demands are higher than the normal municipal settlement with huge energy needed to carry-out continuous research.

An energy deficit in these institutions from the national grid is often supplemented through the independent generation of electricity by heavy generators which increase the environmental pollution and the use of fossil fuel. Sustainable means of alternative energy generation for tertiary institution could help reduce these negative environmental impacts. University communities as model mini cities with a known potential population, activities and lifestyle provide an opportunity for structural evaluation of the WtE associated conditions. Cultural differences, climate, and socioeconomic conditions are expected to have a limiting influence on waste composition variation within a campus.

Most university community's growth rate is strategically monitored by local and international standard for effective running (Alshuwaikhat and Abubakar, 2008). University community can therefore represent a model community suitable for the evaluation of WtE potential especially in developing countries having challenges with solid waste data and record keeping.

1.2. Statement of the problem

Solid waste management is given very low priority in the budget due to limited finances. As a result, very limited funds are provided to the solid waste management sector by the governments, and the levels of services required for protection of public health and the environment are not attained. The disposal service charges collected by the local government waste disposal agents are too little to make any significant impact on solid waste management. However, users' ability to pay for the services is also limited by their income and their willingness to pay for the services which are irregular and ineffective is not high either. The waste collected by the local government authorities waste disposal agents are transported to the approved dump sites which are former mining sites where laterite was mined for building and road construction in the metropolis. (Igbinomwanhia and Ohwovoriole, 2012)

In the University of Benin, The growing population, due to the increase of departments especially in the engineering faculty will see an increase in the level of waste deposits. The management of solid waste continues to be a major challenge in urban areas throughout the world particularly in the rapidly growing cities of the developing world (Foo, 1997).

In the past, environmental aesthetics and health safety were the major concerns in waste management. However, the society demands more than these today, solid waste management must also be sustainable. Sustainable solid waste management is defined as waste management which meets the needs of the present without compromising the ability of future generations to meet their own waste management needs (WCED, 1987).

Waste-to-energy practice in Nigeria is limited to traditional biomass (wood fuel and charcoal) to complement grid heating and cooking in the rural areas. In this study, the quantity of MSW generated per year and the MSW generated per capita per day in the University of Benin will be estimated

1.3. Aim and Objective of the study

The aim of the study is to examine and estimate the energy value of a typical Municipal waste generate in the faculty of engineering of the University of Benin. The specific objective of the study is to:

To examine the composition of municipal waste, generate in the Faculty of Engineering

I. To estimate the energy value of each waste composition recovered from the waste generated

II. Estimate the percentage by mass or each of this component of the solid waste collected from the Faculty.

III. Estimate the overall moisture content of this solid waste stream.

IV. Estimate the percentage by mass of the different elements present in the soild waste.

V. Estimate based in empirical equation the overall energy value of the solid waste stream.

VI. To check for sustainability of the energy value determined

1.3. Scope for the study

The study estimates the energy value of the present waste deposit the faculty of engineering in the university of Benin. Benin. To achieve this nylon (trash bags) were distributed around waste storage points with the faculty for seven days, at the end the waste collected were sorted in compositions and weighed, after it has been weighed it was dried and weighed again. This was to determine the wet weight and dried weight (the weigh was determined on a scale balance), the dried weighed waste was burned in an incinerator, were the energy value were determined, this practice was one daily. Material use to carry out this investigation include plastic bags for collecting waste, gloves for protecting the hand, plastic sheet for sorting/spreading waste, oven for drying waste, scale balance for weighing waste, nose mask from protection of the nose from inhaling offensive odour. the population generating the waste is estimate This give information on the amount of the waste collected, the facilities needed for the collection of waste, a data analysed recorded using Microsoft excel and other important software.

1.4. JUSTIFICATION OF THE STUDY

The study is relevant for the following reasons:

i. Solid waste management is one among many fundamental and essential services provided by municipal authorities in the country to keep urban centres clean, the cleanliness of the city Is helps improve the aesthetic view of the city.

ii. The reduction and control of diseases (cholera) and improvement of the public health of a city or geographical area inhabited by humans and animals can be achieved by proper Solid waste management.

iii. Solid waste management promotes recycling, this is very essential to our environment because it (recycling) helps convert waste into useful material which helps improves the ecology of the environment by making waste the raw material instead of the natural resources.

iv. Proper waste management can help in the production of energy, through waste to energy conversion, this energy can be converted to electricity which can be used in houses and factors.

v. Maximum utilization of lands can be achieved by proper management, when there is a proper collection and disposal of waste, lands can be saved from indiscriminate disposal of waste, this land can be used to for other social economical productive activities which will generate revenue and improve standard of living.

Chapter Two

2.1. Literature review

Waste is substance (solid or liquid) substances generated as a result of human activities, and, being no longer of value for the respective economic, physiological or technological process, are removed from it.

Solid Waste Management (SWM) is defined as the control, generation, storage, collection, transfer and transport, processing and disposal of solid waste consistent with best practices of public health, economic and financial, administrative, legal and environmental considerations (Othman, 2002). Solid waste in a broader sense is understood as any household, industrial and agricultural materials that have been used up. Since such waste accumulates in the territories managed by municipalities responsible for its removal and storage, it is termed 'municipal solid waste'. Sustainable solid waste management is regarded as the progressive and balanced achievement of sustained economic acceptability, improved social equity and environmental quality (Moldan, 1997).

Every unwanted or non-useful solid substance generated in any human population is referred to as solid waste (Kaseva & Mbuligwe, 2003). Over time, consumption practices and activities of economic nature have resulted in generation of MSW (Cointreau, 2006, p. 9) which is basically waste that is generated from different sectors of a society such as households, educational, health and commercial institutions, public places, etc., and which is taken care of either directly or indirectly by the municipal or local authorities (Williams, 2005, p. 74). EEA (2009) defines

MSW as: "…waste from households and other waste which because of its nature or composition is similar to waste from households (cf. the Land Directive). Some of this waste is biodegradable, e.g. Paper and cardboard, food waste and garden waste. Biodegradable waste means any waste that is capable of undergoing anaerobic or aerobic decomposition, such as food and garden waste, and paper and paperboard (cf. Landfill directive)" (EAA, 2009, p. 14).

The components of such waste, often an assorted mix, are seldom the same for different areas due to factors ranging from standard of living and habits of residents to resources and climatic conditions found in each geographical location. MSW is often generated in urban areas and has contents that are organic and inorganic nature; the former being often found more in developing countries than the latter. The reverse is mostly the case in the developed part of the world and this is regarded as a significantly distinctive feature from the waste generated in their developing counterpart (Oteng- Ababio, 2011; United Nations Programme, 2005).

2.2. CLASSIFICATION OF SOLID WASTE

Generally solid waste can be classified into three categories; they are municipal solid waste, industrial solid waste and hazardous solid waste (Oladipo 2012)

Municipal Solid Waste (MSW)

- Municipal solid wastes (MSW): defined as trash, are highly nonhomogeneous mixture of residential, commercial, and industrial sectors. Typical residential and commercial MSW include clothing, disposable tableware, yard trimmings, cans, office disposable tables, paper, and boxes, whereas institutional and industrial MSW contain restaurant trash, paper, classroom wastes, wood pallets, plastics, corrugated box, and office papers. Although the composition of MSW could be highly variable, it is generally accepted that organic materials are the largest component of MSW.
- Industrial waste: industrial wastes are the wastes produce by industrial activity which includes any materials that is rendered useless during a manufacturing process such as that of factories, mills and mining, operations. It is also a solid, semi solid, liquid or gaseous unwanted or residual materials (not including hazardous or waste biodegradable waste), from an industrial operation. Nigerians increasingly have access to packaged goods, often using plastics, which makes waste disposal difficult. The development and widespread use of new packaging substances such as plastics have improved the standards of living for millions, but they have also introduced new threats to the environment, as typified by the histories of dichlorodiphenyltrichloroethane (DDT) and polychlorinated hiphenyte (PC) Thus, industrial development also beings is its wake problem a of environmental pollution that often need abatement. ln Nigeria, the four most industrialized States are Lagos (home to approximately 60% of the Nigerian industries), Rivers, Kaduna and Kano. Collectively. these States share approximately 80% of the Nigerian industry. Clean-up of industrial waste is more cost than prevention. The lowest level in the hierarchy (avoidance, utilization, minimization, recycle, reuse etc) and the one that all other levels strive to eliminate is remediation of the impacts of waste discharged to the environment. The key industries in Nigeria are cement and asbestos, fertilizer and

agro-chemicals, metallurgy and mining. tanneries, textiles and petroleum and Petro chemicals. At present, the petroleum industry contributes over 85% annually to Nigeria's foreign exchange revenues Environmental pollution from these industries is regulated by National Environmental Standards and Regulations Enforcement Agency (NESREA) and various state and other regulatory agencies. Among these agencies, the relationships are overlapping and not harmonized for regulatory environmental enforcement (Oladipa, 2012)

- Hazardous waste: Hazardous Waste Generation and Characterization The 1991 FEPA Guidelines defines hazardous waste as by-products of society that can pose a substantial hazard to human health or the environment when imposed managed, possesses at least one of the four (4) characteristics: ignitability, corrosivity, reactivity, or toxicity, or appears on FEPA lists [10] According to FEPA Act hazardous waste can be determined by ignitability; corrosivity: reactivity; halogenated hydrocarbons concentration, polycyclic aromatic hydrocarbon (PAH) concentration, polychlorinated Dibenzo p-dioxins and dibenzofurans concentrations, and polychlorinated Biphenyls (PCB's).

According to Chaz (2002), four pounds of trash a day are generated by each man, woman and child in cities of developing countries in Africa. These wastes include substantial amounts of paper and cardboard (40%) as well as yard waste (18 %), metals (9%), plastics (8%), and other products. Where does it all go? More than 70% of this material is buried directly in landfills. He further classified solid wastes into steel cans, yard wastes, high density polyethylene, newspapers and aluminium packaging He concluded that for solid waste effective collection, disposal, recycle, reuse and renewal it has to be segregated into biodegradables and non-biodegradables, Biodegradable wastes are waste materials that are capable of being broken down by micro-organisms into simpler substances or basic element which include organic waste, Examples include; kitchen waste, vegetables, fruits, flowers, leaves from the garden and paper. Neo-biodegradable waste can be further segregated into recyclable wastes plastics, paper, glass, metal, etc. The above indicates the various dimensions of waste classification and the need for an agreed classification scheme However, whatever classification is put in place, the issue of management is critical.

2.3. Solid waste characteristics:

2.3.1. Physical characteristics

A team of researchers are of the view that the composition and the quantity of MSW generated form the basis on which the management system needs to be planned designed and operated (Sharholy et al. 2005)

Information and data on the physical characteristics of solid wastes are important for the selection and operation of equipment and for the analysis and design of disposal facilities. The following physical characteristics are to be studied in detail.

i. Density

Density of waste, i.e., its mass per unit volume (kg/m3), is a critical factor in the design of a solid waste management system, e.g., the design of sanitary landfills, storage, types of collection and transport vehicles, etc. To explain, an efficient operation of a landfill demands compaction of wastes to optimum density. Any normal compaction equipment can achieve reduction in volume of wastes by 75%, which increases an initial density of 100 kg/m3 to 400 kg/m3. In other words, a waste collection vehicle can haul four times the weight of waste in its compacted state than when it is uncompacted. Significant changes in density occur spontaneously as the waste moves from source to disposal, due to scavenging, handling, wetting and drying by the weather, vibration in the collection vehicle and decomposition

ii. Moisture content

Moisture content is defined as the ratio of the weight of water (wet weight - dry weight) to the total wet weight of the waste. Moisture increases the weight of solid wastes, and thereby, the cost of collection and transport. In addition, moisture content is a critical determinant in the economic feasibility of waste treatment by incineration, because wet waste consumes energy for evaporation of water and in raising the temperature of water vapour. In the main, wastes should be insulated from rainfall or other extraneous water. We can calculate the moisture percentage, using the formula given below

Moisture content(%)= $\frac{(wet\ weight - dry\ weight)}{dry\ weight} x100$

A typical range of moisture content is 20 to 40%, representing the extremes of wastes in an arid climate and in the wet season of a region of high precipitation. However, values greater than 40% are not uncommon. Climatic conditions apart, moisture content is generally higher in low income countries because of the higher proportion of food and yard waste.

iii. Size of Waste constituents

The size distribution of waste constituents in the waste stream is important because of its significance in the design of mechanical separators and shredder and waste treatment process. This varies widely and while designing a system, proper analysis of the waste characteristics should be carried out.

iv. Calorific Value

Calorific value is the amount of heat generated from combustion of a unit weight of a substance, expressed as kcal/kg. The calorific value is determined experimentally using Bomb calorimeter in which the heat generated at a constant temperature of 25OC from the combustion of a dry sample is measured.

