SOLID WASTE MANAGEMENT PRACTICE IN NIGERIAN MARKET

CASE STUDY OF OBA MARKET, BENIN CITY.

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A PROJECT PRESENTED TO THE DEPARTMENT STRUCTURAL ENGINEERING, UNIVERSITY OF BENIN, IN PARTIAL DOCUMENT FULFILLMENT OF THE REQUIREMENT FOR THE AWARD OF BACHELOR OF ENGINEERIG (B.ENG.) DEGREE IN STRUCTURAL ENGINEERING

FACULTY OF ENGINEERING

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BENIN CITY.

JULY 2021

CERTIFICATION

This is to certify that **OBERUOMO OCHUKO JUSTINE** carried out this project in the Department of Structural Engineering, Faculty of Engineering, University of Benin under my supervision.

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ENGR. EGHOSA BLESSING OMOSEFE

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ENGR. DR. S.O. IYEKE
HEAD OF DEPARTMENT

DEDICATION

This project is dedicated to LORD GOD Almighty, whose infinite mercy has made it possible to complete this research work and also to my Mom, Mrs. O. Rita.

ACKNOWLEDGEMENT

To God Almighty for His Guidance and mercies for the duration of the programme. I also acknowledge the immense contribution of my supervisor Engr. Eghosa Blessing Omosefe and his encouragement and easy access profoundly in this work. The entire staff of the Department of Civil and Structural Engineering including, Engr. Dr. S.O Iyeke, Engr. Kent Nosa, Engr. (Prof) Izinyon Osadolor, Engr. Ihemekpen Isioma Ngozi, Engr. Bobor Lulu Ofure, Engr. O.N. Prince, Engr. O.E. Ekiado, Engr. A. Rawlings, Engr. A. Esther and others whom I am unable to mention but supported me in their own way through suggestions, may God bless you all.

Also, profound gratitude to my parents and family for their love and care and to my friend

ABSTRACT

Solid wastes are virtually everywhere. They are generated at areas where human activities occur. Such areas include homes, schools, recreational centres, restaurants, markets etc. These areas serve as source of solid waste generation. The waste at these sources, especially in markets are often generated in quantities considered hazardous to public health and aesthetically displeasing. Hence, to protect public health, a systematic method is devised to ensure the control of waste generation. Such systematic method is generally referred to as Solid Waste Management (SWM).

For this study, data was collected by administering questionnaires to the traders in the market. Also the data was also gotten from the waste management authority via oral interview and also administrator of questionnaires. The questionnaires was analysed using statistical package and result gotten.

From the study, it was observed that large number of the market trader are unaware of solid waste management practise. The study also reveal that the type of waste generated in urban markets are putrescible and food waste (53.97%), while the least is (3.40%). Landfill was also designed for proper practise of solid waste management.

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CHAPTER ONE

1.0 INTRODUCTION

1.1 Background Study

Man is known to engage in various activities to survive and ensure a habitable environment. These activities involve the interaction with his immediate environment and the utilization of the available resources. However, the consumption and utilization of such resources result to end products that cannot be further consumed and utilized. Such end products are referred to as *Waste.* Solid wastes are virtually everywhere. They are generated at areas where human activities occur. Such areas include homes, schools, recreational centres, restaurant, markets etc. These areas serve as source of solid waste generation. The waste at these sources, especially in markets are often generated in quantities considered hazardous to public health and aesthetically displeasing. Hence, to protect public health, a systematic method is devised to ensure the control of waste generation. Such systematic method is generally referred to as Solid Waste Management (SWM).

Solid waste management may be defined as the discipline associated with the control of generation, storage, collection, transfer and transport, processing, and disposal of solid wastes in a manner that is in accordance with the best principles of public health, economics, engineering, conservations, and that is also responsive to public attitudes. (Tchobanoglous,

Kreith, 2002).

The overall aim of Solid Waste Management is to provide an effective and efficient way of controlling the quantity of unwanted materials generated in a given community. Thus, to meet this objective, certain data are required for an effective practice. One of the most important data

required is the quantity of waste generated. For if the quantity of waste generated in a particular community is known, proper selection of the environmentally and economically effective facilities is assured. Basically, problems arising from the practice are due to inadequate information on the quantity of waste generated and the facilities needed to manage such waste.

The quantity of solid waste generated in a particular community is dependent on the population and the technological advancement of the community in terms of mass production, consumption and lifestyle. As such, the solid waste generated at urban areas is relatively voluminous compared to that generated in suburban and rural areas. Also, commercial areas tend to generate more waste than non-commercial areas. Since the quantity of solid waste generated in urban markets are normally voluminous, requirements for the effective solid waste management in market need to be investigated.

1.2 Problem Statement

The management of solid waste in Nigerian markets is beyond providing facilities and making policies for its collection and disposal. In fact, infrastructures for its collection and disposal are currently employed by public and private sectors. However, the major concern is the degree of effectiveness and efficiency that can be obtained from the implementation and utilization of such policies and facilities respectively. Effective, as used in this context, is described in terms of various disciplines associated with the practice. Such disciplines include economics, engineering, public health, conservation, legislation and administration. Thus:

i. If facilities are required, what quantity and level should it be provided to minimize cost, maintain proper public health, conserves resources and not compromising on the efficiency of the practice?

ii. If policies are required, how should they be implemented according to the best principles of legislation and administration?

According to George Tchobanoglous and Frank Kreith (2002), of the total amount of money spent on solid waste management approximately *50 to 70* percent is spent on the collection activity. Because such a large fraction of the total cost is associated with the collection operation, a *small improvement* in the collection operation can effect a significant savings in the overall system cost. Thus, the need to examine the effectiveness of each operation, facilities and policies cannot be undermined.

1.3 Project aim and Objectives

The aim of the project is to examine the effectiveness of the solid waste management practice in Nigerian markets, taking Oba Market as a case study. The project, amongst many, aims to achieve the following objectives:

i. To present an overview of Solid Waste Management in Nigerian Markets.
ii. To present an overview of the current Solid Waste Management Practice in Oba market.
iii. To document current facilities employed in the management of Solid Waste in the market.
iv. To examine the effectiveness of each functional operation of the practice in Oba Market terms of economy, public health, legislation and other set objectives.
v. To recommend alternative methods that can be employed to improve effectiveness.

1.4 Scope of Study

The scope of the study is limited to *Oba market* in Oredo Local Government Area of Edo State, Nigeria. To fully understand the current solid waste management practice being carried out in Oba Market, a background study of the market and an overview of the practice is presented below.

1.4.1 Overview of Solid Waste Management in Nigerian Markets.

Solid waste management has been identified as one of the major environmental challenges being faced by the country. Nigeria, with a population exceeding 170 million and an estimated population growth of about 2.6%, is the most populous country in Africa and 7th in the world (CIA, 2012). With this estimated population growth, it can be seen that the quantity of solid waste generated yearly is on the rise.

The administrative framework for SWM in Nigeria is three tiered, thus consisting of national and state agencies as well as local bodies. The body charged with overseeing the protection of the environment as well as a natural resource preservation to the end of achieving sustainable development is the Federal Ministry of Environment. Thus, it plays the role of the promulgation, enforcement, and the monitoring of national environmental laws in accordance to international environmental guidelines. Up until 1999, environmental laws and regulations were put forward and enforced by the Federal Environmental Protection Agency (FEPA,

1991). However, these subsequently became the role of the Federal Ministry of Environment. In order to ensure protection of the environment is better managed, all states in Nigeria (and their local governments) have been given the capacity to create related environmental establishments (Ogwueleka, 2009).

The Nigerian Markets are characterized by light to heavy commercial activities depending on the population growth of a particular geographical area. These commercial activities which involves the buying and selling of goods and services lead to the generation of solid wastes which can be in large quantity. Thus, a typical Nigerian market is made up of council members, sectorial association, market sellers and traders and market buyers.

A full length research paper on the *characterization of domestic and market solid wastes at source in Lagos Metropolis* shows a comparative analysis in terms of type and composition of

solid waste generated in households and in market areas. For the study, it has been observed that the average composition of solid wastes per day obtained from markets in four LGAs in Lagos (Ikoyi, Ebute-Metta, Gbagada and Mushin) are 6884.45g, 2352.22g, 391.14g, 176.52g, 176.50g of putrescible, paper, nylon, plastic and metal, respectively. The average weight of putrescible per day ranges from 5004.50 to 7660.00g. Paper ranges from 1959.00 to 3081.25g, nylon ranges from 302.25 to 525.00g. Plastic ranges from 131.25 to 233.75g, metal ranges from 122.50 to 252.50g. (Oyelola, Babatunde, 2008). This data shows that the larger proportion of solid waste generated in Nigerian markets are putrescible and food wastes. Also, solid wastes generated in markets can be recycled and reused.

1.4.2. Overview of Solid Waste Management in Oba Market.

Edo state is one of the most homogeneous states in Nigeria. It has a population of about 4million people (2006 census projection) with a population growth of 2.78% while according to USAID reports, in 2002, Edo state was estimated to have a population of 2.86 million. The adolescence and young adults (10-24 years of age), account for 32% of the population, making Edo state one of the states in Nigeria with a very high concentration of young people. The state is multi religious and multi ethnic with Christianity, Islam and African traditional religion as the most dominant.

Based on economy, Edo state is a home to the growth of major agricultural crops such as rubber, oil palm, cocoa, yam, cassava, rice and plantain. Sugar cane, cashew, oil palm (and its derivative products), groundnuts, soya beans, tomatoes, cotton and tobacco. There is significant animal husbandry industry, with cows, goats, pig's rabbits and sheep being the significant animal husbandry industry. Aside agriculture, Edo state is endowed with industrial mineral resources as quartzite, marble, clay, limestone, chalk, gypsum, gold, petroleum, kaolin and lignite. Factories

such as Guinness Stout Nig. Ltd, wood and timber processing industries, textile mills, carpet manufacturers, floor tile producers, publishing firms, pharmaceutical firms are operational.

Benin City is a city and the capital of Edo State. It is a city approximately 40 kilometres north of the Benin River. It is situated 320 kilometres by road east of Lagos. Benin is the centre of Nigeria's rubber industry, but processing palm nuts for oil is also an important traditional industry. As at 1952, the population of Benin City was put at 53,753 with 28,287 male and 25,466 female according to 1963 census. (Nigeria census, 1963). It then rose to 100,094 in 1991. The population of Benin Metropolis rose to 780,976 and to 1,085,676 in 2006. However, a population projection growth rate of 2.78% is therefore used to project the population in Benin Metropolis from 2006 to 2015. The implication of this geometric increase in population of Benin City metropolis means increase in the generation of solid waste.

Table 1.1: Population of Benin City

Year	**Population**
1952/53	53,753
1963	100,694
1991	780,976
2006	1,085,676
2009	1,146,473
2011	1,187,084
2013	1,227,694
2015	1,268,305

Source: NPC (National Population Commission 1952-2006).

In Benin City, the state government has over the years formulated several policies with a view to improving the sanitary conditions of its environment. Edo state solid waste management policy is designated to support policy guideline of the National Environmental policy. The policy dilemma appears to be how to contain the adverse environmental impacts through proper implementation. (Nwaka, 2005).

Oba Market is located in Oredo Local Government Area of Edo state. The Market, over the years, has generated voluminous quantity of solid waste due to the population growth in the city. It is a market that is characterized by medium commercial activities that involve the selling and buying of consumable goods and services. As such, there is a high generation of putrescible waste in addition to plastics, paper, nylon and metals. According to a full length research on *seasonality and environmental impact status of polyethylene generation and disposal in Benin City Metropolis,* it is observed that Oba market, which recorded a low cellophane generation, is more of a foodstuff markets where women traders dominate. (Aziegbe, F.I. 2007).Thus, from this information, It can be deduced that the kind of waste that is mostly generated from Oba market is related to foodstuff material. The body responsible for solid waste management is the Edo State Waste Management Board.

1.5 Justification of Study

This study aims to outline the solid waste management practice as carried out in Oba market.

The study will, amongst many, help to:

1. Know the estimated quantity of waste generated in the market
2. Characterize the solid waste generated in the market
3. Know the type of collection system adopted by the collection authority.
4. Know the facilities being used by the collection authority
5. Know the disposal method adopted by the collection authority.

CHAPTER TWO

2.0 `LITERATURE REVIEW

2.1 Introduction

Generally, Waste are substances that are unwanted and considered unusable after primary use. However, according to the United Nations Statics Division, Glossary of Environmental Statistics, "*Wastes are materials that are not prime products (that is products produced for the market) for which the initial user has no further use in terms of his/her own purposes of production, transformation or consumption, and of which he/she wants to dispose."*

Waste exists in different forms. They can be solid, semi-solid, liquid or gas. Example of wastes include municipal solid waste, hazardous waste, wastewater, radioactive waste, etc. Therefore, solid waste varies with other forms of waste in terms of physical texture, type and composition.

Solid wastes are unwanted substances which are non-liquid and non-gaseous and consist of organic matter (easily biodegradable) and inorganic (non-biodegradable which include metals, plastics, bottles and broken glasses)

Solid waste management may be defined as the discipline associated with the control of generation, storage, collection, transfer and transport, processing, and disposal of solid wastes in a manner that is in accordance with the best principles of public health, economics, engineering, conservations, and that is also responsive to public attitudes. (Tchobanoglous,

Kreith, 2002.)

The nature and operation of solid waste management varies significantly from nation to nation. The variations are to some extent attributable to prevailing socio-economic, financial, legal and political variables at that level. Also, the primary difference between wastes generated in developing nations and those generated in industrialized countries is the higher organic content

characteristic of the former. Wastes generated in countries located in humid, tropical, and semitropical areas usually are characterized by a high concentration of plant debris; whereas those generated in areas subject to seasonal changes in temperature or those in which coal or wood are used for cooking and heating may contain an abundance of ash. The concentration of ash may be substantially higher during winter. Regardless of climatic differences, the wastes usually are more or less contaminated with night soil. These differences prevail even in wastes generated in large metropolitan areas of a developing country. (UNEP, 2004).

