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ASSESSMENT OF SOLID WASTE COMPOSITION IN EJISU-JUABEN MUNICIPALITY

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ASSESSMENT OF SOLID WASTE COMPOSITION IN EJISU-JUABEN MUNICIPALITY

By

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DECLARATION

I, Boakye Acheampong the under signed, declare that this thesis is my original work and has not been presented for a degree in any other University. All sources of material used for this thesis have been duly cited and acknowledged.

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DEDICATION

This thesis is dedicated to my family and all my loved ones.

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ABSTRACT

Globally there is lack of knowledge about waste generation and composition in rural areas because these types of studies have been conducted mainly in big cities. This leaves the local sanitation authorities without information to properly plan their operations. Solid waste composition analysis is fundamental to proper planning of solid waste management in an area. This study was undertaken to assess the solid waste composition of wastes generated in the Ejisu-Juaben Municipality. The Direct Waste Sorting Method which involves sorting and weighing directly from households where solid waste were generated was used. A total of one hundred and five (105) households with different socio-economic status over a two-month period was selected for the study. Results indicated that the average solid waste generation rate for Ejisu, Atia and Donaso were 0.481 kg/person/day, 0.4573 kg/person/day and 0.372 kg/person/day respectively with a total weight of 1806.351 kg, 342.54 kg and 140.553 kg respectively, expected to grow by 25% by the year 2022. Solid waste generation rates in the municipality which were biodegradable and recyclable in nature were dominated by food, yard and garden waste (67.49 %), plastics (3.57%), metals (2.41%), paper (1.88%), wood (2.48%), glass (2.11%), textile (1.03%), sand and ash (18.98%) suggesting that an integrated waste management approach supported by willingness to source-separation of wastes could be the best option for the municipality. Thus encouraging and formalizing recycling and composting would greatly reduce the amount of solid waste that has to be disposed hence reducing the cost that has to be incurred.

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CHAPTER ONE

1.0 INTRODUCTION

Waste management poses a great challenge to many nations including Ghana. The problem of waste in Ghana is a direct result of the rapidly growing urban population, changing patterns of production and consumption. The Basel Convention (1992) defines waste as a substance or object that no longer has a use or purpose and needs to be disposed off or required to be disposed off by the provision of national law. Municipal solid waste consists of everyday items such as food scraps, paper, metal, plastics, ceramics, textiles, rubber, used batteries, inert, ashes, construction and demolition debris, household goods and many more. Solid waste management refers to the collection, transfer, treatment, recycling and disposal of solid waste. The various options involved in effectively managing waste are source reduction and re-use, composting, recycling, waste combustion and disposal in landfills (United State Environmental Protection Agency (USEPA), 1995). The primary purpose for solid waste management strategies is to address health, environmental, aesthetic, land use, resource and economic concerns associated with improper solid waste management (Wilson, 2007). In the modern world, quantification and composition of solid waste are the most important ingredients of any sound solid waste management system. It is therefore important to have detailed information on quantification and characteristics for proper handling at different stages of the system (Gawaikar and Deshpande, 2006). A number of researches on characterization and quantification have been done worldwide for the purpose of understanding composition of solid waste. Examples include the works of Parizeau *et al.* (2006). Furthermore, Gawaikar and Deshpande (2006) pointed out that proper solid waste management system should inevitably take into consideration the type of waste generated. It is the type and not the quantity that determines the methods and techniques of disposing solid waste. This view is shared by Acurio *et al.* (1997) who contend that the type of decision making that leads to adequate solid waste management should be based on sound understanding of solid waste composition. Furthermore, Gomez *et al.* (2008) noted that characterization of solid waste generation is fundamental for adequate decision making for solid waste management strategy in a city. It is thus clear that, without a thorough knowledge of the composition, the solid waste is bound to be improperly disposed of With regard to this, Al-Khatib *et al.* (2010) noted that the characteristics of solid waste stream and the estimation of solid waste generation rates are critical data required to propose any suitable and viable alternative solutions to municipal solid waste management. In developed countries, there exist data from long term characterization studies and monitoring solid waste streams both at the local and national level (Hristovski *et al.*, 2007). However, such data are virtually non- existent in the developing world as reported by African Development Bank (2002). Hristovski *et al.* (2007) suggested that periodic short-term (one to two weeks) studies on solid waste composition could be a possible solution in the absence of comprehensive scientifically valid data needed to develop an efficient solid waste management system.