The physical properties that are essential to analyse of wastes disposed at landfills are:

v. Field capacity

The field capacity of municipal solid waste is the total amount of moisture which can be retained in a waste sample subject to gravitational pull. It is a critical measure because water in excess of field capacity will form leachate, and leachate can be a major problem in landfills. Field capacity varies with the degree of applied pressure and the state of decomposition of the wastes.

vi. Permeability of compacted wastes

The hydraulic conductivity of compacted wastes is an important physical property because it governs the movement of liquids and gases in a landfill. Permeability depends on the other properties of the solid material include pore size distribution, surface area and porosity. Porosity represents the number of voids per unit total volume of material. The porosity of municipal solid waste varies typically from 0.40 to 0.67 depending on the compaction and composition of the waste.

vii. Compressibility

It is the degree of physical changes of the suspended solids or filter cake when subjected to pressure.

2.3.2. Chemical characteristics

Knowledge of the classification of chemical compounds and their characteristics is essential for the proper understanding of the behaviour of waste, as it moves through the waste management system. The products of decomposition and heating values are two examples of chemical characteristics. If solid wastes are to be used as fuel, or are used for any other purpose, we must know their chemical characteristics, including the following

Chemical: Chemical characteristics include pH, Nitrogen, Phosphorus and Potassium (N-P-K), total Carbon, C/N ratio, calorific value.

Bio-Chemical: Bio-Chemical characteristics include carbohydrates, proteins, natural fibre, and biodegradable factor.

Toxic: Toxicity characteristics include heavy metals, pesticides, insecticides etc.

i. Lipids

This class of compounds includes fats, oils and grease. Lipids have high calorific values, about 38000 kcal/kg, which makes waste with a high lipid content suitable for energy recovery processes. Since lipids in the solid state become liquid at temperatures slightly above ambient, they add to the liquid content during waste decomposition. They are biodegradable but because they have a low solubility in waste, the rate of biodegradation is relatively slow.

ii. Carbohydrates

Carbohydrates are found primarily in food and yard waste. They include sugars and polymers of sugars such as starch and cellulose and have the general formula (CH_2O) X. Carbohydrates are readily biodegraded to products such as carbon dioxide, water and methane. Decomposing carbohydrates are particularly attractive for flies and rats and for this reason should not be left exposed for periods longer than is necessary.

iii. Proteins

Proteins are compounds containing carbon, hydrogen, oxygen and nitrogen and consist of an organic acid with a substituted amine group (NH_2). They are found mainly in food and garden wastes and comprise 5-10% of the dry solids in solid waste. Proteins decompose to form amino acids but partial decomposition can result in the production of amines, which have intensely unpleasant odours.

iv. Natural fibres

This class includes the natural compounds, cellulose and lignin, both of which are resistant to biodegradation. They are found in paper and paper products and in food and yard waste. Cellulose is a larger polymer of glucose while lignin is composed of a group of monomers of which benzene is the primary member. Paper, cotton and wood products are 100%, 95% and

40% cellulose respectively. Since they are highly combustible, solid waste having a high proportion of paper and wood products, are suitable for incineration. The calorific values of oven dried paper products are in the range 12000 – 18000 kcal/kg and of wood about 20000 kcal/kg, which compare with 44200 kcal/kg for fuel oil.

2.3.3. Synthetic organic material (Plastics)

They are highly resistant to biodegradation and, therefore, are objectionable and of special concern in solid waste management. Hence the increasing attention being paid to the recycling of plastics to reduce the proportion of this waste component at disposal sites. Plastics have a high heating value, about 32,000 kJ/kg, which make them very suitable for incineration. But one should note that polyvinyl chloride (PVC), when burnt, produces dioxin and acid gas. The latter increases corrosion in the combustion system and is responsible for acid rain.

v. Non-combustibles:

This class includes glass, ceramics, metals, dust and ashes, and accounts for 12 – 25% of dry solids.

vi. Heating value

An evaluation of the potential of waste material for use as fuel for incineration requires a determination of its heating value, expressed as kilojoules per kilogram (kJ/kg). The heating value is determined experimentally using the Bomb calorimeter test, in which the heat generated, at a constant temperature of 25°C from the combustion of a dry sample is measured. Since the test temperature is below the boiling point of water (100°C), the combustion water remains in the liquid state. However, during combustion, the temperature of the combustion gases reaches above 100°C, and the resultant water is in the vapour form.

While evaluating incineration as a means of disposal or energy recovery, one has to consider the heating values of respective constituents.

vii. Ultimate analysis

This refers to an analysis of waste to determine the proportion of carbon, hydrogen, oxygen, nitrogen and sulphur, and it is done to perform mass balance calculation for a chemical or thermal process. Besides, it is necessary to determine ash fraction because of its potentially harmful environmental effects, brought about by the presence of toxic metals such as cadmium, chromium, mercury, nickel, lead, tin and zinc. One should note that other metals (e.g., iron, magnesium, etc.) may also be present but they are non-toxic.

The following table shows an ultimate analysis of a typical municipal solid waste

Table 2.1.

Element Range	(% dry weight)
Carbon	25-30
Hydrogen	2.5-6.0
Oxygen	15-30
Nitrogen	0.25-1.2
Sulphur	0.02-0.12
Ash	12-30

viii. Proximate analysis

This is important in evaluating the combustion properties of wastes or a waste or refuse derived fuel. The fractions of interest are:

moisture content, which adds weight to the waste without increasing its heating value, and the evaporation of water reduces the heat released from the fuel; ash, which adds weight without generating any heat during combustion; volatile matter, i.e., that portion of the waste that is converted to gases before and during combustion; fixed carbon, which represents the carbon remaining on the surface grates as charcoal. A waste or fuel with a high proportion of fixed carbon requires a longer retention time on the furnace grates to achieve complete combustion than a waste or fuel with a low proportion of fixed carbon.

The following table shows an proximate analysis of a typical municipal solid waste

Table 2.2

Components	Value (%)	
Range	Typical	
Moisture	15-40	20
Volatile matter	40-60	53
Fixed carbon	5-12	7
Glass, metal, ash	15-30	20

2.4. BIOLOGICAL PROPERTIES: It includes:

- Biodegradability of Organic Waste
- Odours

- Breeding of flies

i. BIODEGRADABILITY OF ORGANIC WASTE COMPONENTS

- Volatile solids (VS) content, determined by ignition at 550C, is often used as a measure of the biodegradability of the organic components.
- The use of VS in describing the biodegradability of the organic components is misleading, as some of the organic constituents are highly volatile but low in biodegradability (e.g., Newsprint and certain plant trimmings).
- Alternatively, the lignin content of a waste can be used to estimate the biodegradable fraction, using the following relationship: BF = 0.83 – 0.028 LC
- Wastes with high lignin contents are significantly less biodegradable.

2.5. Solid waste management: Solid Waste Management (SWM) is defined as the control, generation, storage, collection, transfer and transport, processing and disposal of solid waste consistent with best practices of public health, economic and financial, administrative, legal and environmental considerations (Othman, 2002).

Solid waste management has become one of a major concern in environmental lases (Mazzanti and Zobol, 2008). In its scope, solid waste management includes planning, administrative, financial, engineering, and legal functions. Solutions might include complex inter-disciplinary relations among fields such as public health, city and regional planning, political science, geography, sociology, economics, communication and conservation, demography, engineering, and material sciences.

solid waste management is an important facet of environmental hygiene and needs to be integrated with total environmental hygiene planning. Its storage, collection, planning and disposal can lead short-term risks. In the long term, there may be dangers ang particularly from the chemical pollution of water supplies. Management of solid waste reduces or eliminates adverse impacts on the environment and human health and supports economic development and improved quality of life. A number of processes are involved in effectively managing waste for a municipality. These include monitoring, collection, transport, processing, recycling and disposal (UNEP. 2000).

Human technological and economic advancement has made the types and kinds of Solid Waste very diverse and the problem of waste management more complex. Furthermore, poor institutional framework and low capacities as well as lack of resources; both human and capital has put waste management and sanitation conditions in many cities of the Developing World, particularly in Africa, in very deplorable state (N E H A, 2005).

Proper management of waste is important for building sustainable and liveable cities, but it remains a challenge for many developing countries and cities. A report found that effective waste management is relatively expensive, usually comprising 20%–50% of municipal budgets. Operating this essential municipal service requires integrated systems that are efficient, sustainable, and socially supported. A large portion of waste management practices deal with municipal solid waste (MSW) which is the bulk of the waste that is created by household, industrial, and commercial activity. Measures of waste management include measures for integrated techno-economic mechanisms of a circular economy, effective disposal facilities, export and import control and optimal sustainable design of products that are produced.

2.4.1. Methods of Solid Waste Management

There are different methods of solid waste management. The following are some of the recognized methods:

I. Sanitary Landfill

This is the most popular solid waste disposal method used today. Garbage is basically spread out in thin layers, compressed and covered with soil or plastic foam.

Modern landfills are designed in such a way that the bottom of the landfill is covered with an impervious liner, which is usually made of several layers of thick plastic and sand. This liner protects the groundwater from being contaminated because of leaching or percolation.

When the landfill is full, it is covered with layers of sand, clay, topsoil and gravel to prevent seepage of water.

Advantage: If landfills are managed efficiently, it is an ensured sanitary waste disposal method.

Constraint: It requires a reasonably large area.

i. Incineration

This method involves the burning of solid wastes at high temperatures until the wastes are turned into ashes. Incinerators are made in such a way that they do not give off extreme amounts of heat when burning solid wastes.

Incinerators that recycle heat energy through furnace and boiler are called waste-to-energy plants. These waste-to-energy systems are more expensive to set up and operate compared to plain incinerators because they require special equipment and controls, highly skilled technical personnel, and auxiliary fuel systems.

This method of solid waste management can be done by individuals, municipalities and even institutions. The good thing about this method is the fact that it reduces the volume of waste up to 20 or 30% of the original volume.

Advantage: The volume of combustible waste is reduced considerably by burning waste. In the case of off-site pits, it is an appropriate method to minimize scavenging.

Constraint: It can cause smoke or fire hazard and also emits gaseous pollutants.

iii. Recovery and Recycling

Recycling or recovery of resources is the process of taking useful but discarded items for the next use. Plastic bags, tins, glass and containers are often recycled automatically since, in many situations, they are likely to be scarce commodities.

Traditionally, these items are processed and cleaned before they are recycled. The process aims at reducing energy loss, consumption of new material and reduction of landfills. The most developed countries follow a strong tradition of recycling to lower volumes of waste.

Advantage: Recycling is environmentally friendly.

Constraint: It is expensive to set up, and in most emergencies, there is limited potential.

iv. Composting

Due to a lack of adequate space for landfills, biodegradable yard waste is allowed to decompose in a medium designed for the purpose. Only biodegradable waste materials are used in composting.

It is a biological process in which micro-organisms, specifically fungi and bacteria, convert degradable organic waste into substances like humus. This finished product, which looks like soil, is high in carbon and nitrogen. Good quality environmentally friendly manure is formed from the compost that is an excellent medium for growing plants and can be used for agricultural purposes.