The need for solid waste management has been recognized by the international aid and development community. The United Nations Conference on Environment and Development stressed that *'...solid waste production should be minimized, reuse and recycling, maximized, environmentally sound waste disposal and treatment promoted and waste service coverage extended'*.

The scope of solid waste management cuts across many disciplines. The solutions may involve complex interdisciplinary relationships among such fields as political science, city and regional planning, geography, economics, public health sociology, demography, communications, and conservation, as well as engineering and material science. That is to say, for solid waste management to be considered functional and effective, it must therefore protect the public health within a geographical location by the use of engineering facilities in such a cost-effective manner in line with government policies and in such a manner to conserve resources.

2.2 Functional elements of solid waste management

Functional elements of solid waste management are the activities that are involved in the practice from the point of generation to the final disposal. They include:

1. Waste generation
2. On-site handling, storage, and processing
3. Collection
4. Transfer and transport
5. Processing and recovery, and
6. Disposal

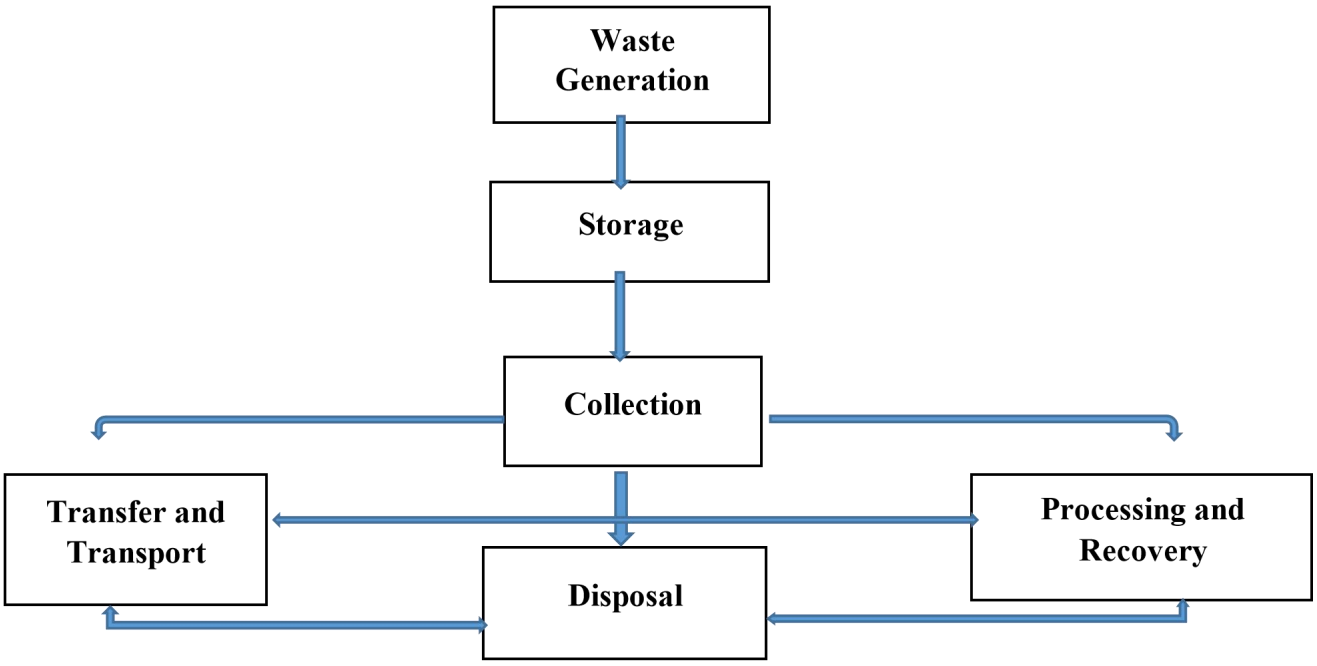

Figure 2-1: Interrelationship of functional elements of a solid waste management.

Table 2.1 Description of Functional Elements of SWM

Functional Elements	Description
Waste Generation	Those activities in which materials are identified as no longer being of value and are either thrown away or gathered together for disposal
On-site handling, storage and processing	Those activities associated with the handling, storage, and processing of solid wastes at or near the point of generation
Collection	Those activities associated with the gathering of solid wastes and the hauling of wastes after collection to the location where the collection vehicle is emptied.

Transfer and Transport	Those activates associated with the transfer of wastes from the smaller collection vehicle to the larger transport equipment and the subsequent transport of the wastes, usually over long distance to the disposal site.
Processing and Recovery	Those techniques equipment and facilities used both to improve the efficiency of the other functional elements and to recover usable materials, conversion products, or energy from solid wastes.
Disposal	Those activities associated with ultimate disposal of solid wastes including those wastes collected and transported directly to a landfill site, semisolid wastes (sludge) from wastewater treatment plants incinerator residue compost, or other substances from the wires solid waste processing plant.

Source: *Adapted from Tchobanoglous, Theisen and Vigil (1993): Integrated solid waste management; Engineering principles and management issues. McGraw-Hill, Inc.*

2.3 Sources, types and composition of solid wastes

Knowledge of the sources and types of solid wastes, along with data on the composition and rates of generation, is basic to the design and operation of the functional elements associated with the management of solid wastes.

2.3.1 Sources

The materials that are collected under the term solid waste include many different substances from a multitude of sources.

i. A small rural community may have known types of solid wastes from known sources (i.e. the wastes are more homogenous).
ii. Urban communities (metropolitan cities) have many sources (The wastes are more heterogeneous.

2.3.2 Types of solid waste

Solid wastes types are enumerated below:

i. **Refuse:** These are the non-liquid decomposable and non-decomposable waste.

ii. **Garbage**: These are decomposable food and kitchen wastes.

iii. **Rubbish:** These represent all non-decomposable wastes except ash.

There are two categories of rubbish:

a. Combustible; - organic in nature and includes items such as paper, cardboard, wood yard clippings, bedding, plastics etc.

b. Non-combustible: - are inorganic materials, which include metals, glass, ceramics, and other minerals.

iv **Ashes**: an incombustible material that remains after a fuel or solid waste has been burnt.

v. **Infectious wastes**: are wastes that contain or carry pathogenic organisms in part or in whole such as wastes from hospitals and biological laboratories soiled with blood or bodily fluids vi. Special wastes: are wastes from residential and commercial sources that includes.

a. Bulky items e.g. large worn out or broken household, commercial, and industrial items like, Furniture, lamps, bookcases, filing cabinets, etc.

b. Consumer electronics which includes worn-out, broken, and other no- longer wanted items such as radios, stereos, TV sets.

c. White goods include large worn – out a broken household, commercial, and industrial appliances such as stoves, refrigerators, dishwashers, clothes washers and dryers vii. Inorganic waste: Glass, crockery (cups, plates, etc.) tin cans, aluminium, and other metals.

viii**.** **Dead bodies**: dead animals like dogs, cows, donkey etc.

ix, **Organic waste**: Food waste, paper, cardboard, plastics, textiles, rubber, leather, wood, yard wastes.

2.3.3 Composition of Solid Waste

Composition is the term generally used to describe the individual components that make up the solid waste and their relative distribution, usually by percent or by weight. Information on the composition of solid waste is important in evaluating equipment needs, systems and management programs and design of facilities.

The Composition of Solid Waste can be classified as physical composition, chemical composition and biological composition.

2.3.3.1 Physical composition of solid wastes

Knowing the characteristics of the physical component of a community solid waste is important for the following purposes:

i. for the selection and operation of equipment and facilities
ii. to assess the possibility for resource of energy recovery
iii. to design and analyse disposal facilities

Ways for physical composition Analysis: Individual component study

i. Analyse the components of municipal solid waste by type
ii. Sorting and separation of each and every component is necessary
iii. Samples each of the heterogeneous refuse of municipal solid waste
iv. Should be representative (at all seasons of the year)
v. Statistical produces (representative ness and randomization)

The types (components) of municipal solid waste may be different from country to country by season, economic condition, developmental level, etc.

Moisture content

The moisture content of solid waste is usually expressed in one of two ways

1. **In the wet** – weight method of measurement: the moisture in a sample is expressed as a percentage of the wet weight of material ii. Dry-weight method, it is expressed as a percentage of the dry weight of the material.

Wet- weight Moisture content is expressed as follows

$$M = \frac{w - d}{w} \times 100 \qquad (2.1)$$

Where: M= wet- weight moisture content, % w= initial mass of sample as delivered, kg d= mass of sample after drying, kg

Table 2.3: Moisture Content of Various Solid waste components.

Component	**Moisture Content % by weight**	
	Range	**Typical**
Food wastes	50 -80	70
Paper	4-10	6
Card board	4-8	5
Plastics	1-4	2
Textiles	6-15	10
Rubber	1-4	2
Leather	8-12	10
Garden trimmings	30-80	60
Wood	15-40	20
Misc. organics	10-60	25

Glass	1-4	2
Tin cans	2-4	3
Nonferrous metals	2-4	2
Ferrous metals	2-6	3
Dirt, ashes, brick, etc.	6-12	8
MSW	15-40	20

Source: Adapted from Tchobanoglous, Theisen and Vigil (1993): Integrated solid waste management; Engineering principles and management issues. McGraw-Hill, Inc.

II, Density

Density is defined as the weight of the material per unit volume. The interest in knowing density of solid waste is to assess the total mass and volume of waste that must be managed.

The densities of solid waste vary markedly with:

i. Geographic location

ii. Season of the year

iii. Length of time in storage

The densities of municipal solid wastes as delivered in compaction vehicles have been found to vary from 178 to 415 Kg/m^3; a typical value is 297 kg/m^3.

2.3.3.2 Chemical composition

Information on the chemical composition of solid wastes is important in evaluating alternative processing and energy recovery options. For example, the feasibility of combustion depends on the chemical composition of solid waste. If solid wastes are to be used as fuel, the four most important properties to be known are:

I. Proximate analysis: Proximate analysis for combustible components of municipal solid waste includes the following tests

   a. Moisture (loss of moisture when heated to 105^0C for 1h)

   b. Volatile combustible matter (additional loss of weight on ignition at 950^0C in a covered crucible)

   c. Fixed carbon (combustible residue left after volatile matter is removed)

   d. Ash (weight of residue after combustion in an open crucible)

II. **Fusing point of ash**: is defined as the temperature at which the ash resulting from the burning of waste will form a solid (clinker) by fusion and agglomeration. Typical fusion temperature for the formation of clinker from solid waste ranges from 1100 to 1200oc.

III. **Ultimate analysis**: the ultimate analysis of a waste component typically involves the determination of the percent of C (carbon), H (hydrogen) O (oxygen), N (nitrogen),S (sulphur) and ash. The results of the ultimate analysis are used to characterize the chemical composition of the organic matter in municipal solid waste.

IV. **Energy content**: the energy content of solid waste is determined by using a full scale boiler as a calorimeter, laboratory bomb calorimeter or calculation.

Table 2.4: Ultimate analysis of Various Solid waste Components.

Component	**C**	**H**	**O**	**N**	**S**	**Ash**
Food waste	48.0	6.4	37.6	2.6	0.4	5.0
Paper	43.5	6.0	44.0	0.3	0.2	6.0
Cardboard	44.0	5.9	44.6	0.3	0.2	5.0

Plastic	60.0	7.2	22.8	-	-	10.0
Textiles	55.0	6.6	31.2	4.6	0.15	2.5
Rubber	78.0	10.0	-	2.0	-	10.0
Leather	60.0	8.0	11.6	10.0	0.4	10.0
Garden trimmings	47.8	6.0	38.0	3.4	0.3	4.5
Wood	49.5	6.0	42.7	0.2	0.1	1.5
Misc. Organics	48.5	6.5	37.5	2.2	0.3	5.0
Dirts, ashes, brick etc.	26.3	3.0	2.0	0.5	0.2	68.0

Source: *Adapted from Tchobanoglous, Theisen and Vigil (1993): Integrated solid waste management; Engineering principles and management issues. McGraw-Hill, Inc.*

Energy values as discarded basis may be converted to a dry basis by using:

$$\frac{KJ}{Kg}(dry\ basis) = \frac{KJ}{kg}(as\ discarded)\left(\frac{100}{100 - \%\ moisture}\right) \quad (2.2)$$

The corresponding equation for a dry ash-free basis is:

$$\frac{KJ}{Kg}(dry\ ashfree) = \frac{KJ}{kg}(as\ discarded)\left(\frac{100}{100 - \%\ moisture}\right) \quad (2.3)$$

2.4 Solid Waste Generation

Waste generation encompasses activities in which materials are identified as no longer being of value and are either thrown away or gathered together for disposal. For example, the warping of a candy bar is usually considered to be of little further value to the owner once the candy is consumed and more often than not it is just thrown away, especially outdoors. It is important in

waste generation to note that there is an identification step and that this step varies with each individual waste. Knowledge of the quantities of solid wastes generated, separated for recycling, and collected for further processing or disposal is of fundamental importance to all aspects of solid waste management.

2.4.1 `Expression of unit generation

In addition to knowing the source and composition of solid waste, it is equally important to have uniform units of expression. For example, universally accepted units for:

i. Household waste (kg/capita/day)

ii. Commercial waste (kg/x/day where x can be m^2 of floor area of commercial establishment, unit volume or dollar in sales, the number of employees, etc.)

iii. Institutional waste (kg/x/day where x can be the number of students, m^2 of the area of park or public place, number of visitors, etc.)

iv. Market waste (kg/x/day where x can be the number of market lots, m^2 of floor area, dollar in sales, etc.)

Industrial waste (kg/x/day where x can be unit volume or dollar of production output, m^2 of floor area, the number of employees, etc.)

v. street sweeping waste (kg/km/day)

vi. drain cleaning waste (kg/km/day)

vii. total waste (kg/capita/day)

2.4.2 Methods used to estimate Waste Quantities

Waste quantities are usually estimated on the basis of data gathered by conducting a waste characterization study, using previous waste generation data or some combination of the two approaches.