Ejisu-Juaben municipality is one of the districts in Ghana that requires urgent attention in the area of waste management. The Municipality's Medium Term Development Plan document reveals that settlements in the municipality host a large population of people but some work in Kumasi and therefore pay their income tax to Kumasi Metropolitan Assembly. The activities of these people have led to a great increase in waste generation without commensurate revenue for its management by the municipality (Ejisu-Juaben Municipal Assembly, 2014). .

Open dumping is the main method of refuse disposal in most settlements. Due to poor management culture of the communities, diseases like Malaria and Diarrhoea were reported in the 2014 District Health Directorate Report. The number of reported cases were: 66,843 for Malaria and 10,404 for Diarrhoea (Ejisu-Juaben Municipal Assembly, 2014).

1.1 PROBLEM STATEMENT

The peri-urban areas surrounding the Kumasi Metropolis are now serving as the recipient of the urban drift. This has therefore brought about an increasing volume of solid waste generation in the Ejisu-Juaben municipality. However, the municipality has no appropriate systems in place to handle the situation, resulting in indiscriminate disposal of waste in water courses, drainage channels and on land. Huge piles of waste resulting from uncontrolled open dumping of refuse have developed into mountains. Many dump sites in the municipality are now close to or are surrounded by human settlements. Leachate, mosquitoes and flies from these sites have become a danger to the inhabitants. Solid waste management is therefore a challenge for the municipal assembly. However, there is neither a scientific study done nor solid waste composition data available in the municipality to propose any viable alternative solutions to the municipal solid waste management. It is therefore necessary to have detailed information on the solid waste composition and quantification for appropriate waste management options to be chosen by decision makers to address the situation. Moreover, waste management practice which uses waste reduction, reuse, recycling and composting for diverting waste can only depend on the information from the composition of waste generated in the municipality.

1.2 OBJECTIVES

1.2.1 THE MAIN OBJECTIVE

The main objective of the study was to analyse the solid waste composition in the municipality to provide information on the materials that are in a given waste stream.

1.2.2 SPECIFIC OBJECTIVES

The specific objectives were to:

1. Assess the solid waste composition in Ejisu-Juaben municipality and determine the amount of each household waste and their relative proportions in the waste stream.
2. Quantify the current solid waste generated and to project the future volume of waste to be generated in the municipality.
3. Predict how much material can be recovered and prescribe appropriate system of solid waste management practice based on the findings of the solid waste composition.

1.3 JUSTIFICATION

Accumulation of waste has direct negative impact on both health and environmental quality. It is therefore important to characterize the waste generated in the municipality to know the overall composition of the waste of interest, since diversion of waste initiatives are often specific to a single material. The planning of these initiatives will depend on the solid waste composition data in the municipality. The municipality may not be involved directly in recycling activities because of lack of capital. However, analysis of the solid waste composition data in the Ejisu-Juaben municipality may create the enabling environment to support private sector participation. Also, the private sector will need solid waste composition data on recyclable items in the waste and quantities generated.

1.4 LIMITATIONS

This study encountered the following limitations:

1. Some inhabitants were reluctant to provide their household waste generated due to superstition.
2. This study did not take into consideration seasonal and occasional changes in waste production due to time and financial constraints.

CHAPTER TWO

LITERATURE REVIEW

2.0 WASTE

Waste is defined by Oresanya (1998) as any unwanted material intentionally thrown away for disposal. Waste, rubbish, trash, garbage or junk is the name given to any useless material. Waste is often subjective because waste to one person may not be waste to another. According to the Basel Convention (1992), wastes are substances or objects which are disposed of or are intended to be disposed of by the provisions of national law. Also under the Waste Framework Directive, the European Union defines waste as an object the holder discards, intends to discard or is required to discard. With regard to this, waste may be generated during the extraction of raw materials, the processing of raw materials into intermediate and final products, the consumption of final products and other human activities.