Advantage: Composting is environmentally friendly as well as beneficial for crops.

Constraint: It requires intensive management and experienced personnel for large scale operation.

v. Pyrolysis

This is a method of solid waste management whereby solid wastes are chemically decomposed by heat without the presence of oxygen. It usually occurs under pressure and at temperatures of up to 430 degrees Celsius. The solid wastes are changed into gasses, solid residue of carbon and ash and small quantities of liquid.

Advantage: This will keep the environment clean and reduce health and settlement problems.

Constraint: The systems that destroy chlorinated organic molecules by heat may create incomplete combustion products, including dioxins and furans. These compounds are highly toxic in the parts per trillion ranges. The residue it generates may be hazardous wastes, requiring proper treatment, storage, and disposal.

To summarize, proper solid waste management is an integral part of environmental conservation that should be observed by both individuals and companies globally.

2.5. Perceived Causes of the waste problem

Some of the many perceived causes of the intractable solid waste problem in some communities are:

I. Waste disposal habit of people

ii. Attitude to work

iii. Lack of adequate equipment, plant and tools necessary for waste disposal and collection

iv. Corruption

iv. Overlap of function of the state enforcement and waste management agency.

Population effect (adewole, 2009)

2.6. **Waste to Energy**: WtE refers to a family of technologies that treat waste to recover energy in the form of heat, electricity or alternative fuels such as biogas. The scope of the term 'Waste-to-Energy' is very wide, encompassing a range of technologies of different scales and complexity. These can include the production of cooking gas in household digesters from organic waste, collection of methane gas from landfills, thermal treatment of waste in utility size incineration plants, co-processing of Refuse

Derived Fuel (RDF) in cement plants or gasification. In many countries, municipal solid waste management (MSWM) has often been regarded as a public service with low priority: a nuisance and a burden. However, insufficient solid waste management (SWM) appears more and more on the political agenda due to increasing health and environmental problems and the discontent of a growing number of citizens with the decreasing quality of life due to rubbish in public spaces. The relevance of MSWM as a public service has often been neglected and its complexity is underestimated. The United Nations Sustainable Development Goals1 (SDG) as well as UN Habitat's New Urban Agenda2 call for improvements in waste management practices as a basic service to citizens. Waste managers and decision makers in developing and emerging countries have to respond to these new challenges, and in recent times waste-to-energy (WtE) has been increasingly viewed as a solution to the problems derived from rising waste quantities in expanding cities as well as rapidly growing energy demands. However, WtE can never solve the problem alone but rather needs to be embedded in an integrated solid waste management system that is tailored to the specific local conditions with regards to waste composition, collection and recycling, informal sector, environmental challenges, financing, resource prices, and other aspects.

2.6.1 Waste-to-Energy for Municipalities

MESSAGE: Dealing with the issue of waste-to-energy means reaching a new level of complexity in an already challenging waste management situation.

Growing concerns regarding shrinking natural resources, contribution of improper waste management to global warming and shortage of power generation have triggered discussions regarding waste as a resource in general and WtE concepts in particular. Decision makers at national and local level in developing and emerging countries may be tempted by technology providers who promise that WtE plants will solve their waste disposal problems, create a lucrative business opportunity and contribute positively to energy supply. As such, waste seems to be an ideal feedstock for energy recovery. So far however, only a limited number of projects built in developing and emerging countries have operated successfully in the long term.

Some positive experiences so far lie in state-of-the-art co-processing in cement kilns and landfill gas collection applied to sanitary landfills. However, to date, there are hardly any anaerobic digesters fed with segregated organic MSW in successful operation on a large scale in developing countries, nor are there more than a handful of waste incinerators in continued operation in developing countries in Africa or Asia. Alternative technologies such as pyrolysis and gasification never moved beyond pilot scale (even in industrialised countries) for mixed MSW fractions.

The framework conditions in most developing and emerging countries are essentially different to those that have seen the rise and successful application of WtE projects in Europe, North America, Japan and China, where utility size WtE plants are increasingly common. A simple technology transfer is often not successful as it does not meet the conditions of developing and emerging countries, especially in terms of financial requirements, input material composition and local capacities. Nevertheless, WtE technologies can improve waste management in fast-growing cities of developing and emerging countries but its application is complex and must consider, amongst others, the following specific circumstances:

- Lower calorific value in MSW than in industrialized countries due to the high moisture (high organic content) and mineral content in waste (e.g. ash, construction and demolition waste);

- Substantial seasonal change in waste composition (i.e. changing consumption pattern during festival seasons, seasonal crops);
- Limited practice of waste segregation at source, a precondition for anaerobic digestion;
- Weak business and operation models;
- Lack of knowledge on how to operate and maintain WtE plants;
- High investment and operating costs which cannot be recovered by existing waste fees and generated additional
- income from energy sales alone;
- Neglecting of livelihood issues for marginalized persons and informal sector workers dependent on the availability
- of recyclables in the waste;
- Lack of monitoring and weak enforcement of environmental standards, leading to public health issues.

2.6.2. Municipal Solid Waste Incineration

Municipal solid waste incineration (MSWI) is the burning of waste in a controlled process within a specific facility that has been built for this purpose. The primary goal of MSWI is to reduce MSW volume and mass and also make it chemically inert in a combustion process without the need of additional fuel (autothermic combustion). As a side effect it also enables recovery of energy, minerals and metals from the waste stream. There are always about 25% residues from incineration in the form of slag (bottom ash) and fly ash. Bottom ash is made up of fine particulates that fall to the bottom of the incinerator during combustion, whilst fly ash refers to fine particulates in exhaust gases which must be removed in flue gas treatment. These residues need further attention and, in the case of the hazardous fly ash, a secure place for final disposal.

2.6.3 TECHNOLOGY DESCRIPTION

The combustible materials in waste burn when they reach the necessary ignition temperature and come into contact with oxygen, undergoing an oxidation reaction. The reaction temperature is between 850 and 1450ºC, and the combustion process takes place in the gas and solid phase, simultaneously releasing heat energy. A minimum calorific value of the waste is required to enable a thermal chain reaction and self-supporting combustion (so-called autothermic combustion), i.e. there is no need for addition of other fuels. During incineration, exhaust gases are created which, after cleaning, exit to the atmosphere via a pipe or channel called a flue. These flue-gases contain the majority of the available fuel energy as heat, as well as dust and gaseous air pollutants which must be removed via a flue-gas purification process. Excess heat from combustion can be used to make steam for electricity generation, district heating/cooling or steam supply for nearby process industry. Plants that utilise cogeneration of thermal power (heating and cooling) together with electricity generation can reach optimum efficiencies of 80%, whereas electricity generation alone will only reach maximum efficiencies of about 20%.

2.6.4. OPERATIONAL ASPECTS

The operation of highly complex MSWI requires well developed technical and management skills. It is much more complex than the operation of a sanitary landfill. Requirements are: a continuous MSW supply chain, a homogenized waste mix fed continuously to the combustion chamber, process parameter and emission parameters adjusted and controlled, scheduled maintenance, the purchase of auxiliary materials and spare parts, guaranteed energy supply to direct customers, managed disposal or further use of process residues, etc. Operational health and safety must be well developed and frequent contact with environmental authorities, the municipality, local communities, civil society and other actors must be maintained. Siting of the MSWI where year-round use of thermal power (heating or cooling) or generated electricity can be ensured is an important factor, increasing the likelihood of reliable revenues. For this reason, MSWI should be sited in industry parks, with short distances to waste sources. Only managers, engineers and technicians with proven capabilities and experiences should be assigned to key functions. If the qualifications are not available locally, international experts need to be contracted long term and a capacity building program launched.

2.6.5. ENVIRONMENTAL ASPECTS

An objective of MSWI is to contribute to an overall reduction of the environmental impact that might otherwise arise from wild dumping, open burning or landfilling of the waste. The volume reduction of waste by incineration helps to save scarce and valuable space for landfill and protect the environment. A fraction of the energy recovered can also be considered to be carbon neutral, due to the biomass content in MSW. However, MSWI facilities also generate large amounts of flue gases which must be treated, even when incineration has taken place under optimum combustion conditions. To avoid irreversible health risks to local populations and the environment, compliance with international emissions standards is essential and continuous monitoring and reporting of emissions must be guaranteed. Pollutants in flue gases take the form of dust and gases such as hydrogen chloride (HCl), hydrogen fluoride (HF) and sulphur dioxide (SO_2). A number of compounds containing mercury, dioxins or nitrogen dioxide (NO_2) may only be removed using highly advanced chemical processes, which substantially increase project costs. The main environmental aspects to deal with are:

- Control and monitoring of process emissions to air and water (including odour);
- Quality and use potential of slag production (e.g. heavy metal contamination levels);

- Secure disposal or recycling of hazardous fly ash residues;
- Process noise and vibration;
- Water and other raw material (reagent) consumption;
- »» Fugitive emissions – mainly from waste storage;
- »» Storage/handling/processing risks of hazardous wastes.

2.6.6. ECONOMIC ASPECTS

MSWI requires a major capital investment and must be supported by long term financial planning and sufficient resources to secure continuous operation and maintenance of the plant. In developing countries initial investment funds may be available; however, financial resources for the operation phase are often not adequately considered. To compare and assess the full financial viability of operating a MSWI, initial investment costs and expected operational costs have to be annualised. For a net cost calculation, any annual revenues from energy and material sales can be subtracted from the annualised capital investment and operational costs to derive an overall cost per tonne of waste based on the annually treated waste

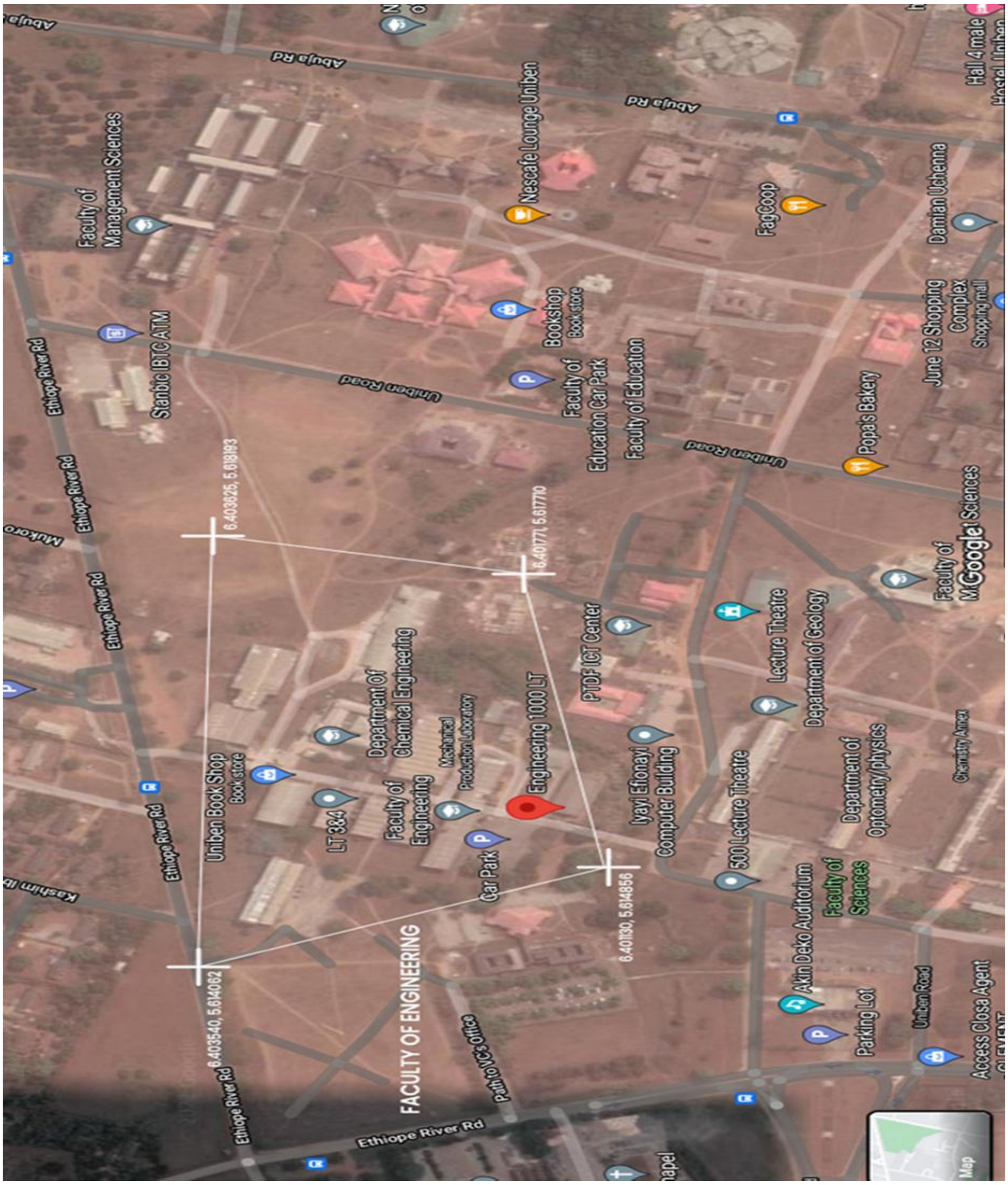
It should be understood that incineration solutions lead to increased costs for waste treatment compared to previously applied landfilling, which may make waste generators prefer to use the current disposal option. Whilst the cost estimates are relatively well established for industrialised countries, it is difficult to provide representative costing information for the developing country context.