Methods commonly used to assess solid waste quantities are:

1. load-count analysis,
2. weight-volume analysis, and
3. Materials mass-balance analysis.

1. **Load-Count Analysis.** In this method, the number of individual loads and the corresponding waste characteristics (types of waste, estimate volume) are noted over a specified time period. If scales are available, weight data are also recorded. Unit generation rates are determined by using the field data and where necessary, published data.
2. **Weight-Volume Analysis.** The use of detailed weight-volume data obtained by weighing and measuring each load will certainly provide better information on the specific weight of the various forms of solid wastes at a given location.
3. **Materials Mass Balancer Analysis.** The only way to determine the generation and movement of solid wastes with any degree of reliability is to perform a detailed materials balance analysis for each generation source, such as an individual home or a commercial or industrial activity. In some cases, the materials balance method of analysis will be required to obtain the data needed to verify compliance with statemandated recycling programs.

2.4.3 Variation in Solid Waste Generation Rates

Solid waste generation rates estimate the amount of waste created by residences or businesses over a certain amount of time (day, year, etc.). The quantities of solid waste generated vary daily, weekly, monthly and seasonally.

Information on the variations to be expected in the peak Residential waste generation rate usually peak during Christmas holiday season and during spring house cleaning days. In many communities, unlimited collection service is provided on designated clean-up days. In general, as

the size of the waste source increases (e.g. from individual residences to a community) the variation in the peak day, week and month decreases.

2.5 Solid waste handling, storage and processing at the source

2.5.1 On-site handling

It is an activity associated with the handling of solid waste until they are placed in the containers used for their storage before collection. This may take place at any time before, during or after storage. On-site handling methods include sorting, shredding, grinding, composting etc.

2.5.2 On- site Storage

The first phase to manage solid waste is at home level. It requires facilities for temporarily storing of refuse on the premises. Individual house holder or business man has responsibility for onsite storage of solid waste.

For individual homes, industries, and other commercial centres proper onsite storage of solid waste is the beginning of disposal.

There are four factors that should be considered in the on-site storage of solid waste. These are the type of container to be used, the location where the containers to be kept, public health, the collection method and time.

1. Storage container

Garbage and refuse generated in kitchens and other work areas should be collected and stored in properly designed and constructed water-proof garbage cans (waste bins). The cans or receptacles can be constructed from galvanized iron sheet or plastic materials. They should have tightly fitting covers. They must be of such size that, when full, can be lifted easily by one man. They should be located in a cool place over platforms, at least 30 centimetres above ground level. After putting in garbage, they should be kept covered. The bins must be emptied at least daily and

maintained in clean conditions. A typical example of garbage can, constructed from galvanized iron sheet, dimensions: diameter 45 cm and height 75 cm, is shown in the figure below.

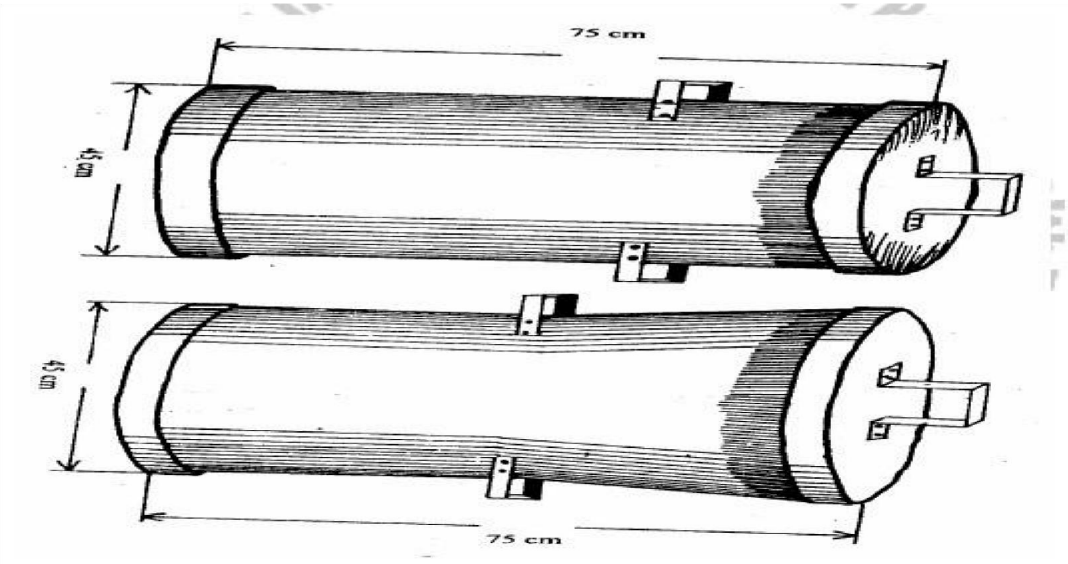

Figure 2.2. Typical Garbage Can with Tightly Fitting Cover
Source: *Gabre-Emanuel Teka (1997): Solid waste disposal from food premise; In Food* ***Hygiene.***

2. Container size (capacity)

Consideration should be given for the size of the loaded container that must be hauled to the collection vehicle or to the disposal site.

Therefore, container size for:-

i. ash up to 80 to 128 litre

ii. mixed refuse should not exceed 120 to 128 litre

iii. rubbish up to 200 litre

iv. office waste is 10-20 litre

v. kitchen waste is 40 litre

vi. garbage is 48 to 80 litre

Galvanized metal is preferable for garbage storage because it is resistant to corrosion.

2.5.3 On- site processing

On-site processing is intended to improve disposal options, recover valuable resources, and prepare materials for recovery as new products or energy. A fundamental objective of on-site processing is resource recovery. A number of processing technologies have been developed for solid waste management and one of the jobs of the engineer is to select and design the most sustainable and cost effective for a given community.

2.6 Collection Methods

This is the removal of refuse from collection points to final disposal site. It is the most expensive part of solid waste management as compared with other operation and management procedures, because it demands special vehicles, experienced people to manage, more manpower, hand tools, and more funds for fuel, salary, maintenance. It includes gathering or picking up of solid waste from the various sources, taking the collected wastes to the location where it is emptied, and unloading of the collection vehicle.

Collection cost has been estimated to represent about 50 to 80% of the total cost of solid waste management depending on the type of disposal facility used. In the USA for example, of the money spent for the collection, transportation and disposal of solid waste, approximately 60-80% was spent on collection. This shows that if the collection system or operation is improved there will be significant saving in the overall cost.

Collection program demands the following more than anything else

i. Special vehicles for different types of wastes (logs, garbage, special wastes)

ii. Experienced people to manage and administer.

iii. More specialized machineries or simple hand tools and manpower.

iv. Monetary funds to be used for fuel, salary, maintenance.

The collection operation of solid waste management is considered from four aspects. These are:

i. Understanding the types of collection services that are provided

ii. The types of collection system, equipment and labour requirement.

iii. An analysis of collection system including component relationship.

iv. General methodology involved in setting up collection routes.

2.6.1 Collection Service

Different types of Collection services are given to residential, commercial and industrial areas. Collection services for Residential areas depend up on the type of dwelling (low rise, detached, attached, high rise apartment etc.) The most common types of Residential Collection services include the following.

1. Curb

In this system the homeowner is responsible for placing the containers to be emptied at the curb (road side) on collection day and for returning the empty containers back to his house.

2. Alleys

This is collection of waste from the alley ways beside houses. Who will take the containers to the collection vehicles could be arranged between the owner of the house and the collection crew (the organization).

3. Set-out

Waste containers are set out from the homeowner's property by additional collection crews that go with the collection vehicle. The owner of the house is responsible for returning the empty containers to their storage location.

4. Backyard/set out set-back

Collection crew that goes with the collection vehicle are responsible for bringing out stored solid waste form the dwelling units and other activities related to collection. It is the only satisfactory system in which the house holder does not get involved.

2.6.2 Frequency of collection.

The frequency of collection depend on the quantity of solid waste, time of year, socioeconomic status of the area served, and municipal or contractor responsibility. In business districts refuse, including garbage from hotels and restaurants should be collected daily except on Sundays.

In residential areas, twice-a-week for refuse collection during warm months of the year and once a week at other times should be the maximum permissible interval. For garbage, it should be collected at least two times weekly in residential sections in summer and winter, however, most commercial establishments should be accorded daily collection service throughout the year

2.6.3 Methods of Loading the Solid waste to Vehicles

i. Direct lifting and carrying of loaded containers to the collection vehicle for emptying

ii. Rolling loaded containers on their rims or rollers to the collection vehicle

iii. Use of small lifts for rolling loaded containers to the collection vehicle

iv. Use of large container into which waste from small containers are emptied and finally lifted by mechanical means.

2.6.4 Types of Collection Systems

Solid waste collection systems may be classified from several points of view. These are:

1. Mode of operation
2. Equipment use
3. Type of waste collected

2.6.4.1 Mode of operation

Solid waste collection systems are classified according to their operation in to two categories.

These are:

Hauled container system: which is a system where the containers used for storage of wastes are hauled to the disposal site, emptied and returned. This system is ideally suited for the removal of wastes from sources where generation rate is high.

There are three main types of hauled container systems:

1. Hoist truck system
2. Tilt-frame container system
3. Trash-trailer system

Stationary container system: where the containers used for the storage of waste remain at the point of generation, except for occasional short trip to the collection vehicle.

There are two main types Stationary Container Systems

1. Mechanically loaded systems
2. Manually loaded systems

2.6.4.2 Equipment used

Some of the equipment used are containers, machineries, hand tools etc. Containers for hauled systems or operation have various sizes and shapes. Basically, since the system is used to haul wastes from sources where the route of generation is high large containers are provided. Hauled

containers system requires only one track, and one driver, to accomplish the collection cycle. But each container picked up must be returned back requiring a round trip travel.

2.6.5 Mathematical Analysis Collection System

Solid waste collection needs a lot of thinking and statistical and mathematical data to base the program. The following formulae are examples.

1. Haul container system

The time required per trip, which also corresponds to the time required per container, is equal to the sum of:

- The pick up
- At site
- And haul times

$$T_{hcs} = P_{hcs} + s + h \quad (2.5)$$

Where T_{HCS} = Time per trip for hauled container system, h/trip

P_{hcs} = pick up time per trip for hauled container system, h/trip s = at site time/trip h= Haul time/trip

For hauled container system Pick up and at site are relatively constant, but the haul time depends on speed and distance. From experience haul time may be approximated by:

$$h = a + bx \quad (2.6)$$

Where:

h = Total haul time, h/trip

a = Empirical constant h/trip

b Empirical constant h/mi

x. = Round trip head distance mi/trip Therefore:

$$T_{hcs} = P_{hcs} + s + a + bx \quad (2.7)$$

And the pick-up time for haul container system per trip for the haul container system is:

$$P_{hcs} = pc + uc + dbc \quad (2.8)$$

Where: P_{hcs} = pick-up time per trip pc = time required to pick up loaded container uc = time required to unload empty container dbc = time required to drive between container location Note: If average time required between containers is unknown use equation h = a + bx.

The number of trips that can be made per vehicle per day with a hauled container system can be determined by:

$$N_d = \frac{[H\ (1 - W) - (t1 + t2)]}{T_{hcs}} \quad (2.9)$$

Where: N_d = No of trips per day

H = Length of work day h/day

W=: Off-route factor, expressed as a fraction t1=time required to drive from dispatch station to the first container location. t2=time to drive from the last container location to the dispatch station.

T_{hcs}= Time per trip for hauled container system, h/trip

Note: (1-w) = off route factor varies from 0.10 – 0.25. Factor of 0.15 is representative for most operation.

The number of trips required per day can be estimated by the following expression:

$$N_d = \frac{v_d}{cf} \quad (2.10)$$

Where: N_d = Number of trips per day V_d= daily waste generation yd^3 per day c = Average container size, yd^3/trip f = Weighted average container utilization factor. (The container utilization factor is the fraction of the container volume occupied by solid waste. Because this factor will vary with the size of the container, a weighed container utilization factor should be used.

2. Stationary Container System

(For mechanically loaded vehicle)

For system using self-loading collection vehicles, the time per trip could be found out using the following equation.

$$T_{scs} = (P_{scs} + s + a + bx) \quad (2.11)$$

Where T_{scs}= Time per trip for stationary container system, h/trip P_{scs}. = pick up time per trip for stationary container system, h/trip

s. = at site time/trip

a=Empirical constant h/trip

b=Empirical constant h/mi

x. =Round trip haul distance mi/trip

For stationary container system, the pickup time is given by:

$$P_{scs} = Ct\ (uc) + (np - 1)(dbc) \quad (2.12)$$

Where: Pscs = pickup time per trip of stationary container system

C_t = No. of containers emptied per trip Uc = Average unloading time per container n_p = No. of containers per pick up location per trip dbc= average time spent driving between container locations ..h/container

The number of containers that can be emptied per collection trip is related directly to the volume of the collection vehicle and the compaction ratio that can be achieved. Thus:

$$C_t = \frac{vr}{cf} \qquad (2.13)$$

Where Ct = No. of containers emptied per trip v = volume of collection vehicle yd^3/trip r = compaction ratio yd^3/container c = container volume f = weighted average container utilization factor

The number of trips required per day can be estimated by using:

$$N_d = \frac{V_d}{vr} \qquad (2.14)$$

Where: N_d = No. of collection trip per day V_d= daily waste generation v = volume of collection vehicle yd^3/trip r = compaction ratio yd^3/container

2.7 Separation, Processing and Transformation of solid waste

2.7.1 Separation and processing of solid wastes

Solid waste managers in developing countries tend to pay little attention to the practice of separating and processing of solid wastes because the wastes they collect are between 50% to 90% organics, dirt and ashes. These municipal wastes, however, are amenable to composting or digestion, provided they contain very low levels of synthetic materials.