Moreover, Americans define food waste or garbage to be table waste and kitchen waste. In addition the United Nations Statistics Division defines wastes as materials that are not prime products (that is products produced for the market) for which the generator has no further use in terms of his or her own purposes of production, transformation or consumption and of which he or she wants to dispose.

According to United Kingdom's Environmental Protection Act 1990, waste include any substance which constitutes a scrap material, an effluent or other unwanted surplus arising from the application of any process or any substance or article which requires to be disposed off, which has been broken, worn out, contaminated otherwise spoiled unless the contrary is proven. However, certain wastes may eventually become resources valuable to others once they are removed from the waste stream (Wei *et al.*, 1997).

2.0.1 LIQUID WASTE

Liquid waste is defined as liquid or mixture consisting of solid matter suspended in a liquid media which is contained within, or is discharged from, any one vessel, tank or other container (New Jersey Environmental Department, 2002).

2.0.2 SOLID WASTE

Solid waste is any waste generated by everyday human activities. Solid waste may be in the form of household garbage, leftovers of food and other wastages. Solid waste can be classified into different types depending on their source:

a) Domestic solid waste
b) Commercial and industrial solid waste which is bulky but not hazardous and
c) Hazardous waste from industries and hospitals that require special handling (Appaswamy,1994).

The report by Zurbrugg (2003) on solid waste management in developing countries states that solid waste is a type of waste which is not in liquid form and has no value to the person who is responsible for it. Solid waste is used to describe non-liquid waste material arising from domestic, trade, commercial and public services. There are eight major classifications of solid waste generators: residential, industrial, commercial, institutional, construction and demolition, municipal services, process and agricultural (WHO, 1984). It comprises countless different materials: dust, food wastes, packaging in the form of paper, metal, plastic or glass, discarded clothing, garden wastes, pathological waste, hazardous waste and radioactive waste (WHO, 1984).

2.1 TYPES OF SOLID WASTE

2.1.1 MUNICIPAL WASTE

Municipal solid waste consists of household waste, construction and demolition debris, sanitation residue and waste from streets. According to the Environmental Protection Agency of America, Municipal solid waste is more commonly known as trash or garbage- consists of everyday items we use and then throw away, such as product packaging, grass clippings, furniture, clothing, bottles, food scraps, newspapers, appliances, paint and batteries. This, in a sense, comes from our homes, schools, hospitals and businesses.

Schubeler *et al.* (1996) defined municipal waste as a refuse from households, non-hazardous solid waste from industrial, commercial and institutional establishments (including hospitals), market waste, yard waste and street sweepings. Municipal solid waste is a broad category of non-hazardous solid waste that includes animal carcasses as well as the typical garbage or trash (USEPA, 2008). Americans generate more than 180 million tons of municipal solid waste each year. This is about 1,300 pounds for each person each year. It means that on average, each of us creates a little over 4 pounds of garbage every day.

2.1.2 HOUSEHOLD WASTE

Household waste is generally defined as waste generated by normal household activities. Household waste collection system varies throughout the world (Mbande, 2003). Household wastes are hazardous solid wastes that are generated in small amounts by individual households across the nation. This category includes various household cleaners, paints, solvents and other chemicals. Some of the items in this category, such as batteries, light bulbs and pesticides, are also considered universal waste. Universal wastes are hazardous solid waste items that are widely generated by all sectors of the population (US EPA, 2008).

Each household generates garbage or waste day in and day out. Items that are no longer needed fall in the category of waste and are thrown away. These include:

- Organic waste: kitchen waste, vegetables, flowers, leaves, fruits
- Toxic waste: old machines, paints, chemicals, bulbs, spray cans, fertilizer and pesticide containers, batteries, shoe polish.
- Recyclable waste: paper, glass, metals, plastics
- Solid waste: sanitary pads, cloth soiled with blood and other body fluids
- Others: ash, sand, etc.