Chapter Three

Methodology

3.1. Description of study Area

This study was carried out in the Faculty of engineering, University of Benin, Ugbowo campus, Benin City, Edo state, Nigeria. The faculty was founded in 1970 and it has an estimated population of about eight thousand people and it is located between latitude 6.4030061 N and longitude 5.615733E. the faculty is home to fourteen departments, with 18 buildings, with The major occupant includes the student (classes and laboratory), academic and non-academic staff (occupying the offices), stores (restaurants). University of Benin has a main environmental health department located in the health centre premises of the university of Benin, Ugbowo campus, Benin city, responsible for all aspects of solid waste management within the university of Benin.



3.2. Sampling method/ Sampling collection

The areas sampled were the classrooms (LT's) of 4 blocks, were the 500L student had their classes, the two 1000LT's where both the 100 and 200 levels receive their classes, the laboratory including the civil, mechanical, petroleum, electrical laboratory, the hall way, and other strategic points (class rooms and offices) in each departmental building, chemical, civil, electrical, petroleum buildings, the car pack, and finally the restaurant and store were items are being sold. A Reasonable number of plastic bags were shared to these sampled areas daily. Simple random sampling technique was adopted Waste generated in these areas were collected daily for seven successive days, the plastic bags collected in each sampling unit were opened onto the plastic sheet and separated into the different compositions and dried.

Equipment used includes

I. Plastic bags for each sampling units (for 7 days for the various sampling units)

II. Weighing scale (one scale to weigh the waste)

III. Pan (used as a container for weighing)

IV. Plastic sheet (to spread waste over it for sorting once collected and labelled from the sampling unit)

vi. Gloves (for handling of the waste)

vii. Nose Masks for (for protection against respiratory infections)

viii. Weighing balance

ix. oven

3.3 Preparation of solid water representative sample (Quarter Method)

After the daily were waste concentrated has been sampled, a random selection of waste using quadrat sampling method which was used to homogenise waste characteristics, the quadrat method in respect to waste sample is carried out by separating the waste into four equal square set after the waste has been homogenised. After that a set is taken and is separated again into four different square set A, B, C and D, then a portion, A, B, C or D, was taken and the method was repeated, this was repeated until a uniform distributed sizable amount of waste was gotten about 50kg.

3.4. Characteristics of solid waste\Weight material(sorting):

The 50kg waste gotten from the from then quarter method were sorted according to their characteristics using board characteristic Formats show below.

Table 3.1. Material classification format used for the composition analysis

Material Classification	Weight (g)
Paper Waste	
Plastic Waste	
Food waste	
Metal waste	
Agricultural waste	
Wood waste	
Total	

3.5 Pulverization of solid Waste Sample:

In this method, collected solid waste is powered by grinding machines, thereby changing the volume and physical characteristics. Once the sorting was concluded, the waste like paper and plastic were shredded while organic and agricultural waste were burned and their residue were recovered also the metals were pulverized so as to reduce the size and when the residual from the burnt waste and the pulverized metal were recovered, they were weighed and taken to the laboratory for AAS (Atomic Absorption Spectrometer) test which was carried out to determine the energy level and recorded.

3.6. Analysis of elemental composition:

The specific load of various element sorted were determined based on the element analysis of the waste component using the Atomic Absorption spectrometer.

Table 3.2.

Atomic Absorption Spectroscope (AAS) is a Spectro analytical	**Element**	**Unit**	**Paper waste**	**Plastic waste**	**Food waste**	**Metal waste**	**Agricultural waste**	**Wood waste**
1	**Hydrogen**							
2	**Carbon**							
3	**Oxygen**							
4	**Nitrogen**							
5	**Potassium**							
6	**Sulphur**							
7	**Ash**							

3.6 Atomic Absorption Spectrometer (AAS) Procedure:

Sample preparation and introduction involves rendering a liquid or solid into a state that the instrument can process for elemental analysis. In the case of flames AAS, this involves atomizing the sample, which involves the creation of a fine mist dispersion. Afterward, the mist is fed into a flame to breakup any remaining molecular bonds. In graphite furnace AAS, the liquid sample is introduced into the cuvette directly, where it is transformed into a fine mist.

The sample is then exposed to a source of radiation, which typically originates from the light source. This light source has been set to defined wavelength, and the metal atoms in the sample absorb their wavelength (or not). When absorption occurs, the result is a light spectrum that has reduced light intensity in one or more of its area. This reduces intensity is characteristics of a given element and helps to identify it, as well as to determine its concentration.

Afterwards, the analysis is excited by different light source and emits a mixture of wavelengths. Following dispersion of these wavelengths (including the characteristics wavelength of the analyte), the AAS instrument detector measures wavelength intensity. Because element concentration is a function of its wavelength intensity, the concentration of the target element can be determined. Also, by establishing samples can be analysed quantitatively.

3.6.1. Moisture content:

the 50kg waste sample gotten from the quarter method were weighed(wet weighed), they were spread on a nylon layer to dry under the sun for 24hrs after which it was placed in an oven at a temperature of 105°C for 2hrs to dry, it was then The heated or dried sample was then removed from the oven using metal tongs and placed into a desiccator for cooling and then weighed (dry weight). The weight and dry weights were then recorded. The percentage moisture content for each waste area was then obtained through the following formula below

Moisture content =$\left(\frac{wet\ weight - dry\ weight}{dry\ weight}\right)$ x100%

3.6.2. Nitrogen content:

Introduction:

The nitrogen content of the sample was determined by Kjeldahi digestion, and the resulting Ammonium ion was measured calorimetrically. Element such as Iron and Manganese, which may interfere in the alkaline medium during colorimetric determination, was first complexed with sodium Potassium Tartrate. The Ammonia was calorimetrically as the indophenol blue complex by reaction with alkaline Sodium Phenate and sodium Hypochlorite (Miroslav and Vladimir, 1999)

B: Mirco- Kjeldahl Digestion Apparatus

The recommended Micro-Kjeldahl Digestion apparatus used in the experiment include:

1. 30ml Kjeldahl
2. Micro Kjeldahl

C: Reagents

The Reagent used in this experiment include;

1. Concentrated Sulphuric acids
2. Kjeldgahl catalyst (one tablet of sodium containing 0.05g selenium), each tablet is 1g (Miroslav and Vladimir, 1999)

D: Procedure

1. 0.2g of finely ground soil was weighed into 30ml Kjeldahl digestion flask. After which one tablet of catalyst and conc. H_2SO4 was added. The resultant combination and/or mixture was well shaken to ensure complete mixing of the sample and catalyst mixture.

2. The 30ml Kjeldahl was placed on the heater and was allowed to digest for about 45 minutes.

3. On completion of the digestion, the mixture was cleared or removed from the heater, cooled until just warm to touch, and 10ml of distilled water was added. It is important that the mixture in the Kjeldahl flask does not solidify before the addition of water, as it is time consuming re-dissolving the solids.

4. The solution was decanted through a Whatman filter paper No. 42 into 100ml volumetric flask and was washed in the Kjeldahl flask with 2 or 3 small aliquots of distilled water and the entire washings was emptied into the volumetric flask via the filter paper and make up to volume. The total Nitrogen is determined in the filtrate as follows, (Miroslav and Vladimir, 1999)

i. 5ml of the filtrate from the digest was pippetted into a 25ml flask and 2.5ml of the Alkaline Phenol was added after which the resultant solution was well shaken

ii. 1ml of Sodium Potassium Tartrate was later added to the resulting solution above and shaken thoroughly to ensure homogeneity.

iii. 2.5ml of Sodium Hypochlorite or Bleach was added to the above mixture in 'ii' shaken thoroughly and allowed to develop colour, and then make to the mark.

iv. The reading was taken calorimetrically at 630mm.

E: Calculation:

Total Sample Nitrogen was estimated using the mathematical model below;

$$\%N = \frac{Instr. Reading\ Reciprocal\ of\ slope\ x\ Colour\ Vol.\ x\ Digest\ Vol.\ x10^{\circ}\ x100xCf}{Weight\ of\ Sample\ x\ Aliquot\ taken}$$

Where: CF correction factor

3.6.3. Potassium Content:

Introduction

Typically, Atomic Absorption (AA) or Inductivity Coupled Plasma-Optical Emission Spectrometry (ICP OES) is used to measure potassium ion, by first extracting the potassium ion from sample soils by 1 mol/L ammonium acetate (CH3COONH4). These are the methods performed in laboratories.

A simpler method for a rapid measurement of potassium ion in sample uses the LAQUAtwin potassium ion meter B-731. The extraction method is the same as the lab method. The following procedure explains how you can measure K+ with good correlation to analytical lab tests.

Method

1. Put 1g each of air-dried sample (four samples) in 100mL glass beakers, two beakers per soil sample.

2. Prepare two kinds of extraction per sample, one by adding 20 ml of 1 mol/L CH3COONH4 to one beaker, and 20ml of 0.01 mol/L CH3COONH4 to another beaker.

3. Shake the beakers around 1 hour to extract K+ from the sample using a bench top shaker.

4. Calibrate LAQUAtwin B-731 with 150mg/L and 2000mg/L K+ standard solutions included in the product.

5. Measure potassium ion concentration of the filtrated solution with calibrated B-731 and with. ICP-OES (e.g. HORIBA Jobin Yvon. Model ULTIMA2).

6. Perform this measurement with 4 different samples.

7. take the average of the sample test result

3.6.4. Carbon content:

Determination of Carbon

A. Apparatus

The apparatus used in this experiment to determine the Sample sample Carbon include

1. 250ml conical flask

2. 50ml Burette

3. 10ml Pipette.

b. The Reagents Required: Reagents used in this experiment to determine the sample Carbon include

1. N potassium dichromate

2. 0.4N Ferrous Ammonium

3. Cone. Sulphuric acid

4. Phosphoric acid

5. 1% Diphenylamine in conc. H_2SO4 (Miroslav and Vladimir, 1999)

c. Preparation of Sample

About 50g of air-dried fine Topsoil was passed through the 2mm sieve, and was immediately grinded to a fine consistency for carbon and nitrogen determinations. The ground sample was also passed to a 0.5mm sieve. Before grinding, the sample was checked for roots and organic debris.

(Miroslav and Vladimir, 1999)

Procedure:

Organic Carbon was determined as follows:

1. A sample of soil containing about 0.2g of carbon (0.1-0.5g) was emptied into a 250ml a burette and then of conical flask.