Key concepts in municipal waste processing.

i. Waste reduction includes all means of reducing the amounts of waste that must be collected and disposed of by solid waste authorities ranging from legislation and agreements within a community.

ii. Source reduction includes any procedure to reduce wastes at the point of generation, in contrast to sorting out recyclable components after they have been mixed together for collection.

iii. Recycling: the process of transforming materials into secondary resources for manufacturing new products.

iv. Redemption centre: waste trading enterprise that buys recyclable materials and sells to brokers. Sometimes also called "buy-back centre".

v. Producer responsibility: Producers of products or services accept a degree of responsibility for the wastes that result from the products/services they market, by reducing materials used in production, making repairable/recyclable goods, and/or reducing packaging.

vi. Resource recovery: Resource recovery means the obtaining of some economic benefit from material that someone has regarded as waste. It includes

vii. Reuse: being used for the same purpose again (such as refilling a soft drinks bottle);

viii. Recycling: processing material so that it can be used again as the same material, such as the processing of waste paper to make pulp and then new paper;

ix. Conversion - processing the material to make something different (such as producing padding for clothing and sleeping bags from plastic bottles, or producing compost from food waste)

x. Energy recovery - usually referring to the burning of waste so that the heat can be used for energy e.g. electricity.

2.7.2 Materials Recovered from Municipal solid Wastes

Materials that are separated for recycling from municipal solid waste are aluminium, paper, plastics, glass, ferrous metal, nonferrous metal, yard wastes, construction and demolition wastes and tires

2.7.3 Techniques involved in resource recovery

Compaction which mechanically reduce the volume of solid waste

Chemical volume reduction by incineration

Mechanical size reduction by shredding, grinding and milling

Component separation by hand sorting, air separation magnetic separation and screening

2.7.4 Promoting waste reduction and materials recovery at the national and local levels

Action for waste reduction can take place at both national and local levels. At the national level, the main routes to waste reduction are:

i. redesign of products or packaging;

ii. promotion of consumer awareness; and

iii. Promotion of producer responsibility for post-consumer wastes (this applies mostly to industrialized countries).

At the local level, the main means of reducing waste are:

i. diversion of materials from the waste stream through source separation and trading;

ii. recovery of materials from mixed waste;

iii. Pressure on national or regional governments for legislation on redesigning packaging or products; and iv. Support of composting, either centralized or small-scale.

2.8 Transport and Transfer of Solid Wastes

The transfer and transport of solid wastes refers to the means, facilities, and appurtenances used to effect the transfer of these wastes from one location to another, usually more distant location.

Typically, the contents of relatively small collection vehicles are transferred to larger vehicles that are used to transport the waste over extended distances either material recovery facilities or to disposal sites. Transfer and transport operations are also used in conjunction with material recovery facilities to transport recovered materials to markets or waste- to- energy facilities and to transports residual materials to landfills.

Transfer stations are used to collect the refuse at a central location and to reload the wastes in to a vehicle where the cost per kilogram-kilometre ton-mile will be less for the movement of the ultimate waste to the disposal site. Transfer stations are employed when the disposal site is situated at significant distance from the point of collection.

A transfer station can reduce the cost of transporting refuse by reducing man power requirement and total kilometres. A transfer station may include stationary compactors, recycling bins, material recovery facility, transfer containers and trailers, transfer packer trailers, or mobile equipment.

Transfer and transport station should provide welfare facilities for workers (lockers, toilets, showers); small stores for brooms, shovels, cleaning materials, lubricants, parking facilities for hand trucks, sweepers , refuse collectors, and office and telephone for the district inspector.

2.9 Solid Waste Disposal

In disposal of solids wastes, it is recommended that the following will be done to avoid any risks:

i. the disposal site to be 30 meters from water sources in order to prevent possible contamination

ii. prevention of underground water pollution should be taken into account

iii. iii. Radioactive materials and explosives should not be together. iv. Site should be fenced to keep way scavengers.

iv. all surface of dump should be covered with materials

v. All wastes should be dumped in layers and compacted.

vi. disposal site should be about 500 meters from residential areas

2.9.1 Solid waste disposal methods

Generally there are several methods of solid waste disposal that can be utilized. These methods are:

1. Ordinary open dumping
2. controlled tipping/burial
3. Hog feeding
4. Incineration
5. Sanitary landfill
6. Composting
7. Grinding and discharge in to sewer
8. Dumping into water bodies
9. Disposal of corpus

1. **Open dumping**

Some components of solid waste such as street sweepings, ashes and non-combustible rubbish are suitable for open dumping. Garbage and any other mixed solid wastes are not fit or suitable because of nuisance and health hazard creation. Generally, solid waste is spread over a large area, providing sources of food and harbourage for flies, rats and other vermin. It causes unsightly odour and smoke nuisance and hazards.

Advantage of open dumping

i. Can take care of all types of solid wastes except garbage

ii. It causes less health problem if proper site is selected.

iii. Needs less labour and supervision

Disadvantage of open dumping

i. Attraction of flies, mosquitoes and other insects as well as stray dogs, rats, and other animals.

ii. Creation of breeding sites for rodents, arthropods and other vermin Creation of smoke, odour and nuisance

iii. It makes the lands and other surrounding areas useless.

iv. It leads to cuts and wounds.

v. It attracts scavengers, both humans and animals.

Controlled tipping/burial

Controlled or engineered burial is known as Controlled Tipping or Sanitary Land Fill System. In places where there is no organized service, this system can be done by digging shallow 2 trenches, laying down the generated waste in an orderly manner, compacting the waste manually or mechanically and covering with adequate depth of earth or ash at the end of each day's work. The process is repeated each day systematically at appropriate locations. This system can be considered an adaptation of what is technically called the SANITARY

LANDFILL system in municipal solid wastes management service.

Hog feeding

The feeding of garbage to hogs has been practiced for many years in different parts of the world. But there is surprising high incidence of trichinosis among hogs which are fed with uncooked garbage. To use garbage for hog feeding it has to be cooked at temperature of 100 ^{0}C for 30

minutes just to be on safe side. Cooking the garbage before Hog feeding will not reduce the food value.

Incineration

Incineration is a process of burning the combustible components of garbage and refuse.

The disadvantage of this method is that only combustible materials are incinerated, hence there is a need for separation of the waste into combustible and non-combustible. The noncombustible needs separate disposal. Generally there are two types of incinerators, the open and the closed systems.

In the open system the refuse is incinerated in a chamber open to the air; while the closed system contains a special chamber designed with various parts to facilitate incineration. It requires a chimney of appropriate height to provide a good flow of air thorough the combustion chamber. There are varieties of designs for small scale incinerators. The size can be varied depending on the volume of the refuse to be incinerated.

Landfill design, construction, and operation

The problem of managing the increased volume of solid waste is compounded by rising public resistance to siting new landfills. There are five general phases of landfill construction:

i. site selection;

ii. site investigation;

iii. design;

iv. daily operation; and,

v. Landfill completion or closure.

The primary methods used for landfill are called:

1) Area method;

2) Trench method; and,

3) Depression method.

The **area method** is used when the site conditions do not allow the excavation of a trench.

Typically an earthen levy is constructed and refuse is placed in thin layers against this levy and compacted. In a day, the compacted waste will reach a height of approximately 200 to300 meters and at the end of the day, a minimum of 15 centimetres inches of daily soil cover is applied as a barrier to disease vectors (e.g., it prevents the hatching of flies and the burrowing of rodents) and also prevents fires, odours, scavenging, and blowing litter. When the final design height is reached, a final soil cover is placed on top of the material. Each of the day's work of refuse is entombed in a "cell."

The **trench method** is most suitable in locations where the depth to the groundwater table does not prevent one from digging a trench in the ground. In this method, a trench is excavated with a bulldozer. Refuse is then placed in the trench and placed in thin layers that are compacted. The operation continues for the day until the desired daily height is reached. Again, daily cover is placed over the refuse to produce a "cell."

The **depression method** occurs at sites where natural features such as canyons, ravines, dry borrow pits, and quarries are available that can be filled in. Care is given to the hydrology of the site. For example, canyons are filled from the inlet to the outlet to prevent backing up of water behind the deposited refuse.

Closure When a landfill has reached its capacity, it is ready for closure. The final cover must be designed and constructed to have a permeability less than or equal to the bottom liner system or natural subsoil, or a permeability no greater than $1x10^{-5}$ cm/sec, whichever is lower.

The final cover must be constructed of an infiltration layer composed of a minimum of 45 centimetre of earthen material to minimize the flow of water into the closed landfill. The cover must also contain an erosion layer to prevent the disintegration of the cover. The erosion layer must be composed of a minimum of 15 centimetre of earthen material capable of sustaining plant growth.

A sanitary landfill is a site where solid wastes are placed on or in the ground at a carefully selected location by means of engineering techniques that minimize pollution of air, water and soil, and other risks to man and animals.

Landfill operation site layout

In planning the layout of a sanitary landfill site, the location of fill must be determined by:

i. access roads
ii. equipment shelters
iii. scales to weigh wastes of needed
iv. storage site for special wastes
v. top soil stock pile sites
vi. landfills area and extension

A. Operation schedule

i. arrival sequence for collection vehicles
ii. traffic patterns at the site
iii. Time sequence to be followed in the filling operation.
iv. effects of wind and other climatic conditions
v. commercial and public access

B. Equipment requirement

The type, size and amount of equipment required for sanitary landfill will be governed by size of community served, the nature of site the selected, the size of the landfill and the methods of operation. The types of equipment that have been used at sanitary landfill include: crawler, scrapers, compactors and water trucks.

Advantages of sanitary landfill

i. it is relatively economical and acceptable method

ii. initial investment is low compared to other proven methods

iii. the system is flexible - can accommodate increase in population

iv. May result in low collection cost, as it permits continued collection of refuses. All types of refuses may be disposed of the site may be located close to or in populated areas, thus reducing the length of hauling cost of collection

v. it enables the reclaiming of depression and sub marginal lands for use and benefits of the community

vi. completed landfill areas can be used for agricultural and other purpose

vii. unsightliness, health hazards and nuisance of open dumping can be eliminated ix. may be quickly established

viii. several disposal sites may be used simultaneously

Disadvantages of sanitary landfill

i. Sometimes suitable land within economical hauling distance may not be available.

ii. Relatively large areas of land are required.

iii. slow decomposition of refuse in fill

iv. An adequate supply of good earth cover may not be readily accessible.

v. If not properly located seepage from fills into streams may increase the chance for stream pollution.

vi. Needs a careful and continuous supervision by skilled personnel.

vii. If not properly done can deteriorate into open dumping. (ordinary dumping) viii. Special equipment are required.

CHAPTER 3

3.0 METHODOLOGY

3.1 Study Area

This study was carried out in Oba market complex in Oredo Local Government Area, Edo State Nigeria. It lies between Abehe street ($6^0$20'6.378"N, $5^0$37'7.24"E), Ekpenede Street

($6^0$20’4.435”N, $5^0$37’17.118”E), and Ore Oghene Road ($6^0$20’9.43”N, $5^0$37’7.936”E) with an estimated floor area of 31578m^2 (Google Maps, 2016). Like most places in Benin, it experiences two distinct climatic seasons; namely dry (October to March) and wet (April to September) seasons. A period of cold, dry, dusty winds known as “Harmattan” occurs from December to February annually. Benin, of which Oba market is a part, has annual average high temperature range between 30.7^{0}C and average annual precipitation of 2074mm (climatedata.eu, 2016). The Oba Market Complex has a total floor area of 63156m^2. Its traders are mainly women selling food, shoes, clothing and a whole lot of products. A welldeveloped network of major roads, access roads and streets also exist in the Market. This assemblage of infrastructure makes Oba market the hub of economic and industrial activities generating different types of solid wastes. With the upsurge in the number of traders, volume of activities, and in fact, the increasing trend in commercial activities in the market, there has been a tremendous increase in the volume of solid waste generated within the area.

Fig3-1 Map of Oba Market

3.2 DATA COLLECTION

Data for this study were generated from a lot of sources. The first sets of data were those on waste generation rates. For effective collection of these data, plastic bags were distributed to 25 shops selected randomly for the storage of solid waste generated for a period of 1 day. Each sample of the solid wastes was collected daily and coded for recording purposes. At the end of the 1-day period, each sample was measured in terms of weight and volume and values obtained were recorded for computation. Detailed procedure for the collection of data for the generation rate is outlined on the subsection below.

The second sets of data were those on the collection operations. Two sets of questionnaires were prepared by the students in accordance to the ***Annex 2 of: WHO (1996). Guides for Municipal Solid Waste Management in Pacific Countries. Healthy Cities Healthy Islands Document Series, No 6. World Health Organization, Western Pacific Region.*** The first set of questionnaire was targeted to the market traders and a total number of 100 questionnaires were administered.

The second set of questionnaire was targeted to the authority responsible for the collection of solid waste within the study area. The authority responsible for the collection of solid waste management in Oba market is the Edo State Waste Management board. Other forms of data are collected from other literatures concerned with Solid Waste Management Practice within the market environments.

All the data obtained were carefully sorted out, serialized and analysed. Data on quantity of waste collected, pick-up time, haul-time, off-route time etc., were all fitted into a model for evaluation of waste collection efficiency in the area.

3.2.1 PROCEDURE FOR SOLID WASTE GENERATION SURVEY

3.2.1.1 Selection of Sample Area

The selection of the sample area for solid waste generation survey was performed in accordance to instructions outlined in Annex 1 of: WHO (1996). *Guides for Municipal Solid Waste Management in Pacific Countries. Healthy Cities - Healthy Islands Document Series, No 6. World Health Organisation, Western Pacific Region.* However, a total number of 25 shops were selected for the experiment instead of 50. These 25 shops were further divided into six categories namely: Food items/vegetable stores, provision stores, clothing and jewelleries, cosmetics, meat/fish and others respectively.

The equipment used and the procedure followed are outlined below.