2.1.3 CONSTRUCTIONAL WASTE

Constructional waste consist of unwanted material produced directly or incidentally by construction industries. Constructional waste consists of such waste as waste building material and rubble. The rubble is generated from activities at new construction sites, remodeling, repair and demolition operations on houses, commercial buildings, repair of roads, pavements and other structures. Materials that may be found in construction and demolition waste are treated and untreated wood scrap; tree parts, tree stumps and brush, concrete, asphalt, bricks, blocks and other masonry; plaster and wallboard, roofing materials, corrugated cardboard and paper, ferrous and nonferrous metal, non-asbestos building insulation, plastic scrap, dirt, carpets and padding, glass (window and door) and other materials (New Jersey State Department, 2002).

Construction waste recycling is the separation and recycling of recoverable waste materials generated during construction and remodeling. Packaging, new material scraps and old materials and debris all constitute potentially recoverable materials. In renovation, appliances, masonry materials, doors and windows are recyclable.

2.1.4 AGRICULTURAL WASTE

Agricultural waste is a subcategory of municipal waste and is a waste that is generated by the rearing of animals and the production or harvesting of crops or trees. According to the US Environmental Protection Agency, "agricultural waste is made up of those materials such as manure and animal output, in either solid or liquid form, from poultry and other livestock, harvest remains from grains, oil seed, vegetable and crops (USEPA, 2014).

2.1.5 COMMERCIAL WASTE

Commercial waste consists of paper, cardboard, plastics, wood, food wastes, construction and demolition materials, hazardous wastes, ashes, special wastes which comes from sources such as stores, hotels, restaurants, markets, office buildings, print shops, auto repair shops, medical facilities, institutions etc. (Tchobanoglous *et al.*, 1993).

2.2 WASTE CHARACTERIZATION AND QUANTIFICATION STUDIES

Analysis of the total quantity of waste in the entire waste stream, by weight or by volume, is known as waste quantification. Analysis of the composition of the waste stream by material types (such as glass, paper, metal, etc.) or by product types (such as glass containers, magazines, cans, etc.) is frequently referred to as waste characterization (Papachristou *et al*., 2009).

Certain wastes may eventually become resources valuable to others once they are removed from the waste stream. The knowledge of the characteristics of waste is vital for long term waste management planning and calculating the size of waste disposal facilities such as incinerators, landfills and recycling facilities. Waste management services which use waste reduction, reuse, recycling and composting for diverting waste from waste disposal facilities can only depend on information from the composition of waste generated.

2.3 FACTORS AFFECTING HOUSEHOLD WASTE COMPOSITION

Solid waste composition in households is influenced by a lot of factors. They may include:

- Socio-economic factors: The wealth of households influences consumption and disposal patterns at a fundamental level and hence the type and amount of waste produced. Kenneth (1976) discussed the economic aspects of household's decisions to produce more or less refuse. He mainly analyzed the theoretical concept about household behaviour on waste generation due to the changes in income, price of refuse service, frequency of service, site of refuse collection and packaging.
- Time: The amount of waste produced in a household can fluctuate significantly between days of the week, between weeks or months of the year and between years.
- Housing type: The housing type in a community can have a large influence on the amount of waste produced and the composition. This is because some housing types may have gardens while others may not keep one. The number of occupants in a household also depends on the housing type and subsequently the waste they produce. The housing type has a direct bearing on the socio-economic and demographic status of a place.