2. 10ml of N k_2Cr2O7, was added from an automatic pipette or Conc. H_2SO4. to 10ml

3. The above combination was shaken for 1 minute and the mixture was allowed to cool on an asbestos sheet.

4. 60ml of distilled water was added to the cool solution to make the volume up to 150ml. The mixture was further shaken to allow further cooling.

5. After adding 5ml of Phosphoric acid and 8-10 drops of 1% Diphenylamine solution the solution assumes a dark violet colour.

6. The above dark-coloured mixture was further titrated with 0.4N ferron Ammonium Sulphur solution until the colour changes to green which is an indication of the end point.

0.2g of Glucose was weighed in triplicate and treated as above (Miroslav and Vladimir,1999).

Calculation:

Soil Organic Carbon was estimated using the mathematical model below

(% Carbon = Titre x 0.24)

3.6.5. Sulphur Content Determination

I. Scope

This method is used to determine the total sulphur content (expressed as sulphur trioxide SO, of a sample)

II. **Apparatus**

(a)Splitters - as in AS 1141.2

(b) Sieve - 200 mm diameter, AS 150 µm.

(c) Muffle furnace with temperature gauge

(d) Gas burner capable of producing a temperature of 1000°C.

(e)Steam bath,

(g) Sand bath on hotplate Platinum crucible with lid - 50 mL capacity

(h)Balance with limit of performance not exceeding 0.5 g. Analytical balance with limit of performance: not exceeding ± 0.0005 g.

(j) Ovens thermostatically controlled and mechanical ventilated to operate at a temperature:

(1) not exceeding 80°C;

(ii) 105-110°C.

(k) Desiccator.

(1) Screw-top plastic jar of about 2 L capacity, plastic and glass beakers, glass wash bottle, stirring rod, rubber policeman, dishes and trays

(m) Filter funnel with flask.

(n) 500 mL beakers

(0) Filter papers - Whatman grades No. 42 and 540 (hardened)

Iii. Reagents

All reagents are to be of recognized analytical reagent quality.

(a) Barium Chloride 5% solution: dissolve 50 g of barium chloride ($BaCl,2H,O$) in 1 litre of distilled water.

(b) Silver Nitrate Solution: 1% in distilled water.

(c)Sodium Carbonate Solution: 1% in distilled water.

(d) Methyl Red Solution: 0.1% in ethanol.

(e) Hydrochloric Acid: dilute 1:11

iv. Sample Preparation

(a) Obtain a bulk sample of the material to be tested using the appropriate procedure detailed in AS 1141.3.1, 3.2, AS 1289.1.2.1 or RC 300.03

(b)As the test procedure requires a test sample that is finer that 150 µm, using procedures detailed in AS 1141.3.1 or Test Method RC 301.01, reduce the mass of the bulk sample as appropriate by crushing, splitting or quartering, and grinding or milling, to provide a representative sample of approximately 50 g which all passes the 150 um AS sleve.

Procedure

(a) Oven dry the well-mixed, representative sample at a temperature not exceeding 80°C (see Note I).

(b) Obtain a test sample of about 1 g and place in a platinum crucible of known mass. Determine and record the mass of the test sample to the nearest 0.1 mg. (c) Add about 8 g of sodium carbonate to the test sample and mix thoroughly. No unmixed rock or sample powder must remain in the crucible.

(d) Gently heat the crucible, with lid slightly a jar, over a flame until all moisture is driven off. Gradually raise the temperature until the contents fuse and melt. Swirl the contents of the crucible occasionally to bring the denser particles into the melt (see Note II).

(e) When fusion is complete, remove the crucible from the flame and swirl the contents until the melt solidifies as a thin layer. Once the red-heat has dissipated, dip the crucible to two-thirds of its depth in distilled water until cold.

(f) Reheat the crucible to about 300-400°C and again dip it into distilled water and allow to cool completely

(g) Transfer, without loss, the solidified melt fragments into a plastic beaker, all solid. material still adhering to the crucible being dislodged with hot water and by scrubbing with a rubber policeman, (h) Dilute to about 150 mL with hot distilled. water and place on steam bath until the solids are completely disintegrated and in suspension.

(i) Transfer the solution to a Whatman hardened No. 540 filter paper in the glass funnel and filter into a 400 mL glass beaker. Wash the precipitate well with hot 1% sodium carbonate solution. The solution plus the washings should make up about 250 mL.

(j) Add a few drops of methyl red and acidify the solution with 1:1 hydrochloric acid until the methyl red endpoint is reached. Then add 5mL of the acid in excess.

(k) Bring the solution to the boil and boil for 2 minutes to expel any carbon dioxide then. add, with stirring, 20 ml of the barium chloride solution. Boil for five Minutes.

(I) Place above steam bath for at least 2 h then allow the, solution to cool, preferably overnight (particularly if it is known that the sulphate content is low).

(m) Transfer, without any loss, the liquid and precipitate to a Whatman No. 42 filer paper in the glass funnel

(n) Wash the precipitate several times with cold water until the washings are essentially free from chloride, as indicated by only slight opalescence of the filtrate when a few drops are tested with 1% silver nitrate solution. Do not over wash.

(o)Transfer the filter paper and precipitate to a platinum crucible of known mass and chart and consume the paper slowly, without flaming, over the flame of a burner until it is apparent that all carbon has been consumed.

(P)Ignite the residue in a muffle furnace at approximately 900°C for 1 h.

(9) Cool in a desiccator for 10 min and weigh the barium sulphate residue (see Note III).

VI. Calculation

Calculate the sulphur (expressed as SO_2) present

in the test fraction as follows:

$$SO_2 = \frac{mass\ of\ ignited\ precipitate\ (g) x 0.343}{mass\ of\ test\ fruction\ (g)}$$

3.6.5. Energy content:

once the percentage mass of each element has been gotten, the energy content will be calculated using the following process.

i. Computation of Result in a tabular form, showing the wet weight, dry weight and mass percentage of each element

ii. Calculation of general moisture content using the formula:

$$\text{Moisture content: } (\frac{Total\ wet\ weight - total\ dry\ weight}{(dry\ weight)}) x 100$$

iii. Calculation of the moisture content of each component using the moisture content formula

iv. Computation of chemical composition using the formula: "Dry weight x percentage by mass dry basis" for each component and compute in a tabular form

v. Computation the summation of each element in a tabular form

vi. Conversion of Moisture content to H_20 and add the mass percentage from the hydrogen and oxygen to the computed summation of element respectively.

vii. Final computation of Mass of element and computation of percentage mass of elements

viii. Computation of the summation of element as mole by using the fomular : $Mole = \frac{mass}{molar\ mass}$

ix. Computation of the Chemical formula (with and without sulphur, nitrogen and potassium respectively also taking oxygen as then smallest element)

x. Estimating of the energy content of the was waste using modified Dulong's formula H (kj(kg))= $337C + 1428 \left(H - \frac{O}{8}\right) + 9s$.

Chapter Four
RESULTS AND DISCUSSION
4.1.0. RESULTS

4.1.1. Computation of Result in a tabular form, showing the wet weight, dry weight and mass percentage of each element

Table 4.1.

			Percent by Mass Dry Basis						
Components	**Wet weight**	**Wet weight**	**Carbon**	**Hydrogen**	**Oxygen**	**Nitrogen**	**Sulphur**	**Ash**	**Potassium**
Food Wastes	0.723	0.474	51.0	6.9	41.3	3.7	0.3	4.2	5.9
Paper	0.354	0.278	47.5	6.4	46.5	1.3	0.3	5.7	4.7
Agricultural Waste	0.322	0.186	48.3	7.2	47.2	1.2	0.4	4.9	5.2
Plastics	0.804	0.656	54.6	6.3	27.6	0.2	0.1	3.1	2.9
Textiles	0.042	0.028	52.1	5.9	33.5	3.9	0.3	5.6	3.4
Wood	1.1	0.782	48.7	5.5	44.6	0.4	0.2	2.7	4.4

4.1.2. Calculation of general moisture content using the formula:

Moisture content: $\frac{\textbf{Total wet weight − total dry weight}}{\textbf{dry weight}} \boldsymbol{x100}$

Moisture content: $\left(\frac{Total\ wet\ weight - total\ dry\ weight}{dry\ weight}\right)$ x 100

Total wet weight: 2.404kg

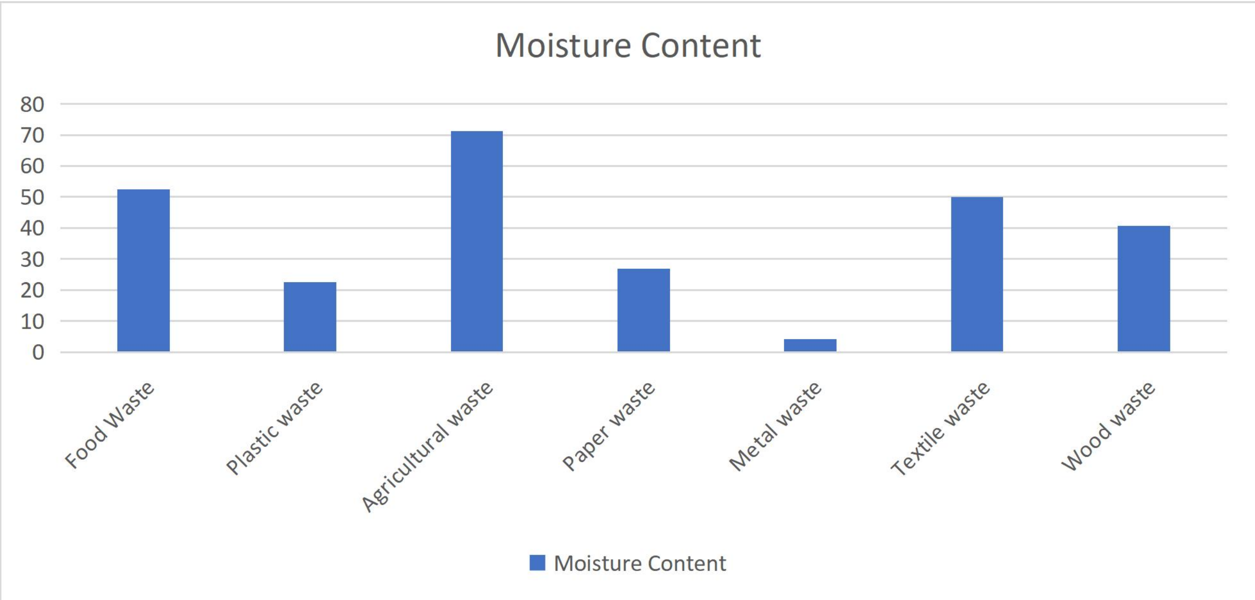
Total dry weight: 2.274kg

Moisture content: $\left(\frac{2.404-2.274}{2.274}\right)$x100 = 5.71%

4.1.3. Calculation of the moisture content of each component using the moisture content formula

Table 4.2

Components	Moisture content (%)
Food Waste	52.53
Paper waste	26.97
Agricultural waste	73.11
Plastic waste	22.56
Textile waste	50.00
Wood waste	40.67