3.2.1.2 Equipment

Plastic bags - 1 (day) x 25 shops

Weighing scale

Bucket - (a) to measure volume of waste; and (b) To be used as a container for weighing

Plastic sheet - to spread waste over it for sorting

Gloves - for workers to handle waste

3.2.1.3 Preparation of Sample

i. Numbers were assigned to shops for the purpose of data recording and analysis.

ii. Plastic bags were coded by markers according to the numbers assigned to shops.

iii. Survey of floor area were carried out by tape measurement and recorded in the data sheet.

3.2.1.4 Procedure

i. The plastic bags were collected from the respective shops according to their number.

ii. Each plastic bag was weighed and the weight was recorded in the data sheets according to the numbers assigned to the shops.

iii. The waste were separated on the plastic sheet into different types (e.g. vegetables/putrescible matter, bones, paper, textiles, plastics, grass/leaves/wood, leather/rubber, metals, glass/ceramic, miscellaneous). The separated waste were put into different plastic bags for weight measurement.

iv. The weight of each type of waste was measured and recorded.

v. The waste was dumped properly and the equipment used were cleaned.

3.2.2 SURVEY QUESTIONNAIRES

3.2.2.1 Structure of Questionnaire for Market Traders

The structure of the questionnaires as used in the market is categorized into the following operations corresponding to the functional elements of solid waste management.

The Questionnaire is structured in such a manner as to obtain information on the necessary functional operations associated with solid waste management. It contains 18 questions cutting across operations from collection to disposal

The cover page of the questionnaires opens with a preface and at the bottom, viable information such as the name, sex and nature of the business is obtained.

Question 1 seeks to obtain information on the awareness of the shop owners to the term “Solid Waste Management.”

Question 2 seeks to obtain information on the kinds of commodity being sold by shop owners.

Question 3 seeks to obtain information on the kind of waste that is mostly generated by the respective shop owners and the quantity generated.

Question 4-6 deals with the generation aspect of solid waste. It considers factors such as variation in the quantity generated during the days of the week, months of the year with particular emphasis on festive seasons.

Question 7-8 considers the onsite storage of the solid waste generated. It seeks information on the type and size of storage container adopted by the shop owners.

Question 8-10 deals with the onsite handling of the solid waste as generated by the shop owners. It seeks information on the collection method and the frequency of collection by the shop owners for onsite storage.

Question 11 deals with the onsite processing and recovery/reuse of the solid waste.

Question 12-15 deals with the collection service as provided by the contractor. It seeks information on the frequency of collection by the contractor, equipment used by the contractor as observed by the shop owners, amount of money being remitted at the end of the month for service provided.

Question 16-17 considers the disposal aspect of the practice. It seeks information on the disposal facility as used by the board and also methods of disposal by the shop owners.

Question 18 seeks to obtain feedback and suggestions on possible ways of improving the management of solid waste that is being generated by the respective shop owners.

3.2.2.2 Structure of Questionnaires for Collection Authority

The Format of the questionnaire is adapted from ***Annex 2 of: WHO (1996). Guides for Municipal Solid Waste Management in Pacific Countries. Healthy Cities Healthy Islands Document Series, No 6. World Health Organization, Western Pacific Region.***

The survey questionnaire is mainly concerned on solid waste management service survey. As such, it is targeted to Boards and Contractors who provides such services. It is organized in sections. Such include:

Introduction

This questionnaire is designed to facilitate the assessment of the current situation of solid waste management service in an urban area. The information collected by this questionnaire for all the urban areas in a country, in turn, can be used to evaluate the status of the solid waste management sector in the country. To enable an accurate assessment, it is important that all information requested in the questionnaire should be provided as completely and accurately as possible.

General Information

Seeks to obtain the name and address of authority responsible for solid waste management, the area of jurisdiction, the estimated population, the department responsible for solid waste management and the functions performed by the department.

Planning and Development

This section seeks to obtain information on physical characteristics of solid waste, Storage and the standardization policy of the authority with regards on-site storage equipment. Also, the amount of waste collected per day is obtained in this section.

Operation

The operation section seeks to obtain information on the Contractual services offered by the Contractor. Also, data regarding vehicles and equipment associated with the operation are obtained

Human Resource

Personnel for solid waste management service is obtained.

3.3 METHODS EMPLOYED FOR DATA ANALYSIS

Computation of weight of solid waste generated

$$Average\ daily\ solid\ waste\ generated$$

$$= \frac{Total\ average\ weight\ of\ solid\ waste}{Total\ floor\ area} \qquad 3.1$$

$$Total\ weight\ generated = average\ daily\ solid\ waste\ generated\ per\ floor\ area \times total\ floor\ area\ of\ Oba\ Market \qquad 3.2$$

Characterization of solid waste

$$Percentage\ composition\ of\ X$$

$$= \frac{weight\ of\ X}{Total\ weight\ of\ solid\ waste} \times 100 \qquad 3.3$$

Collection System Computation

This evaluation was carried out by the application of a structural time-based model proposed by Tchobanoglous et al (1993) which is used for predicting the level of efficiency in solid waste collection for a stationery container system of waste collection. According to this model, the time required per trip of waste collection is given by the equation:

For system using self-loading collection vehicles, the time per trip could be found out using the following equation.

$$T_{scs} = (P_{scs} + s + a + bx) \qquad 3.4$$

Where T_{scs}= Time per trip for stationary container system, h/trip

P_{scs}. = pick up time per trip for stationary container system, h/trip

s. = at site time/trip

a=Empirical constant h/trip

b=Empirical constant h/mi

x. =Round trip haul distance mi/trip

For stationary container system, the pickup time is given by:

$$P_{scs} = Ct\ (uc) + (np - 1)(dbc) \quad 3.5$$

Where: Pscs = pickup time per trip of stationary container system

C_t = No. of containers emptied per trip Uc = Average unloading time per container n_p = No. of containers per pick up location per trip dbc= average time spent driving between container locations .h/container

The number of containers that can be emptied per collection trip is related directly to the volume of the collection vehicle and the compaction ratio that can be achieved. Thus:

$$C_t = \frac{vr}{cf} \quad 3.6$$

Where Ct = No. of containers emptied per trip v = volume of collection vehicle yd^3/trip r = compaction ratio yd^3/container c = container volume f = weighted average container utilization factor

The number of trips required per day can be estimated by using:

$$N_d = \frac{V_d}{vr} \quad (3.7)$$

Where: N_d = No. of collection trip per day V_d = daily waste generation v = volume of collection vehicle yd^3/trip r = compaction ratio yd^3/container

Efficiency in waste collection "EWC" may then be estimated as

$E_{wc} = 1 - w + w_o$

W_o = allowable off-route activity time

W = off-route factor

This implies that if the off-route factor (w) is equal to the allowable off-route factor (W_o) i.e.

[$W = W_o$], then the collection system is 100% efficient.

CHAPTER FOUR

4.0 ANALYSIS AND DISCUSSION OF RESULTS 4.1 Survey Data of Oba Market

Table 4.1 Latitude and Longitude of Oba Market

Boundary	Latitude	Longitude

Abehe street, Benin city	$6^0$20’6.378”	$5^0$37’7.24”
Ore Oghene Road	$6^0$20’9.43”	$5^0$37’7.936”
Abehe Street	$6^0$20’1.863”	$5^0$37’15.033”
Ekpenede Street	$6^0$20’4.435”	$5^0$37’17.118”

Source: (Google Earth, 2016)

Figure 4.1 Survey Area of Oba Market (Google Maps, 2016) Source:

Google Maps, 2016.

4.2 Data Obtained From Questionnaire Survey

Table 4.2. Gender Distribution

Gender	**Frequency**	**Percentage**

Male	35	35%
Female	65	65%
Total	100	100%

Source: Field Survey, 2016.

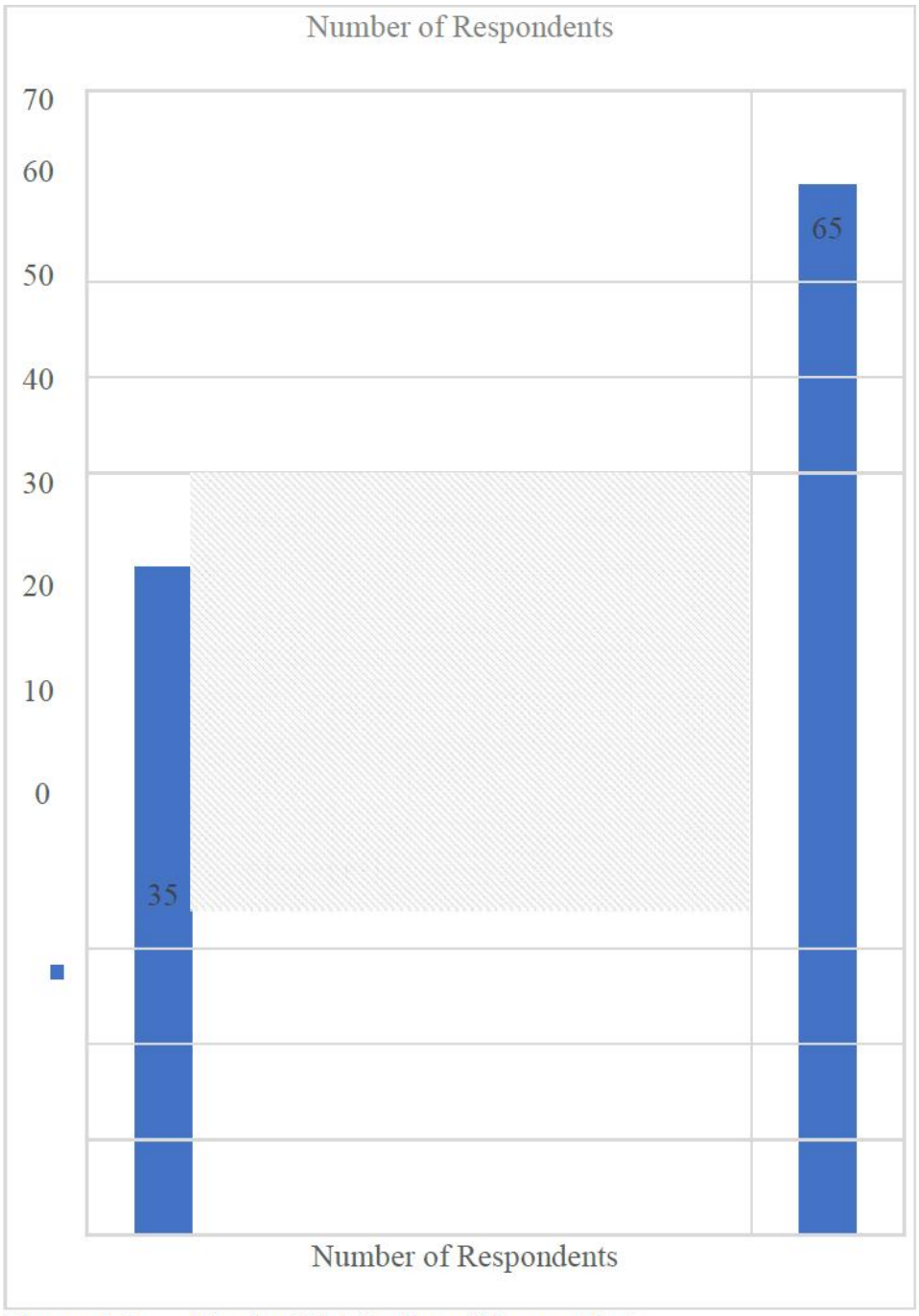

Figure 4-2 Gender Distribution of Respondents.

Table 4.3. Category of shops visited

Category	Frequency	Percentage
Food items / vegetables	20	20%
Provision Store	20	20%
Clothing / Jewelleries	15	15%
Cosmetics	15	15%
Meat Sellers & Fish	20	20%
Others	10	10%
Total	100	100%

Source: Field Survey, 2016.

Figure 4-3 Category of shops visited

Table 4.4 Number of Respondents aware of the term "Solid Waste Management"

Response	Frequency	Percentage
Yes	17	17%
No	83	83%
Total	100	100%

Source: Field Survey, 2016.

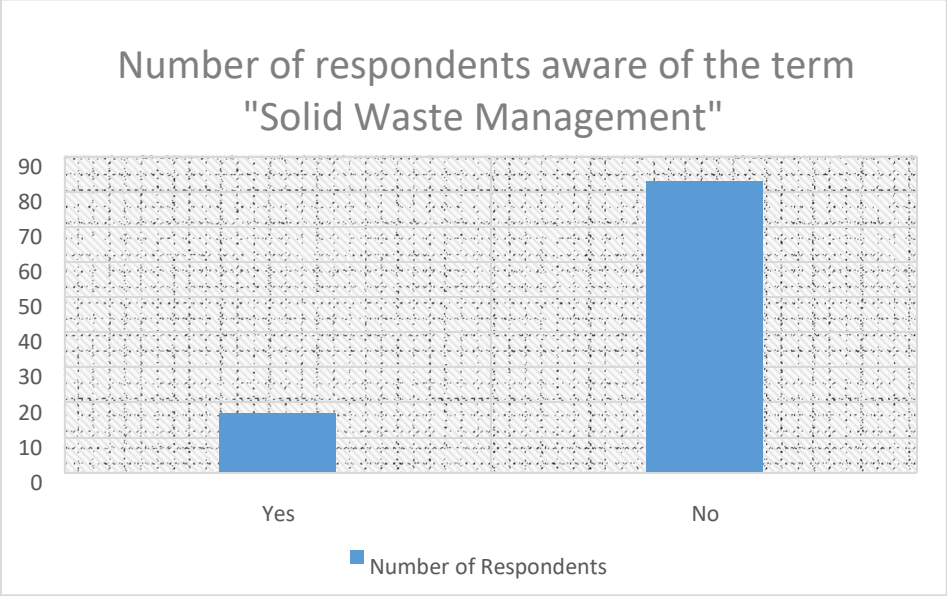

Figure 4-4 Number of Respondents aware of the term "Solid Waste Management"

Table 4.5 Weekly variation in Generation of Solid Waste

Response	**Frequency**	**Percentage**
Constant Generation	59	59%
Depends on Sales	17	17%
Saturdays	13	13%
Mondays	4	4%
No observation	7	7%
Total	100	100%

Source: Field Survey, 2016.