- Land use: The type of activity which a people living in a place are involved in has an effect on waste composition. The composition of waste from an agricultural land, commercial area or an industrial setting may differ because of the different activities taking place in each of these places. Waste from a rural development may be different from that of an urban development, in terms of their composition due to differences in activities in these places.
- Seasonality, weather and climate: One of the primary factors that affect waste composition is seasonality, since it has an effect on waste generation rates, more especially on organic garden waste. For example waste patterns in the rainy season are different from that of the Harmattan, when it is very dry and trees tend to shed their leaves.
- Demography: The profession, age and education structure of a population bears relationship with waste composition, recycling scheme participation and residual composition.
- Culture: Culture influences the perception or attitude that people have to waste. This is because culture has an effect on the type of activity undertaken in an area, the types of food people consume and the amount or type of goods purchased. All these impact on the composition of waste disposed off.
- Type of waste and recycling services provided in an area: The type of waste and recycling services provided in area is perhaps one of the biggest impacts on collected household residual composition than any of the above. The type of waste collection containers used and materials recycled can lead to significantly different capture rates for different materials recycled can lead to significantly different capture rates for different materials. It also has a significant impact on

materials such as green waste, construction and demolition waste in the household waste stream.

2.4 CLASSIFICATION OF WASTE COMPONENTS

2.4.1 METHODOLOGIES FOR WASTE CHARACTERIZATION

The method for the characterization of waste depends on factors such as the available funds for the exercise or the kind of results expected. Some of these methodologies are outlined below:

1. Multivariate Data Analysis

Multivariate data analysis can be useful for displaying an overview of collection and composition data and identify influential variables, clusters and trends. Such an overview is free from preconceived ideas and may point out where it is interesting to go into details. Multivariate data analysis is useful for displaying an initial overview of collection and composition data.

2. Direct Waste Analysis

Direct waste analysis is a widely used methodology for obtaining waste information (Brunner and Ernst, 1986). Direct waste analysis entails the direct examination of waste at the point-of-generation (that is in homes, at the plant, office, store or institution), or of waste delivered to a waste processing facility or to a waste disposal site. This may be to acquire information on the quantity of waste or waste composition or both. Waste quantification estimates are usually based on samples of waste taken directly from the waste streams of interest. Sample size and selection are guided by factors such as the scope of the study, variability within the population and the desired precision of the waste quantity estimates.

The most common practice is to sort the waste by hand into pre-determined materials or product categories or a combination of the two. In cases where it is not possible to sort the entire load, sub-samples of the load can be analyzed. A rough sort can be performed in order to separate out large items, before proceeding with fine sorting of the remaining material.

Traditionally, waste is characterized by weight, even though it is also possible to do the exercise by volume (SENES Consultants Limited, 1999). In addition to weight and composition, it is also sometimes required to measure the moisture content of the waste as well as its chemical composition (that is, energy content, elemental concentration and volatility. These are very meaningful if the objective of the analysis is to determine the suitability of the waste stream for incineration (Chang- Ching *et al.,* 1993).

Direct sorting is generally considered to be more accurate than other techniques but it is also more expensive and time-consuming.

3. Sampling and visual classification

Visual classification is done by the estimation of the proportions of different components of the waste stream, based on the amount of each type of material in the sample that can be seen by the auditor (DEFRA, 2004). This method is applied where the waste stream is fairly homogenous and difficult to sort (bulky waste).

4. Questionnaire Surveys

Questionnaire survey involves the collection of data at point of generation rather than at waste disposal facilities. Questionnaire surveys seek for information from inhabitant managers or other office personnel about the quantities and characteristics of waste from their households, workplace, etc. A key weakness of the questionnaire survey is that, very few companies or households keep records on the amount of waste that their company or household generates, let alone the composition of that waste (Chang-Ching *et al.,* 1993). Although questionnaire survey is the lowest cost alternative to other approaches, researchers generally regard questionnaire estimates as an educated guess (Yu and Maclaren, 1995). An earlier study of Yu and Maclaren (1995) showed that waste composition data on industrial waste obtained from questionnaire survey correlates poorly with field data.

5. Conversion Factors

This method involves the conversion of activity indicators, such as economic sales data for a certain area into estimates of the weight or volume of solid waste categories generated. According to the Technical University of Berlin, conversional factor is mostly used in industrial waste by using the production data for materials in the waste stream taking into account the lifetime of products (TU Berlin, 2001).