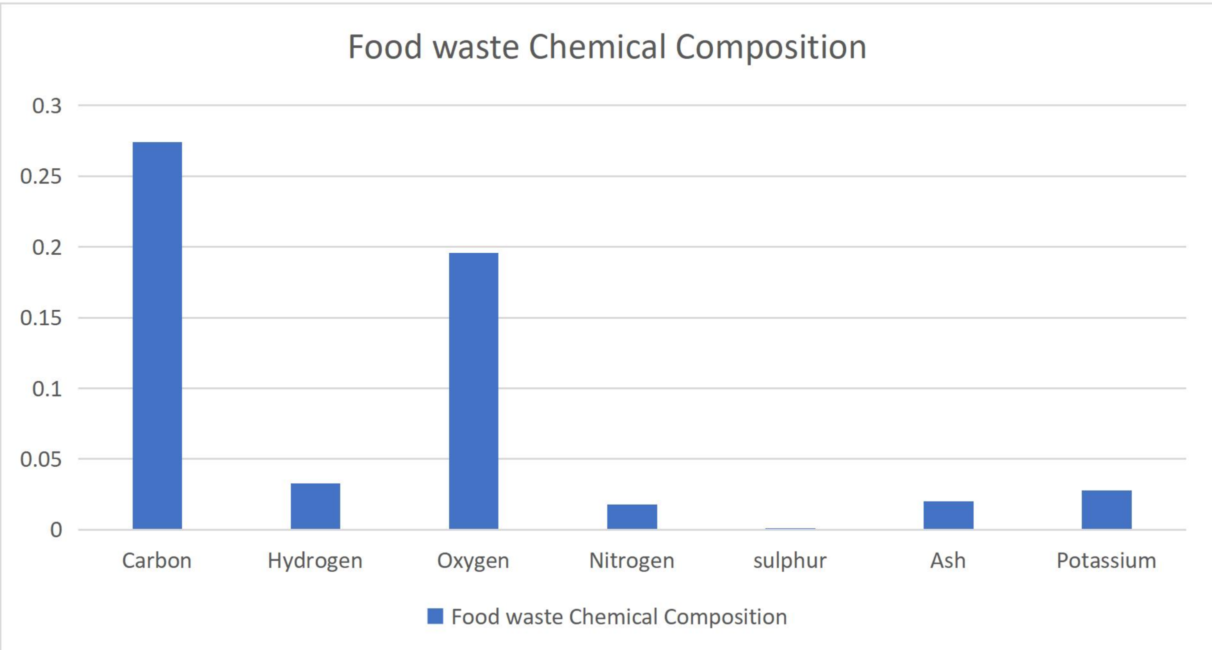


4.1.4. Computation of chemical composition using the formula: "Dry weight x percentage by mass dry basis" for each component and compute in a tabular form

4.1.4.1. **Food Waste**:

Table 4.3

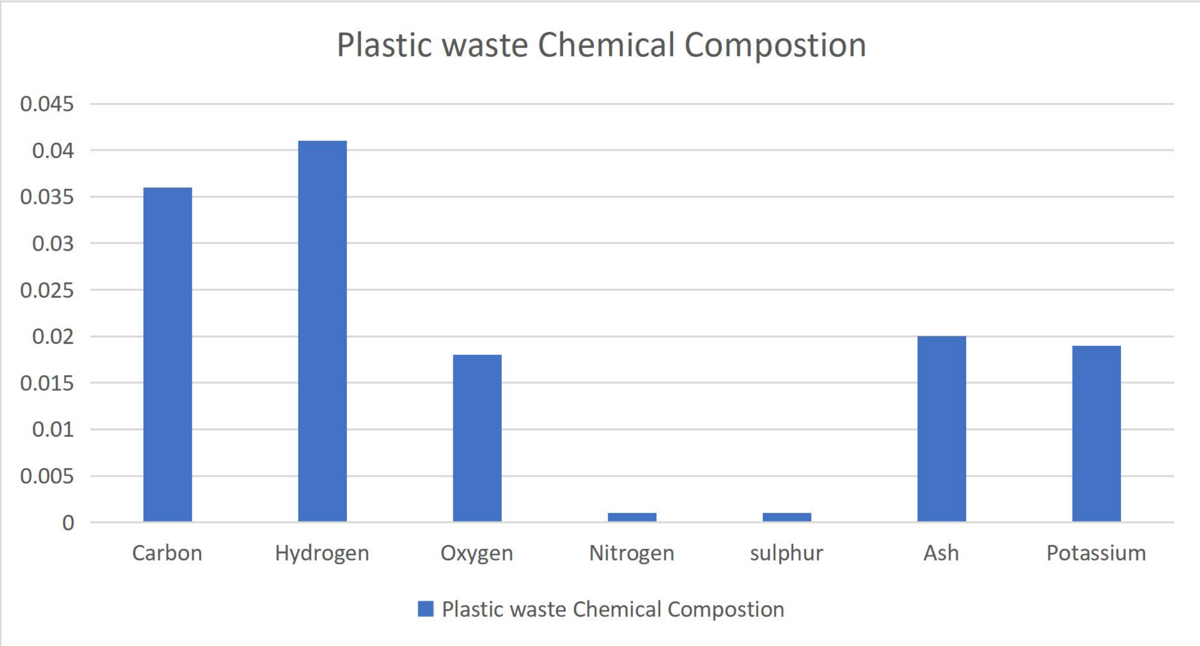
Component	Dry weight	Mass of element	Chemical composition
Carbon	0.474	0.510	0.274
Hydrogen	0.474	0.069	0.033
Oxygen	0.474	0.413	0.196
Nitrogen	0.474	0.037	0.018
Sulphur	0.474	0.003	0.001
Ash	0.474	0.042	0.020
Potassium	0.474	0.059	0.028



4.1.4.2. Plastic

Table 4.4

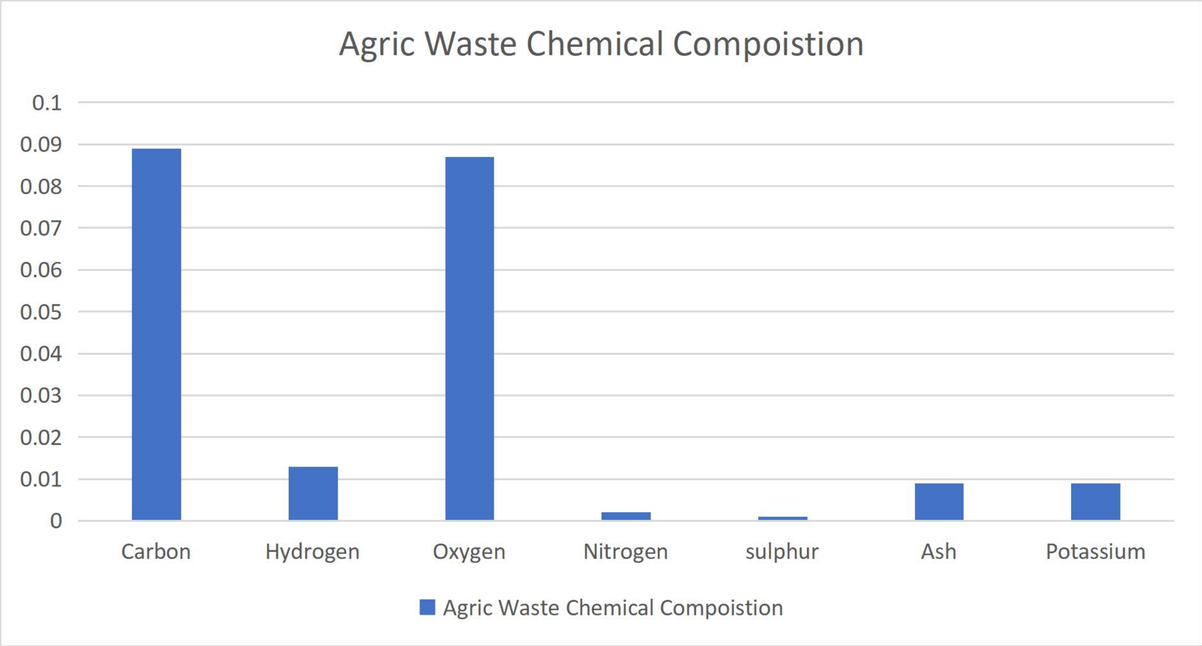
Component	Dry weight	Mass of element	Chemical composition
Carbon	0.656	0.546	0.036
Hydrogen	0.656	0.063	0.041
Oxygen	0.656	0.276	0.181
Nitrogen	0.656	0.002	0.001
Sulphur	0.656	0.001	0.001
Ash	0.656	0.031	0.020
Potassium	0.656	0.029	0.019



4.1.4.3.Agric

Table 4.5

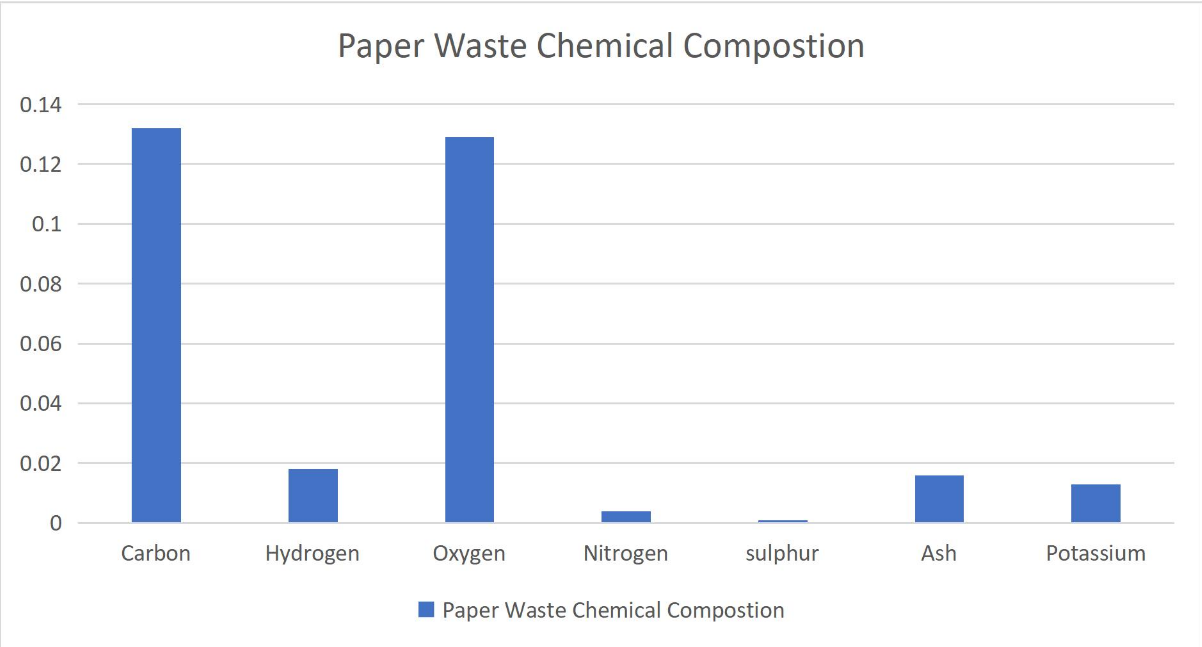
Component	Dry weight	Mass of element	Chemical composition
Carbon	0.186	0.483	0.089
Hydrogen	0.186	0.072	0.013
oxygen	0.186	0.472	0.088
Nitrogen	0.186	0.012	0.002
Sulphur	0.186	0.004	0.001
Ash	0.186	0.049	0.009
Potassium	0.186	0.052	0.009