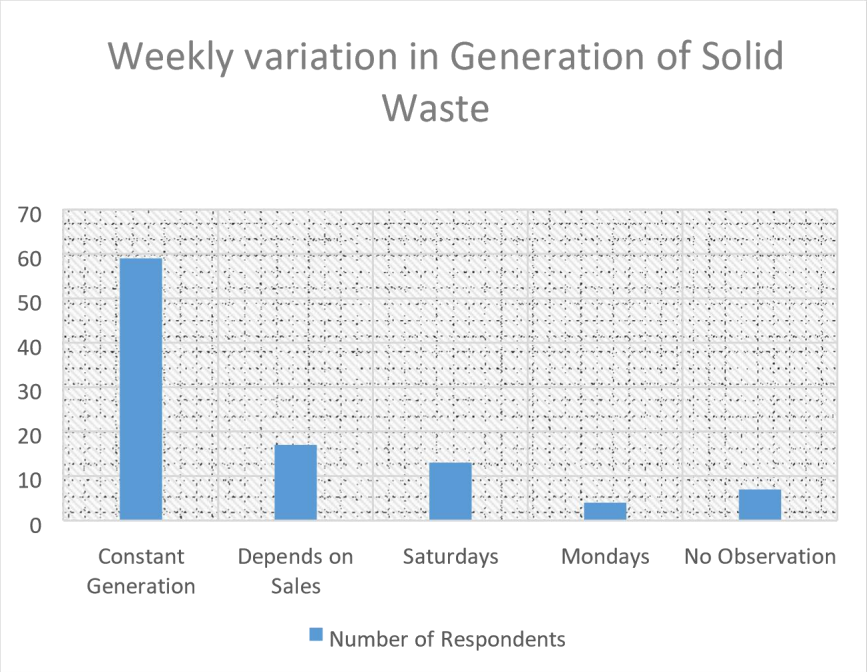

Figure 4-5 Weekly variation in Generation of Solid Waste **Table**

4.6 Monthly variation in Generation of Solid Waste

Response	Frequency	Percentage
Constant Generation	47	47%
August	9	9%
December	15	15%
Depends on Sales	4	4%
No observation	25	25%
Total	100	100%

Source: Field Survey, 2016.

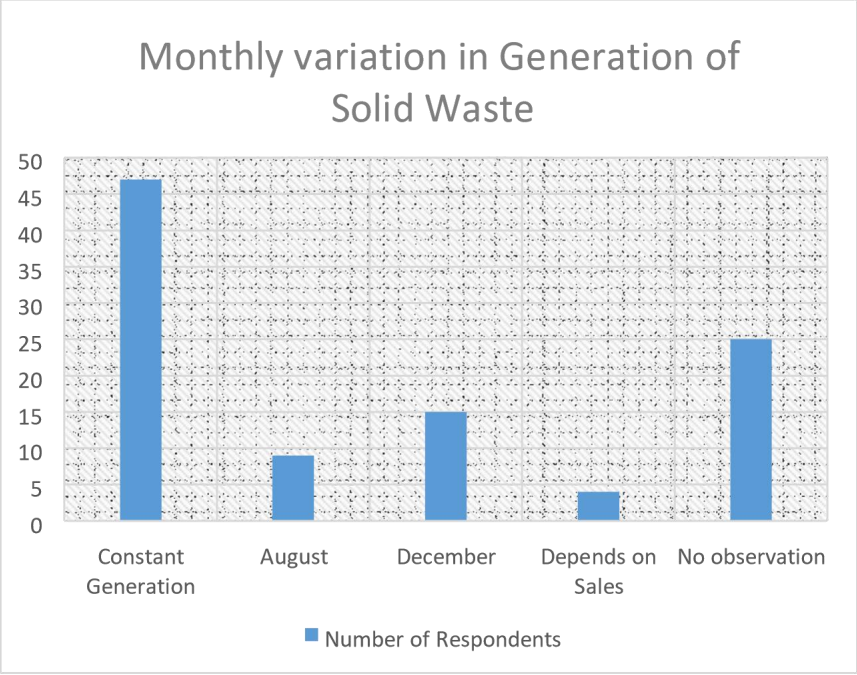

Figure 4-6 Monthly variation in Generation of Solid Waste

Table 4.7. Generation of Solid waste on Festive seasons

Response	Frequency	Percentage
Yes	67	67%
No	33	33%
Total	100	100%

Source: Field Survey, 2016.

Figure 4-7 Generation of Solid waste on Festive seasons **Table 4.8**

Number of Respondents using Storage container

Response	**Frequency**	**Percentage**
Yes	92	92%
No	8	8%
Total	100	100%

Source: Field Survey, 2016.

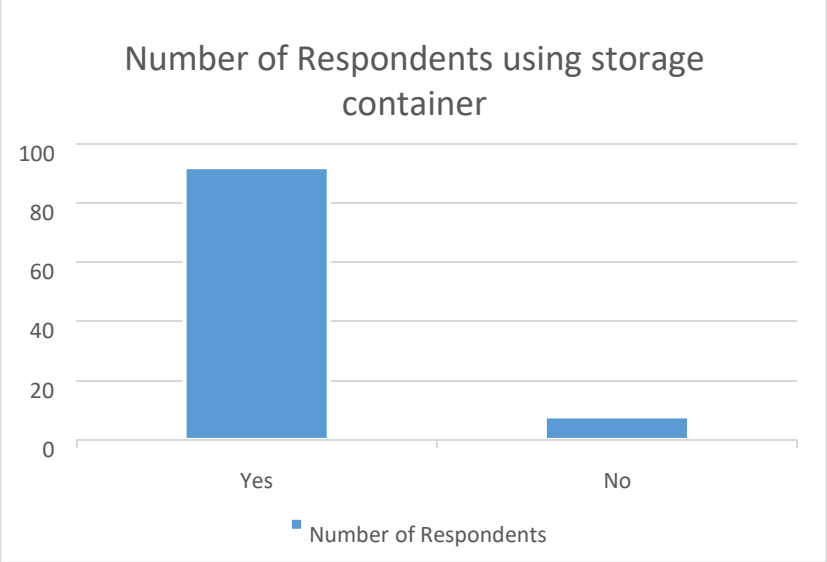

Figure 4-8 Number of Respondents adopting storage container

Table 4.9 Size of Storage Container

Response	Frequency	Percentage
Small	68	73.91%
Medium	17	18.48%
Large	7	7.61%
Total	92	100%

Source: Field Survey, 2016.

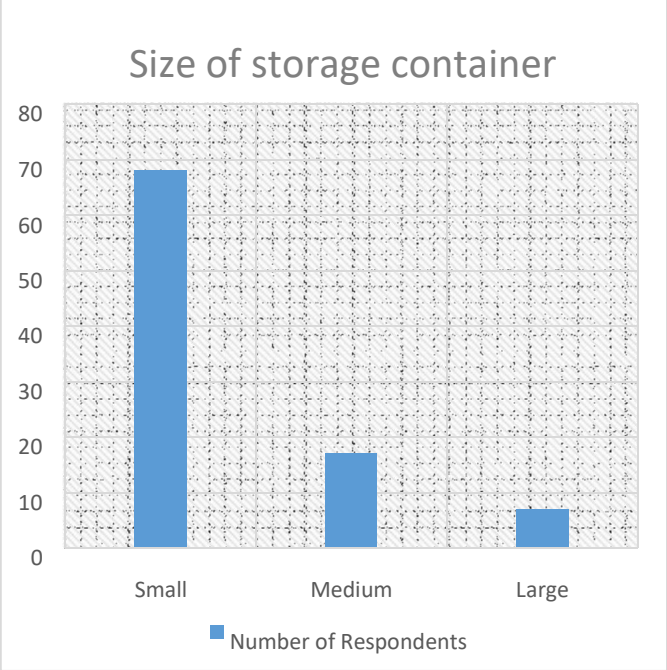

Figure 4-9 Size of Storage Container

Table 4.10 Collection of same type of waste in a storage container

Response	Frequency	Percentage
Yes	11	11.96%
No	81	88.04%
Total	92	100%

Source: Field Survey, 2016.

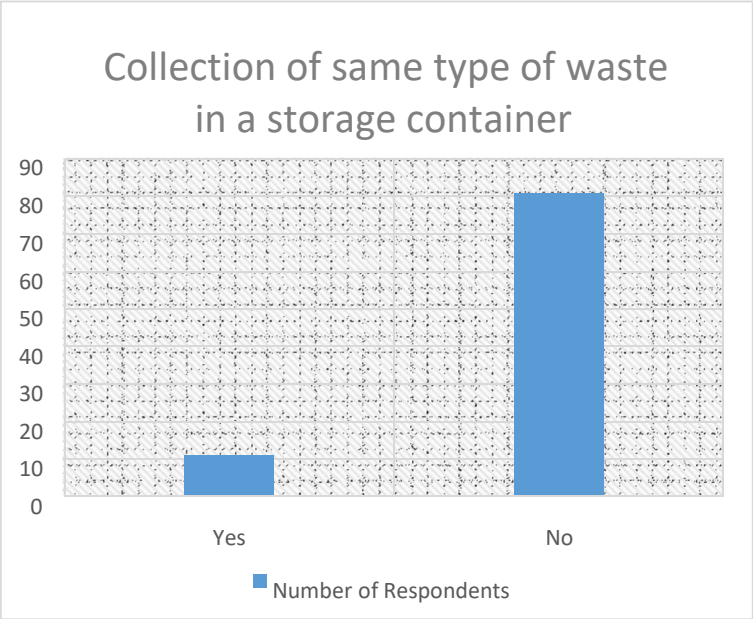

Figure 4-10 Collection of same type of waste in a storage container

Table 4.11 Frequency of on-site collection by traders

Response	Frequency	Percentage
Everyday	62	67.39%
Once in 2 days	23	25%
Once in a week	7	7.61%
Total	92	100%

Source: Field Survey, 2016.

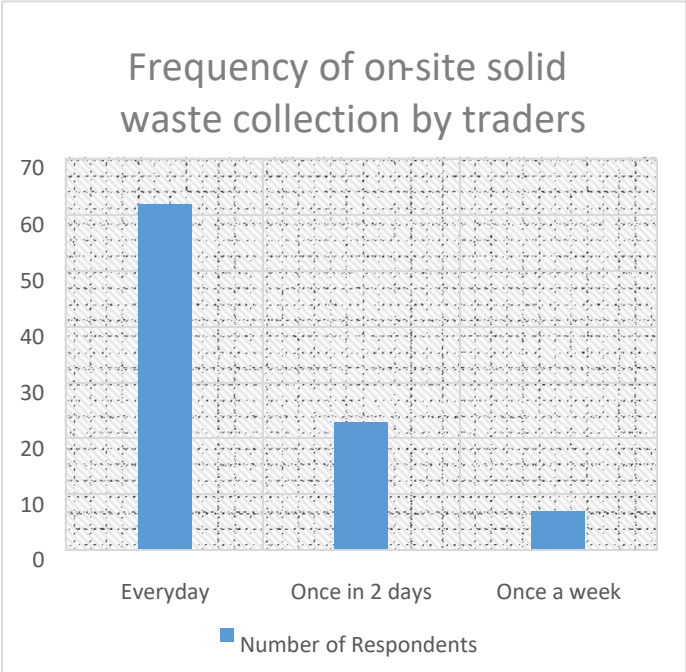

Figure 4-11 Frequency of on-site collection by traders

Table 4.12 Reuse of Solid waste stored

Response	Frequency	Percentage
Yes	14	14%
No	86	86%
Total	100	100%

Source: Field Survey, 2016.

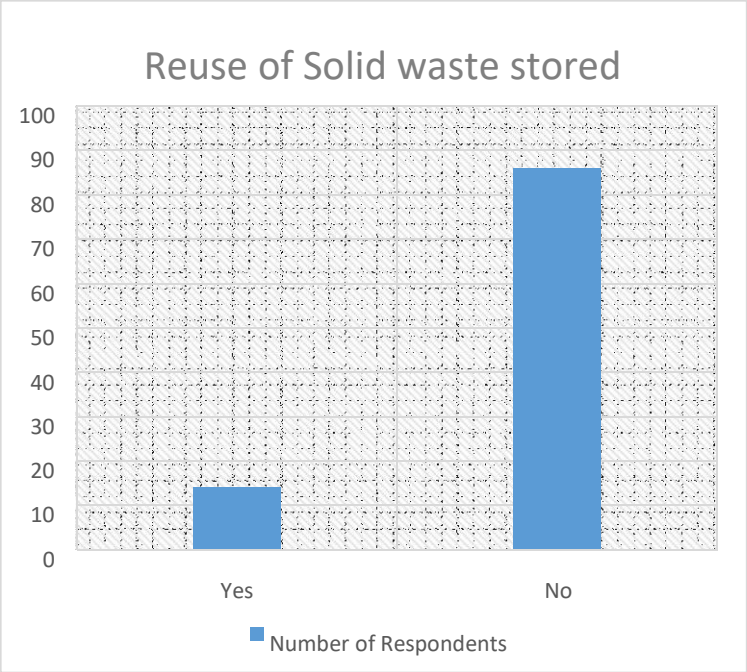

Figure 4-12 Reuse of Solid Waste Stored

Table 4.13 Form of collection service

Response	Frequency	Percentage
General Collection Ground	81	88.04%
Take waste to the Collection Vehicle	11	11.96%
Total	92	100%

Source: Field Survey, 2016.