2.5 WASTE GENERATION RATES

The absence of adequate, reliable national data on solid waste management makes it difficult for comprehensive solid waste management strategies to be developed particularly in the urban areas as the rate of solid waste generation has a considerable bearing on collection strategies and even the choice of transporters to disposal sites (Kesse *et al.,* 2005). More studies on solid waste generation need to be carried out in order to produce the necessary statistics for national action plan on waste management.

Table 2.1 to 2.3 give values for waste generation rates in some studies from different locations in Ghana.

Table 2. 1 Typical solid waste figures in Kumasi

Description	**Low/Medium Income**	**High Income**
Refuse Generation (kg/cap/day)	1.08	0.8
Refuse Generation (m^3/cap/day)	0.0032	0.0024
Garbage (%)	89	79
Paper (%)	2.5	65
Others (%)	**8.5**	**14.5**

Source: Edmundson (1981)

Table 2. 2 Typical solid waste figures in Accra and Kumasi

Average Waste Component	**Accra % (w/w)**	**Kumasi % (w/w)**
Biodegradable/ Organic	65.0	64.0
Paper and Cardboard	7.5	3.0
Plastics and rubbers	7.5	4.0
Glass	2.0	1.0
Metals	3.5	1.0
Wood	2.0	3.0
Textile	0.3	3.0
Inert	1 2.7	21.0
Generation (kg/person/capita)	**0.68**	**0.60**

Source: Kumasi Metropolitan Assembly, 2009

Table 2. 3 Waste Generation Characteristics for Accra, 1999

Type of Residential Area	Population 1994	Waste Generation Parameters Kg/cap/day	kg/l	l/cap/day
High Class Residential	136,500	0.46	0.30	1.20
Medium Class Residential	1,764,000	0.38	0.41	1.30
Low Class Residential	1,599,500	0.28	0.50	0.80
Values for Accra	**3,500,000**	**0.38**	**0.49**	**1.00**

Source: Fobil, 2001

2.6 WASTE COLLECTION AND DISPOSAL

The level of service for waste collection also varies markedly in most industrialized countries. Services have expanded to the extent that over 90% of the population have access to waste collection. This is not the case in developing countries (United Nations Environment Program (UNEP), 1991). The failure to provide adequate collection services poses a serious threat to human health in many developed countries. Burial in controlled landfills continues to be the most prevalent means of disposing off solid waste including hazardous waste. About 70% of urban solid waste is disposed off in this way in the United States and most European countries. Incineration and recycling also play a key role in the management of urban and industrial waste (UNEP, 1994).

2.6.1 TECHNICAL OPTIONS FOR SOLID WASTE MANAGEMENT

- House-to-House collection

This type of collection is for high-income, well-developed communities where access of high quality (paved roads to all premises) and the customers can afford the purchase of approved storage containers and payment of the high service charges. Customer participation comprises the purchase of a standard container and its placement outside the premises on scheduled days, for collection by the operator.

- Communal collection

This is also referred to as central container services. This option is considered for low-income communities. The customer participation is through carrying the waste to the communal receptacle (portable metal container), which is carried away when full and replaced by an empty one.

- Block collection

This is referred to as the Bell system. It provides services to a cluster of adjacent premises. Collection is announced by the ringing of a bell or the blowing of a horn on days specified for collection; the collection vehicle then waits for an agreed period before moving to the next point of collection. (Manual for the Preparation of District Waste Management Plans in Ghana, 2002).

2.7 WASTE MANAGEMENT OPTIONS

No single solution has been acknowledged that completely answers the question of what to do with solid waste. Every community has its own unique outline regarding solid waste. The approaches of people in different regions of each country vary regarding waste management practice. The diversity of communities and their waste is one reason why no single approach to waste management has been accepted as "the best" method. Since there is no ideal method, every community must create its own "best approach" to dealing with its waste. However, all communities have the same alternatives (Palczynski *et al.*, 2002).