4.1.4.4.Paper

Table 4.6

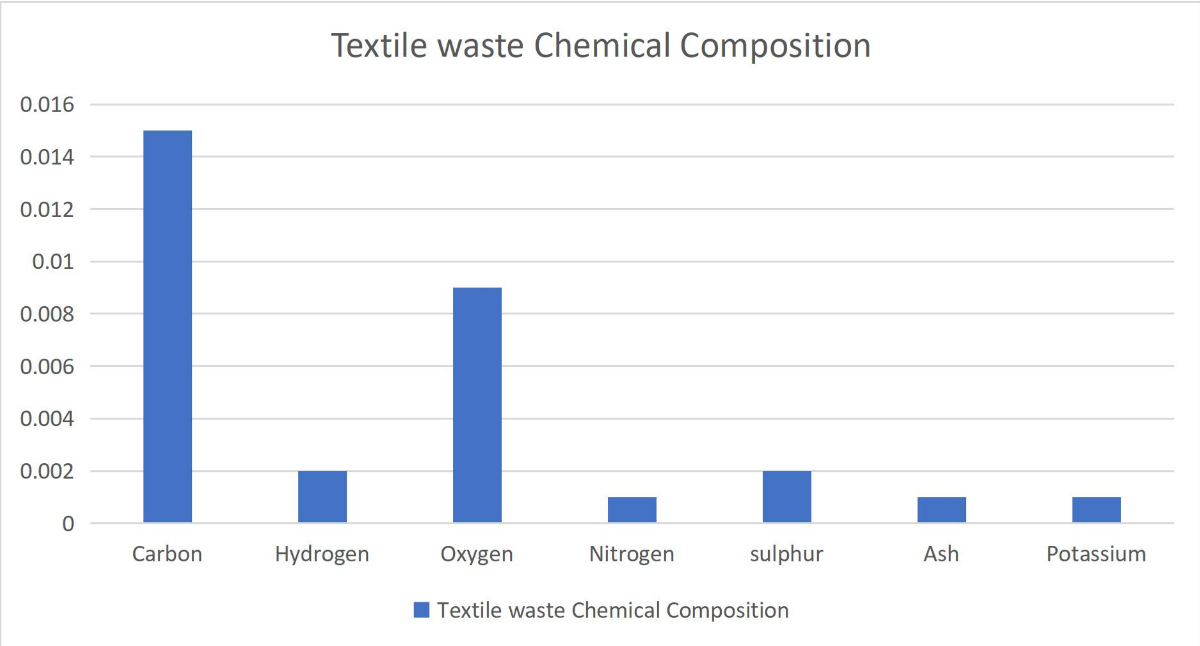
Component	Dry weight	Mass of element	Chemical composition
Carbon	0.278	0.475	0.132
Hydrogen	0.278	0.064	0.018
oxygen	0.278	0.465	0.129
Nitrogen	0.278	0.013	0.004
Sulphur	0.278	0.003	0.001
Ash	0.278	0.057	0.016
Potassium	0.278	0.047	0.030



4.1.4.5.Textile

Table 4.7

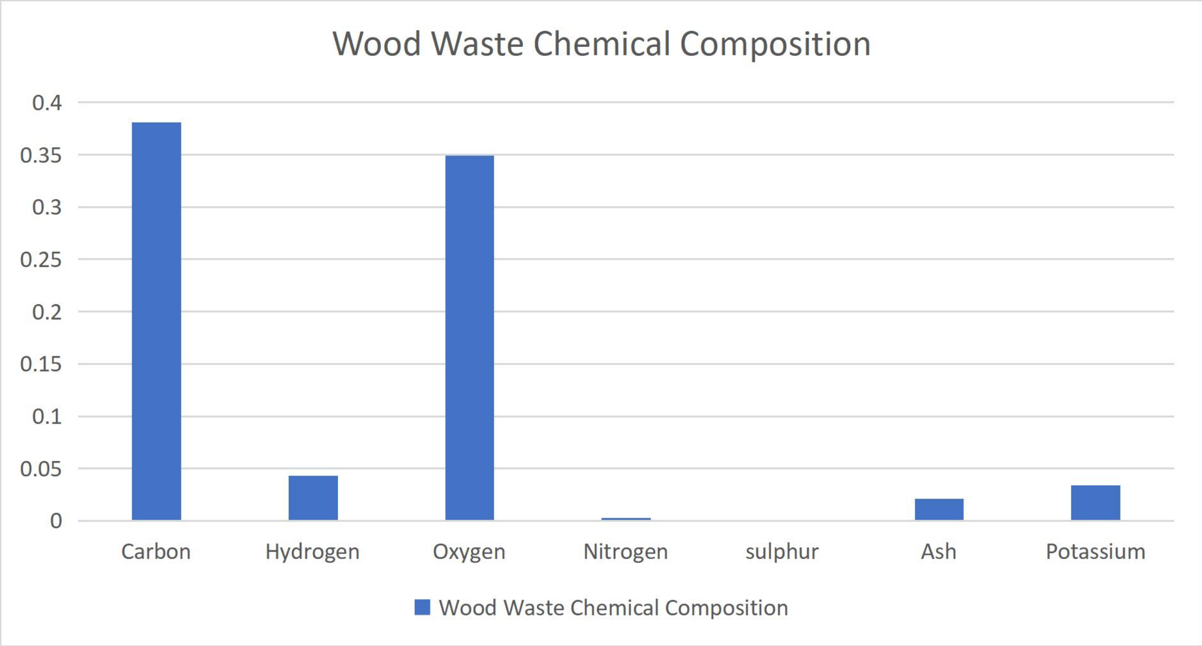
Component	Dry weight	Mass of element	Chemical composition
Carbon	0.028	0.521	0.015
Hydrogen	0.028	0.059	0.002
oxygen	0.028	0.335	0.009
Nitrogen	0.028	0.039	0.001
Sulphur	0.028	0.003	0.001
Ash	0.028	0.056	0.001
Potassium	0.028	0.034	0.001



4.1.4.6.Wood

Table 4.7

Component	Dry weight	Mass of element	Chemical composition
Carbon	0.782	0.487	0.381
Hydrogen	0.782	0.055	0.043
oxygen	0.782	0.446	0.349
Nitrogen	0.782	0.004	0.003
Sulphur	0.782	0.002	0.001
Ash	0.782	0.027	0.021
Potassium	0.782	0.044	0.034

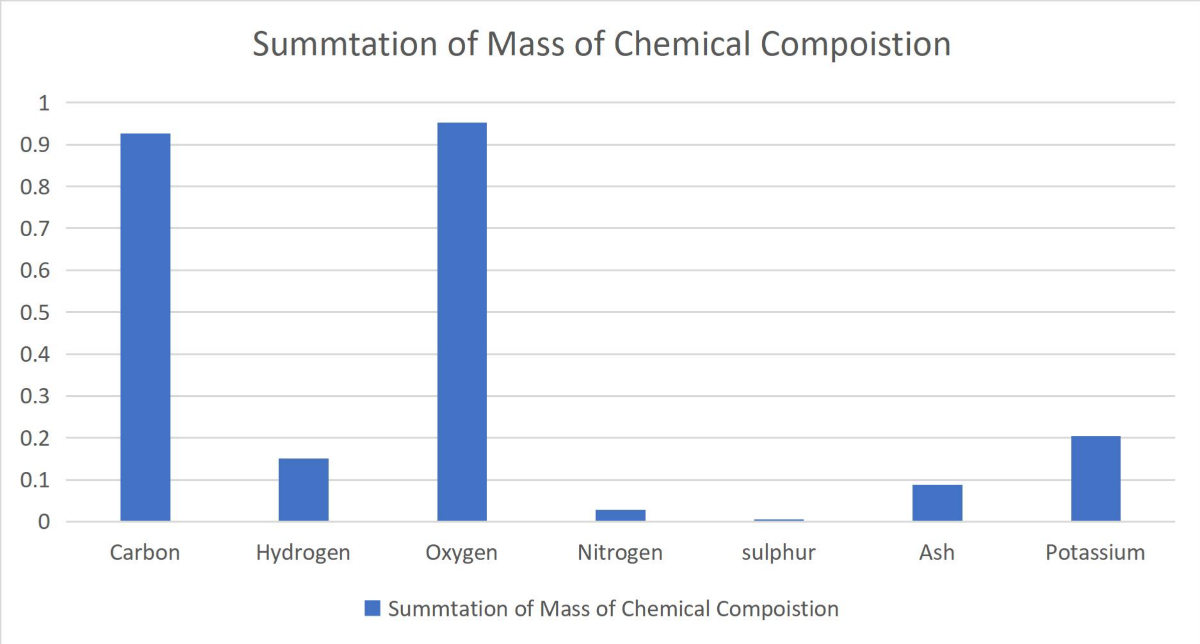


4.1.5. Computation the summation of each element in a tabular form

Moisture content: 5.71%

Table 4.8

Element composition	Mass (kg)
∑Carbon	0.927
∑hydrogen	0.150
∑oxygen	0.952
∑Nitrogen	0.029
∑sulphur	0.006
∑ash	0.088
∑potassium	0.104



4.1.6. Conversion of Moisture content to H20 and add the mass percentage from the hydrogen and oxygen to the computed summation of element respectively:

the moisture content is converted to hydrogen and oxygen and it is added to the initial total hydrogen and oxygen

Mass of H_2O = 2+16 = 18kg/mol

Mass of hydrogen in moisture H= $\frac{2}{18}$ x 37.19 = 4.13kg

Mass of oxygen in moisture O= $\frac{16}{18}$x 37.19 = 33.05kg

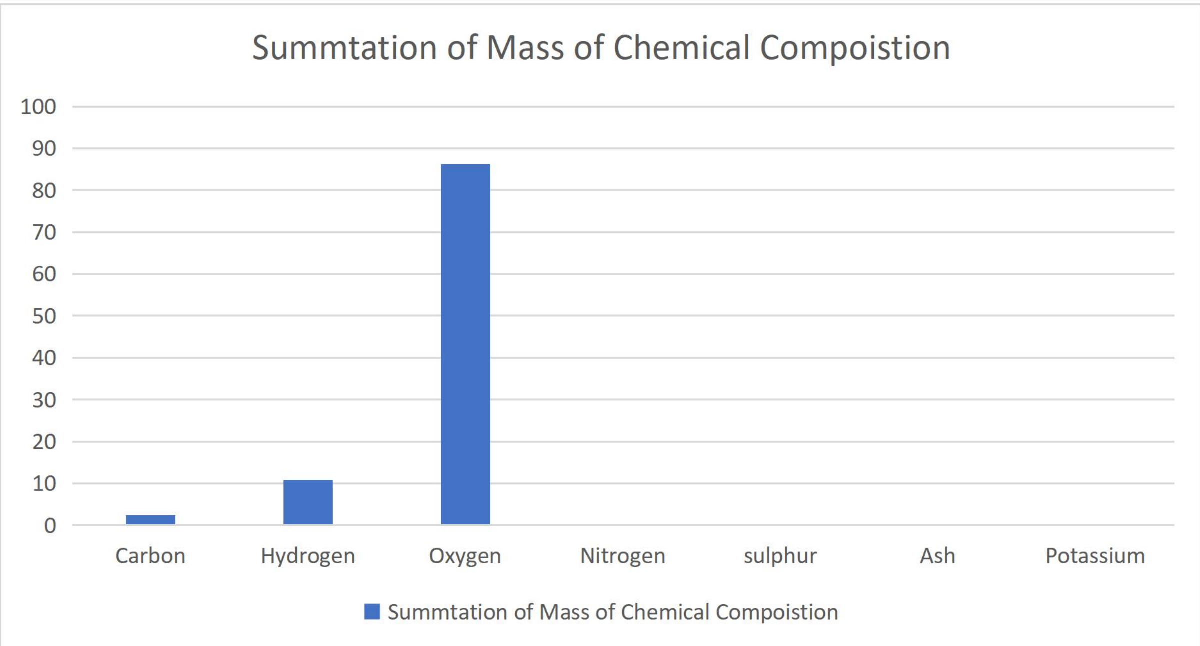
The value gotten are added to the initial value of hydrogen and oxygen.