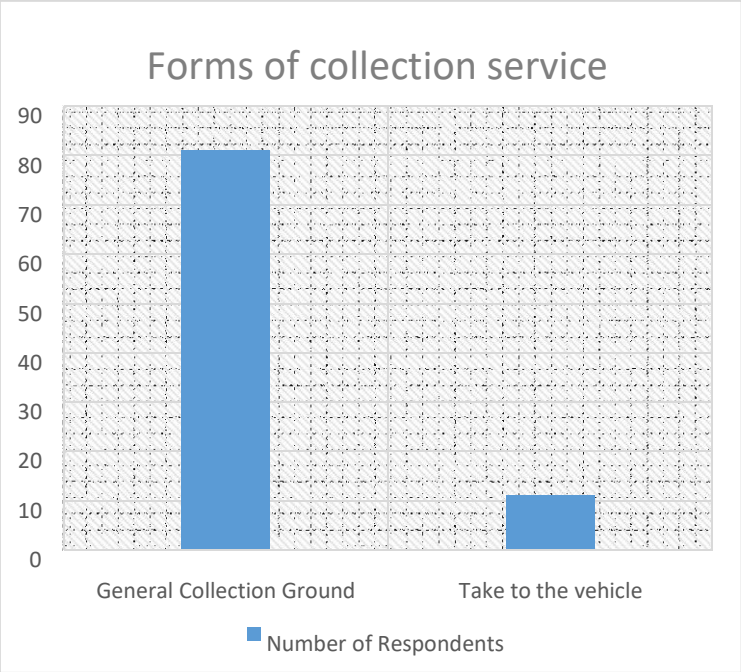

Figure 4-14 Form of collection service

Table 4.14 Number of respondents who know the disposal site

Response	Frequency	Percentage
Yes	5	5%
No	95	95%
Total	100	100%

Source: Field Survey, 2016.

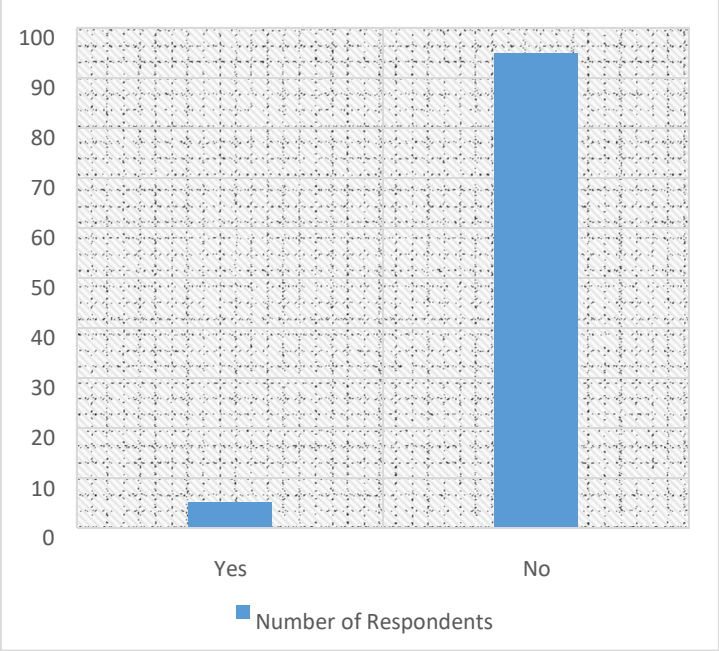

Figure 4-14 Number of respondents who know the disposal site

Table 4.15 Number of Respondents who dispose their wastes themselves

Response	Frequency	Percentage
Yes	100	100%
No	0	0%
Total	100	100%

Source: Field Survey, 2016.

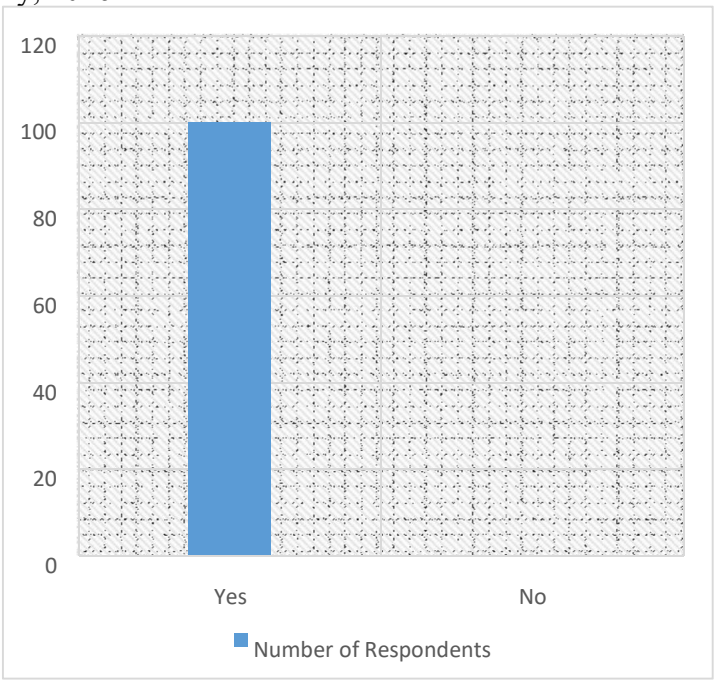

Figure 4-15 Number of Respondents who dispose their wastes themselves

Table 4.16 Suggestions on better alternatives on Solid Waste Management

Response	Frequency	Percentage
Yes	28	28%
No	72	72%
Total	100	100%

Source: Field Survey, 2016.

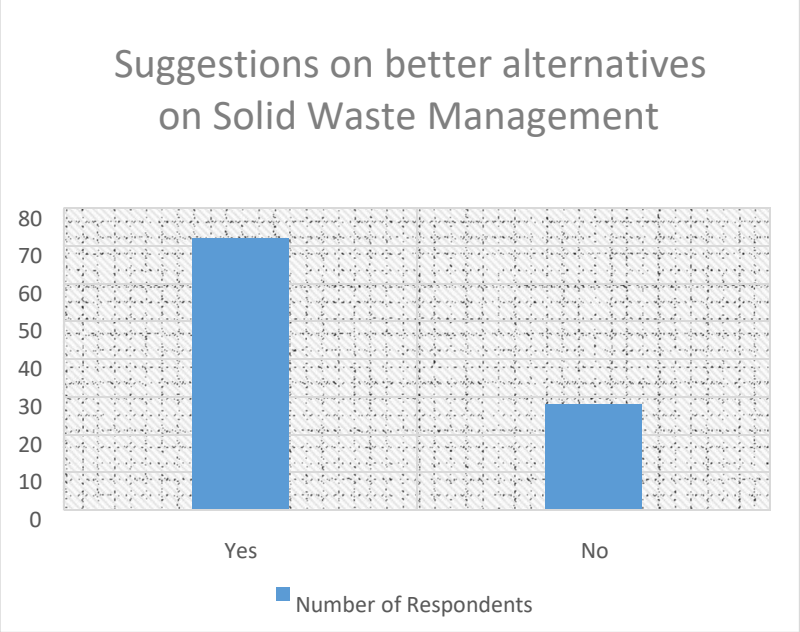

Figure 4-16 Suggestions on better alternatives on Solid Waste Management

4.3 DATA OBTAINED FROM FIELD WORK SURVEY

Table 4.17 Data Sheet for Daily Generation Rate

Shop/ Office No	Shop Category	Average Floor Area m2	Average Daily Weight (kg)
1	F	4	2.400
2	P	4	0.440
3	P	4	0.450
4	F	4	2.500
5	V	4	23.040
6	F	4	1.080
7	CJ	4	0.640
8	M	4	2.400
9	V	4	19.080
10	M	4	3.080
11	F	4	2.400
12	P	4	0.640
13	M	4	2.040
14	V	4	22.300
15	P	4	0.340
16	O	4	1.040
17	M	4	2.600
18	V	4	15.080

19	V	4	21.040
20	F	4	2.240
21	C	4	0.500
22	CJ	4	0.340
23	P	4	0.440
24	O	4	0.840
25	C	4	0.240
Total		100	127.19

F - Food Items P - Provision

CJ - Clothing/Jewelleries

M - Meat Sellers & Fish O - Others.

Source: Field Survey, 2016.

4.3.1 COMPUTATION OF SOLID WASTE GENERATED IN OBA MARKET.

From the table 4.17 above,

Total average daily weight of solid waste generated = 127.19kg

Total average areas of stores = 100m^2

$$\therefore \textbf{Average solid waste generated per area per day} = \frac{127.19}{100}$$

$$= \textbf{1.2719kg/m}^2\textbf{/day}$$

Estimated area of Oba Market Complex = 31578m^2

Since Oba Market Store Complex is a Storey building,

Therefore, total estimated area = 31578 × 2 = **63156m^2**

Waste generated due to the area = 63156 × 1.2719 = **80328.1164kg/day ≈ 81 tonnes**

Table 4.18 Data Sheet for Composition

Category	Total Weight (kg)	Percentage composition (%)
Vegetable / Putrescible	68.60	53.97
Paper	15.30	12.04
Textiles	5.10	4.01
Plastics	21.40	16.84
Glass	4.40	3.40
Metals	4.80	3.80
Others	7.50	5.94
Total	127.1	100

Source: Field Survey, 2016.

4.3.2 COMPUTATION OF CHARACTERIZATION OF SOLID WASTE IN OBA MARKET

From the table 4.18 above,

Percentage composition of vegetable / putrescible $= \frac{68.60}{127.1} \times 100 = 53.97\%$

Percentage composition of Paper $= \frac{15.30}{127.1} \times 100 = 12.04\%$

Percentage composition of Plastic $= \frac{5.10}{127.1} \times 100 = 4.01\%$

Percentage composition of Textiles $= \frac{21.40}{127.1} \times 100 = 16.84\%$

Percentage composition of Metals $= \frac{4.40}{127.1} \times 100 = 3.40\%$

Percentage composition of Glass $= \frac{4.80}{127.1} \times 100 = 3.80\%$

Percentage composition of others $= \frac{7.50}{127.1} \times 100 = 5.94\%$

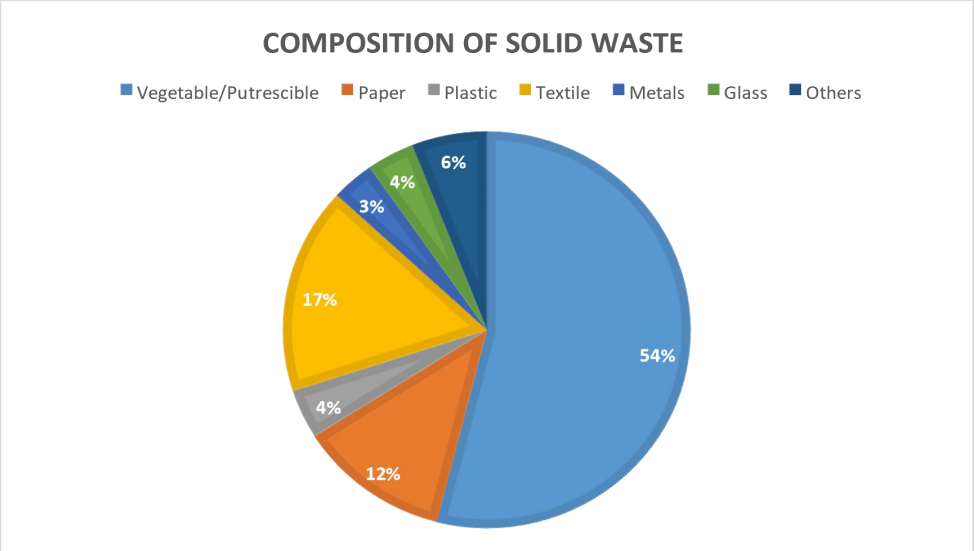

Figure 4-17 Percentage Composition of Solid Waste

4.4 DATA OBTAINED FROM THE BOARD.

Table 4.19 Personnel involved in Waste Collection Process in Oba Market

Company	**Waste Collection Day**	**Number of Units**				**Total**
Edo State Waste Management Board		Manager	Supervisor	Labour	Drivers	
	Other Day	1	2	5	1	9
	Sanitation Day	1	2	7	2	12

Source: Field Survey, 2016.

Table 4.20. Type, Capacity, Market Price and Number of Units of Collection Equipment

Used in Oba Market

Equipment	**Capacity in tonnes**	**Number of Units**
Compactor	15	2
Roll on Roll up	3	3
Green lifter Truck	8	1
NDDC Skip Truck	5	15
Open tippers	5	3

Source: Field Survey, 2016.

Table 4.21. Estimated Quantity of Waste Collected/ Day

Company	**Waste Collection Day**	**Average Estimated Weight Collected By Equipment in tonnes**
Edo State Waste Management Board		
	Other Day	90
	Sanitation Day	110

Source: Edo State Waste Management Board, 2016 (interview)

Table 4.22 Disposal

Items	Disposal Site		
	Site 1	**Site 2**	**Site 3**
Name of site	Otofure	Iguomo	Ikhueniro
Total area (m^2)	25871.64	16500	44398
Disposal method (See notes below)	Open dumping	Open dumping	Open dumping
Existence of waste pickers or scavengers on site	Yes	Yes	Yes
Existence of open burning on site	No	No	No

Note:For disposal method, please specify as follow:

O = Open dumping

C = Controlled tipping (with occasional soil cover)

S = Sanitary landfill (with daily cover)

D = Dumping into water body (river/sea etc.)

4.4.1 `COMPUTATION OF EFFICIENCY OF COLLECTION SYSTEM

Table 4.23 Collection system time

Parameters	Time (minutes)
Average pick-up time	360
Average haul time to dumpsite	20
Average On-site time	10
Average off-route time	30

Source: Edo State Waste Management Board Personnel (Driver), 2016.

From table 4.23 above,

For a stationary container system which is practiced in Oba Market Total haul time for the stationary container system, $\boldsymbol{T_{scs} = P_{scs} + s + h}$ All parameters are defined in the previous chapters.

$$= 6 + \frac{10}{60} + \frac{20}{60} = 6.5\text{h/trip}$$

Thus, it takes 6 hours 30 minutes to collect waste in Oba Market.

The efficiency of the collection system Given that $EWC = 1 - w + w_0$

Where EWC=Efficiency of waste collection system in %

W=off-route factor

W_0=allowable off-route time

$$w = \frac{30}{60} = 0.5$$

Assuming an allowable off-route time of 60mins,

$EWC = 1 - 0.5 + 60 = 60.5$

Hence, from the information obtained, the efficiency of the collection system is 60.5%.

4.5 DISCUSSION OF RESULTS QUESTIONNAIRES

From the questionnaires been distributed, it can be seen that:

The method adopted was based on random sampling of which 65% are women and 35% were men.

Food items/ Vegetables 20%, Provision store 20%, Clothing /Jewelleries 15%, Cosmetics 15%, Meat sellers & Fish 20%, others 10%. About 83% of the traders interviewed have not heard of the term “solid waste Management.” Such large percentage can be attributed to the educational background of the traders. Few of the traders must have had formal education.

In terms of the variation of generation of solid waste, about 59% observe a constant daily generation while about 13% observe an increase in generation of waste on Saturdays. This is due

to the fact that customers have time to shop in the market and hence increase in the quantity of solid waste collected. About 47% observe a constant monthly generation while 15% observe an increase in generation in December. Corroborating with 67% observation on increase in quantity generated on festive periods. This is not a surprising fact because December is a festive period. Shopping spree occur during this period and therefore increase in quantity of solid waste generated.

In terms of storage 92% of the respondents adopt a storage container of which 73.91%, 18.48% and 7.61% adopt small, medium and large containers respectively.

There is little trend of reuse carried out in Oba market. This can be observed that 86% of the generators collect the different type of waste in the same container. Hence, recycling activity can be a very challenging one at this stage. The 14% women who separate their waste on-site do so in order to feed pigs and other livestock. These women are in the food/Vegetable category.

In terms of solid waste handling, 67.39% collect their waste into the storage bin everyday while 25% collect once in 2 days. About 7.61% collect once in a week.

About 88.04% take their solid waste for temporary storage in the "general collection ground." This large number is responsible for the voluminous quantity of waste seen in front of Oba market and they tend to be aesthetically displeasing and pose serious threat to human health. The reason for the general collection ground is that the officials do not come inside the market to carry out wastes as they used to, hence wastes are temporarily stored in the general collection ground. The remaining 11.96% take their wastes directly to the collection vehicles on collection days which is about 3 times a week.

The characterization of solid wastes are as follows: 53.97% Vegetable / putrescible, 12.04%Paper, 4.01%Plastic, 16.84%, Textiles, 3.40%Metals, 3.80% Glass, 5.94% others.

From the data obtained from the experiment, an estimated weight of 81 tonnes is generated daily in the Oba Market Complex. However, this cannot be taken as the average weight since wastes are also generated from pedestrian traffic, hawkers, street sweepers etc. Hence, in the design of Landfill, this value should be multiplied by a factor of safety to cover for such unforeseen generated waste.

The board collects an estimated weight of 90 tonnes on a normal and collects about 110 tonnes during sanitation days. This is due to the fact that every traders collects his wastes to the general collection vehicle. In terms of personal requirement, a total of 9 personnel are employed for a normal daily collection activity while an increase of about 3 personnel are employed on sanitation days. In terms of equipment capacity, the board has 2 Compactor, 3 Roll on Roll up, 1 Green lifter Truck, 15 NDDC Skip Truck and 3 Open tippers

Collection involves the provision of services and the selection of appropriate technologies. In Oba market, the authority responsible for the collection process is the EDO Solid Waste Management Board.

The service is set by agreement between the waste collector and the waste generator. In this case, the agreement is that everyone pays a sum of ₦300 every month for the services.

From the analysis, it can be seen that it takes about 6 hours 30 minutes on a normal day to dispose waste to collect wastes from the market to the disposal site at Otofure. This means that a maximum of 3 trips can be made per day.

The efficiency of the collection system is evaluated to be 60.5%. The efficiency, based on the structural time model, implies that 60.5% of the total time was used for the collection operation. The remainder is used for off-route activities. Such off-route activities can be repairs of vehicle, fuelling and other personal routines.

It is observed that the separation of the solid waste is performed on the disposal site. However better alternative can be ensured if the separation process is being carried out by the generators at the generation point. Hence extra containers for recycling can be provided to ensure a better source-separation process.

CHAPTER 5

5.0 CONCLUSION AND RECOMMENDATION

5.1 CONCLUSION

The project has tried to examine the effectiveness of solid waste management in Nigerian markets. Taking Oba Market as the case study, certain conclusions are drawn from the data and analysis presented in the previous chapter. They are:

i. Large number of the market traders are unware of the solid waste management practice itself. Their notion of solid waste management revolves around generation, storage, collection and disposal. Other operations such as recycling, processing and resource recovery is a mirage to them.

ii. The type of waste that is generated in Oba Market is putrescible and food wastes (53.97%) while the least is metals (3.40%).

iii. On-site collection of waste is a commingled i.e. there is no on-site source separation of solid wastes. Some sort of separation of solid waste occur at the disposal site iv. The onsite handling of waste in Oba Market is aesthetically displeasing and pose a serious threat to the health of persons within that area due to the adoption of the general collection ground. Traders have no standardized storage containers for onsite storage thus small nylon bags, cartons, small plastic containers and various others are used.

iv. The authority responsible for the collection of wastes in Oba Market do not have adequate data on the quantity and the composition of waste that is been generated daily. This is a serious problem that should not be overlooked. It has been stated in the previous chapters

that knowledge of the quantity and composition of waste is necessary for the design of facilities and operations for an effective practice. Collection system being adopted by the board is the stationary collection system.

v. The adoption of the "general collection ground" is uneconomical in two ways. Firstly, too much time is spent on the pick-up operation because the labourers will have to gather the waste using a shovel before manually loading the collection vehicle.

Hence, if a small number of labourers is used, then worker's fatigue is inevitable. Secondly, too much labour is used for the pick-up operation. Hence, more cost is incurred.

vi. Facilities necessary for the collection of the waste is adequate. However, the schedule/ layout is not functional in terms of time and cost. For example, an average time of 6 hours is spent on the pick-up activity. The adoption of 1100litres storage bins is relatively inefficient compared to the quantity of waste generated. The storage cans currently provided are few and relatively of small capacity.

vii. Traffic congestion affects the collection activity. In markets where traffic congestion is relatively high, more time is spent on the pick-up and haulage. Hence, the number of trips that can be made in a day is reduced which implies that the quantity of waste that is collected per day is reduced to that effect.

viii. The siting of the open dump site is not in accordance to public health. For example, the open dump site at Otofure is not far from residential areas. As such, it pose a threat to the health of individuals living in that area. The source of the wastes delivered at the dumpsites were not indicated. However the dumpsites receives waste from all sources of waste in the metropolis. The waste disposal trucks and other vehicle that deliver waste to the site drive into the dumpsite through the access road and dump their waste. The

workers at the site used shovel to manually push the waste from the road and try to spread them as much as their strength can go. Thereafter, scavengers descend on the waste to pick up recyclable materials for sale. Observation of the waste at the time of the scavenging activity at the dump sites revealed that serious decomposition has occur in the waste and this is a treat to the health of the workers. Thereafter the workers at the site set the waste on fire for volume reduction without pollution control. The solid waste dumpsites in the metropolis are former mining site where laterite was mined during the road construction work in the metropolis. The question of public health was also considered about the location of the dumpsites sites. One of the two functioning dumpsites sites at the time of this research work was located by a stream of water. This of course can cause eutrophication. Hence there is a serious indication of adverse effect on people in the metropolis as the stream is one of the source of water. Open dumping is observed for the solid waste management practices. A more precise quantity of waste can be obtained if a landfill is designed especially for market wastes.

In conclusion, the effectiveness of the solid waste management system is satisfactory in terms of equipment and personnel requirements for the collection system. However, the system is not satisfactory in terms of operations of the waste collectors. The temporary storage of waste in the general collection ground is not satisfactory in terms of cost and time. Also, the siting of the open dumpsite in Otofure is not far away from residential houses, hence not satisfactory in terms of public health.

5.2 RECOMMENDATION

From the conclusions, certain recommendations are made below:

i. A programme should be organized to sensitize market traders on the operations of solid waste management and the benefits derived from it with emphasis on recycling and resource recovery

ii. Storage container should be standardised by the market officials. Every trader should own at least two storage containers. One for putrescible waste and the other for recyclable materials.

iii. Provision of large storage containers at strategic points at the curb of the walkway by the collection authority and market officials. This would serve as a temporary storage for waste and it would be easier to load these wastes to the collection vehicle thereby reducing pick-up time and workers fatigue. Less labour is required cost is reduced.

iv. Both manual and mechanical collection are used for the collection of wastes from commercial facilities. Because many large cities have extreme traffic congestion during the day, solid wastes from commercial establishments are collected in the late evening and early morning hours. Where manual collection is used during the evening hours, wastes from commercial establishments are put into plastic bags, cardboard boxes, and other disposable containers, which are placed on the curb for collection. Waste collection is usually accomplished with a three- or, in some cases, four-person crew, consisting of a driver and two or three collectors who load the wastes from the curb side into the collection vehicle. In most evening collection operations, the driver remains with the collection vehicle for reasons of safety.

v. A site should be selected where wastes from commercial areas are deposited. This is necessary because not only would it serve as an additional disposal site, but wastes deposited at this sites can be measured and hence a more accurate data on the quantity of waste generated in market areas can be obtained over time. This would be essential for further design of necessary solid waste management facilities and operations. A sanitary landfill should be adopted for the following reasons:

Advantages of sanitary landfill

x. it is relatively economical and acceptable method

xi. initial investment is low compared to other proven methods

xii. the system is flexible - can accommodate increase in population

xiii. May result in low collection cost, as it permits continued collection of refuses.

All types of refuses may be disposed of.

xv. the site may be located close to or in populated areas, thus reducing the length of hauling cost of collection xvi. it enables the reclaiming of depression and sub marginal lands for use and benefits of the community

xvii. completed landfill areas can be used for agricultural and other purpose xviii. unsightliness, health hazards and nuisance of open dumping can be eliminated xix. may be quickly established xx. several disposal sites may be used simultaneously

5.2.1 DESIGN OF LANDFILL

Design parameters

Estimated waste generated per day in Oba Market = 80328.116kg/day

Density of municipal solid waste=297kg/m^3 (Tchobanoglous, Theisen and Vigil, 1993)

Design Period = 20 years.

a. Determination of Landfill volume

Adopting a factor of safety of 1.8,

Assume all the waste gets to the disposal site,

Maximum estimated waste generated per day in Oba Market = 1.8×80328.116kg

= 144590.6088kg

$$volume\ of\ waste\ generated\ per\ day = \frac{144590.6088kg}{297kg/m^3} = 486.837m^3$$

$volume\ of\ waste\ generated\ per\ year$ = 486.837 × 365 = 177695.505m^3

≈ 177700m^3

Thus, expected volume of waste generated for the design period = 177700×20=3554000m^3

Assuming all the waste generated gets to the landfill,

Let maximum height of landfill be 12m (Davis and Masten, 2009),

Let the ratio of cover to compacted fill be 0.2 (Davis and Masten, 2009, Peavy et al, 1985)

$$Total\ area = \frac{volume(m^3)}{height(m)} = \frac{3554000}{12} = 296166.667m^2 \approx 296200m^2$$

Use area of 296200m^2

Assuming a rectangular section,

Let L=2B

Therefore, L×B=296200m^2

2B^2=296200m^2

$$B = \sqrt{\frac{296200}{2}} = 385m$$

Therefore, L=2×385=770m

Thus, provide 770m×385m×12m landfill volume (3557400m^3)

b. Determination of the volume of cover material

Since the ratio of cover to compacted fill is 0.2,

Therefore, total cover =3554000×0.2=710800m^3 (to be excavated from the landfill site)

5.3 Further Research

It is obvious that funding is a major constraint in solid waste management; hence special attention should be paid to financial planning for commercial solid waste management by the Waste management authorities in the metropolis. The government should create special charges that will be paid by and business operators in the metropolis. And these charges should be dedicated to management of solid waste in general in the metropolis. The collection of these charges should be planned is such a way that the difficulties associated with the collection of levies and charges currently in the metropolis will be eliminated.

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APPENDIX

Have you heard about Solid Waste Management Practice? Yes/No.

State the major commodity/commodities you sell in your

store……

1. Identify the type of Solid Waste generated in your store and tick the quantity

COMPONENT Food Waste	Large quantity	Medium Quantity	Small Quantity
Paper			
Plastic and rubber			
Organic or vegetables			
Glass and ceramic			
Ferrous metal			
Aluminium			
Wood			
Textile			
Garden waste			
Electrical Waste			
Others			

What day(s) of the week do you generate Solid Waste the most/least

…….

What month(s) of the do you generate Solid Waste the most/least

……..

Do you generate more solid waste on festive season e.g. Christmas, Sallah etc?

Yes/No

Do you adopt a storage container for collection of solid waste? Yes/No

Give reasons

……

If yes, what is the size of the storage container? Small/ Medium/

Large.

Do you collect the same type of waste in one container? Yes/No

e.g. all paper in one container.

How often do you collect waste in the storage container?

……

Do you reuse any of the waste in a useful manner? Yes/No

If yes, describe

……

……

Do you subscribe to any solid waste collection service? Yes/No

If yes, what is the name?

……..

How do they collect these wastes

……

Where are the containers placed before pick up

……

How often is solid waste collected by the officials? E.g. twice a week ……

Do you know where the officials dispose these wastes? Yes/No

If yes, where

……

Do you dispose the generated waste yourself? Yes/No

If yes, how and where do you dispose them?

……

Do you think there is a better way of managing your waste? Yes/No

If yes, describe

……

Student measuring the weight of solid waste