4.1.7. Final computation of Mass of element and computation of percentage mass of elements

Table 4.9

Element composition	Mass (kg)	Percentage (%) of mass
∑Carbon	0.927	02.35
∑hydrogen	0.150+4.13	10.35
∑oxygen	0.952+34.00	86.91
∑Nitrogen	0.029	0.075
∑sulphur	0.006	0.016
∑ash	0.088	0.223
∑potassium	0.104	0.265
	∑mass 39.43	

Percentage(%) of mass = $(\frac{mass}{\sum mass})$ x 100



4.1.8. Computation of the summation of element as mole by using the fomular : Mole=mass/(molar mass)

Table 4.10

Element composition	Mass (kg)	Molar mass	Mass/molar mass
∑Carbon	0.927	12.01	0.0770
∑hydrogen	0.150+4.13	01.01	4.2390
∑oxygen	0.952+34.00	16.00	0.4700
∑Nitrogen	0.029	14.70	0.0020
∑sulphur	0.006	32.06	0.0002
∑potassium	0.104	39.09	0.0026

4.1.9. Computation of the Chemical formula (with and without sulphur, nitrogen and potassium respectively also taking oxygen as then smallest element)

Table 4.11

Element composition	Mass/molar mass	Smallest mole (sulphur)	Smallest mole (Nitrogen)	Smallest mole (potassium)
∑Carbon	0.0770	382.178	38.2170	28.800
∑hydrogen	4.2390	20981.1	2098.18	1581.4
∑oxygen	0.4700	2328.73	232.673	175.37
∑Nitrogen	0.0020	10.0000	1.00000	0.7530
∑sulphur	0.0002	1.00000	10.1000	0.0074
∑potassium	0.0026	13.4000	1.34000	1.0000

Element composition	Mass/molar mass	Smallest mole (0xygen)
∑Carbon	0.0770	0.164
∑hydrogen	4.2390	9.107
∑oxygen	0.4700	1.000

Formulas

With sulphur: $C_{382.178}H_{20981.1}0_{2326.73}S_{1}$

Without sulphur $C_{382.178}H_{20981.1}0_{2326.73}S_{0.1}N_{1}P_{1.34}$

With Nitrogen: $C_{38.217}H_{2098.18}N_{1}$

Without Nitrogen: $C_{0.164}H_{9.107}O_{1}$

With Potassium $C_{28.80}H_{1581.41}O_{175.37}P$

4.1.10. Estimating of the energy content of the was waste using modified Dulong's formula $H\left(kj(kg)\right) = 337C + 1428\left(H - \frac{O}{8}\right) + 9s$

$$H\,(kj(kg)) = 337C + 1428\left(H - \frac{O}{8}\right) + 9S$$

Kj(kg)= 337C + 1428 (H – $\frac{O}{8}$)+9S

C= % 0f mass carbon =2.35

H= % of mass hydrogen = 10.85

0= % of mass of oxygen = 34.00

Energy value is

Kj(kg)= 337(2.35) + 1428 (10.85 – ($\frac{O}{8}$)) + 9S

Sulphur = 0.016

$Kj(kg) = 337(2.35) + 1428\ (10.85 - (\frac{o}{8})) + 9(0.016)$

897.409kj(kg)

4.1.11. Sustainability

2.274kg of dry waste give us waste give us 897.409kj, and 1 kilojoule = 0.00028kWh (Wikipedia)

897.409kj will equal 0.2493kWh

Nigeria electricity usage per capita 366.85kWh (Worlddata)

The population of the University of Benin is estimated at 75000 student (Wikipedia)

Total solid waste generated per person in Ekehuan campus in raining season is 32.67kg and dry season is 26.46kg (Okorose 2017),

In a year a student generates 59.13kg of waste.

Total waste produced by student in a year is estimated at 75000 x 59.13= 4434750kg,

2.274 give us 0.2493kWh

4434750 gives us 1105583.175kWh

Total electricity needed in a year standard = number of student x electricity per person

Total electricity needed in a year= 75000 x 366.85kWh =27511500kWh

Percentage of electricity provided by waste = $\frac{Energy\ produced\ by\ waste}{standard\ Energy\ needed} x100$

$$\frac{1105583.175}{27511500}x100 = 4.01\%$$

From the calculation the Energy produced by the waste is 4.01% of the energy needed in a year.

4.2. Discussion

We can be observed that food waste makes up a large portion of the waste produced in the faculty of engineering, plastic, agricultural, paper, metal and clothes waste respectively

It can be noted that the Dulong's formula is for heat calculation is dependent on Four major elements, which are Carbon, hydrogen, oxygen and sulphur. can be easily deduced directly from the chemical composition table we can note that wood waste has the highest value of carbon, hydrogen and oxygen with 0.381, 0.042 and 0.347 respectively. next the food waste with carbon 0.274, hydrogen 0.033 and oxygen 0.196. Also, Paper waste which have carbon 0.132, hydrogen 0.018 and oxygen 0.0129, plastic waste with carbon 0.0365, hydrogen 0.0413 and oxygen 0.1810, next textiles waste has which was carbon 0.015, hydrogen 0.002 and oxygen of 0.001, the least was that of Agricultural waste with carbon 0.089 hydrogen 0.013 and oxygen 0.087. the sulphur content of each of the component are relatively low 0.0016. all this were computed to produce an energy of 897.409kg(kj)

Chapter Five

Conclusion & Recommendation

5.1. CONCLUSION

The Estimating of energy content from municipal waste was performed successfully, all objectives were accomplished, the examination of the composition of municipal waste was performed and we discovered the percentage dry mass basis of each component, the percentage mass of each of the component of solids where determined, the overall moisture content was also determined from the sample collected and the energy value was calculated to be 897.409kj, the sustainability was checked and it was discovered that it could generate about 4.01% of energy needed for the University which is a great way of converting waste to wealth.

5.2. Recommendation

i. The energy estimated, if utilized by the school can help not only in Managing waste but also in generating energy that can help reduces cost and also generate electricity when there is power failure to key part of the school.

ii. Further research should be done to understand better method of conversion of waste into energy.

iii. Proper waste disposal should be practise to easy collection of waste for further studies.

Reference

Alshuwaikhat, H.M., Abubakar, I. 2008. An integrated approach to achieving campus sustainability: assessment of the current campus environmental management practices. Journal of Cleaner Production 16, 1777–1785.

Adewuyi, G.O; Obi-Egbedi, NO; Babayemi, JO (2008). Paper Presented at the National Conference on Development and the Environment, University of Ibadan, 17-19 January P.P, 68.

A. P. Sincero, G. A. Sincero,"Environmental Engineering a Design Approach". U. S. Edition. Prentice Hall of India, New Delhi. 2006. Pg 524.

Cheng, H., Hu Y. 2010. Municipal solid waste (MSW) as a renewable source of energy: Current and future practices in China. Bioresource Technology 101, 3816–3824

Chaz (2002). Recycle the Net

EU, "Directive 2010/75/EU of the European Parliament and of the Council of 24 November 2010 onindustrialemissions (integrated pollution prevention and control)," EUR-Lex, Brussel, 2010.

EPA. 2016. "Municipal Solid Waste." https://archive.epa.gov/epawaste/nonhaz/municipal/web/html/. Accessed June 6, 2018

Foo, T.S., (1997). Recycling of domestic waste: early experience in Singapore. Habitat International 21, 277-289.

G. Kiely, "Environmental Engineering," International Editions, McGraw Hill, New York, 1998. Pp 640.

H. S. Peavy, D. R. Rowe, G. Tchobanoglous,"Environmental Engineering," International Edition, McGraw-Hill, New York, 1985. Pg 585.

Igbinomwanhia, D.I., and Ohwovoriole, E. N. (2012), A Study of the Constraints to Residential Solid Waste Management in Benin Metropolis, Nigeria. Journal of Emerging Trends in Engineering and Applied Sciences (JETEAS) 3 (1): 103-107 © Scholarlink Research Institute Journals, 2012 (ISSN: 2141-7016). Online @ jeteas.scholarlinkresearch.org Indexed by Google Scholar

Moldan, B., Billharz, S. and Matravers, R. (eds) (1997). Sustainability Indicators: A Report on the Project on Indicators of Sustainable Development, John Wiley and Sons, Ltd, Chichester, p. 415

National Bureau of Statistics (2012): Annual Abstract of Statistics, 2012 Federal Republic of Nigeria online @ www.nigerianstat.gov.ng,

NEHA (2005). Environmental and Health Impacts of Household Solid Waste Handling and Disposal Practices in Third World Cities: The Case of the Accra Metropolitan Area, Ghana. http://depts.washington.edu/envhlth/acad_programs/eh/ (Accessed; February, 2012).

National Population Commission (2007): 2006 Population Census Final Figure. Federal Republic of Nigeria Official gazette, No. 25 Vol 81

Okeniyi, J.O. Anwan, E.U., Okeniyi, E.U. 2012. Waste Characterization Recoverable Energy potential Using waste generated in model community in Nigeria. Journal of Environmental Science and Technology 5(4), 232-240.

Okorose Juliet 2017 . Assessment of solid waste management in the University of Benin Ekehuan campus, Benin city Edo state, page 48.

Ogunjuyigbe, A.S.O., Ayodele, T.R., Alao, M.A., 2017. Electricity generation from municipal solid waste in some selected cities of nigeria: an assessment of feasibility. Potential Technol. J. Renew. Sus. Energy Rev. 80, 149–162.

Othman J. and Noor Fazni Harun. (2002). Economic Instruments and Willingness to Pay for Solid Waste Management Services. Chapter in Chamhuri Siwar, et. al. (ed.), Policies to Improve Municipal Solid Waste Management. LESTARI Publisher. Universiti Kebangsaan Malaysia, Bangi.

Oyedepo, S. O. 2012. On energy for sustainable development in Nigeria.

Prospects: The 2014 Revision, Highlights," United Nations, New York, 2014.

Renewable and Sustainable. Energy Reviews 16, 2583– 2598

Sharholy, M., Ahmad, K., Mahmood, G. and Trivedi, R. C. (2008). Municipal Solid Waste Management in Indian Cities - A Review. Waste Management 28 (2). 459-467.

UNEP (2005) Selection, Design and Implementation of Economic Instruments in the Solid Waste Management Sector in Kenya: The Case of Plastic Bags, UNEP-ETB, Geneva.

United Nations, Department of Economic and Social Affairs, Population Division, "World Urbanization

U.S. Environmental Protection Agency (2006) Municipal Solid Waste in the United States,

2005 Facts and Figures online @ www.epa.gov

U.S. Environmental Protection Agency (2015) MSW Characterization Methodology. online @www.epa.gov/sites/production/files/2015-09/documents/06numbers.pdf

WED (1987) Our Common Future. World Commission on Environment and Development. Oxford University Press, Oxford.

www.worlddata.info/africa/nigeria/energy.comsuption.php.

https://en.m.wikipedia.org/wiki/university_of_benin_(Nigeria)

https://www.thermofisher.com/ng/home/industrial/spectroscopy-elemetal-isotrope-analysis/spectroscopy-elemenatal-isotope-analysis-learning-center/trace-elemental-analysis-tea-information/atomic-absorption-aa-information/aa-sample-preparation.html

https://www.ijser.org/paper/estimation-of-moisture-content-of-household-solid-waste.html

olaleyo.M.Amoo and Richard.Lfagbenle (2013). Renewable Municipal Solid Waste pathways for energy generation and sustainable development in the Nigeria context. Amos and Fagbenle international journal of energy and environmental engineering 2013, 4:42. http:www.journal-ijeee.com/comtent/4/1/42

Appendix

DEPARTMENT OF CIVIL ENGINEERING
WATER RESOURCES AND ENVIRONMENTAL ENGINEERING LABORATORY
UNIVERSITY OF BENIN, P.M.B 1154, BENIN CITY

Technical Information: **Date Received: 09-06-2021**

Nature of Test: **Elemental Analysis**

Nature of Sample: **Solid Waste Components**

Digestion Reagents: **Equal volume of Nitric Acid/Hydrochloric Acid**

Strength of Reagents: **5% by volume**

Caution: **This result is applicable only to the sample brought to the laboratory for testing.**

Typical Data on the Ultimate Analysis of the Combustible Components in Municipal Solid Wastes

	Percent by Mass Dry Basis						
Components	**Carbon**	**Hydrogen**	**Oxygen**	**Nitrogen**	**Sulphur**	**Ash**	**Potassium**
Food Wastes	51.0	6.9	41.3	3.7	0.3	4.2	5.9
Paper	47.5	6.4	46.5	1.3	0.3	5.7	4.7
Agricultural Waste	48.3	7.2	47.2	1.2	0.4	4.9	5.2
Plastics	54.6	6.3	27.6	0.2	0.1	3.1	2.9
Textiles	52.1	5.9	33.5	3.9	0.3	5.6	3.4
Wood	48.7	5.5	44.6	0.4	0.2	2.7	4.4