Solid waste constitutes a huge challenge for local governments due to its constant increase and the majority of the municipalities do not keep records on waste generation, origin and characteristics. This lack of information means that the decisions regarding proper waste management are based on assumptions and inferences which bring about its mishandling with serious consequences for the environment (Buenrostro and Bocco, 2003). Examples thereof are river and ground water contamination by landfills, leachate, soil pollution and greenhouse gas emission.

Solid waste management is an integral part of public health and environmental control (USEPA, 1995). No single solution has been identified that completely answers the question of what to do with solid waste. The attributes of people in different regions of each country vary regarding waste management practice. The recent development in waste management is the concept of integrated waste management.

2.7.1 INTEGRATED SOLID WASTE MANAGEMENT

Integrated solid waste management refers to the complementary use of a variety of practices to safely and effectively handle municipal solid waste. The strategy used to develop an integrated solid waste management system is to identify the levels at which the highest values of individual and collective materials can be recovered.

Integrated waste management systems follow a general hierarchy of waste management as shown in Fig 2.1

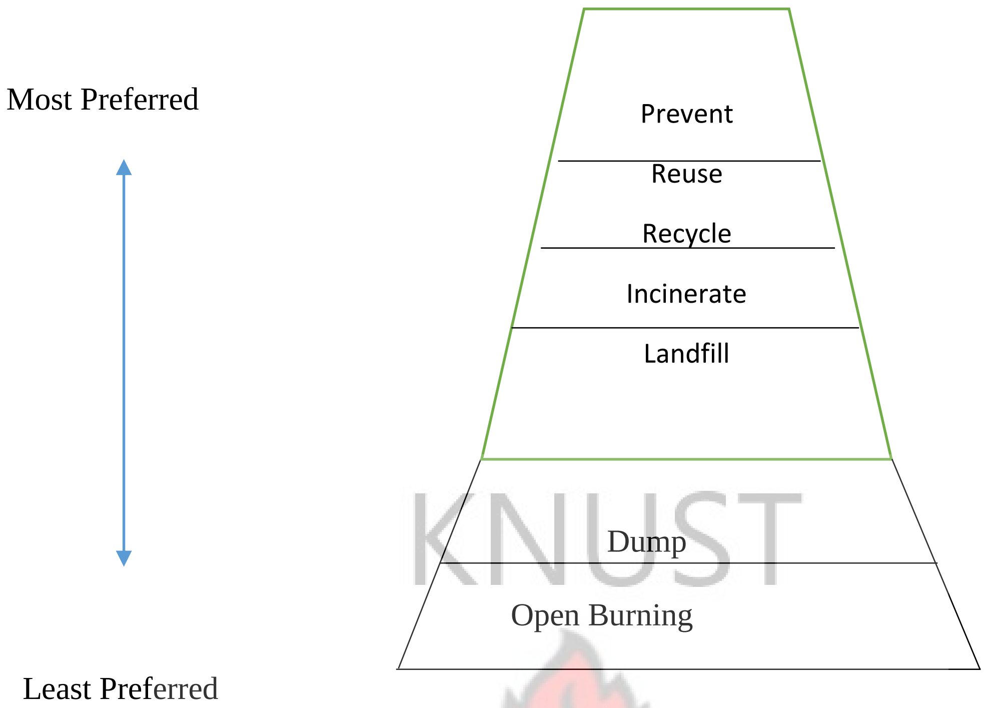

Fig 2. 1 The waste hierarchy

***With energy recovery**

Tchobanoglous *et al.* (1993) defined integrated waste management as the selection and application of appropriate techniques, technologies and management programmes to achieve specific waste management objectives and goals. According to a 1992 report by the Stockholm Environment Institute, residents in Accra, Ghana, generated about 800 tons of solid waste per day in 1990, with an annual increase of 6% where most of the waste was organic. Integrated solid waste management decision makers must take into account the environmental, social, economic and institutional dimensions. The economic factors include the cost and benefits of implementation of the programme and the available municipal budgets for the waste management. Environmentally, the solution would seek to address problems such as increased risk of epidemics and ground water pollution. The institutional dimensions of integrated solid waste management aims to build a system which involves the main stakeholders. Finally, social dimensions of such programme include employment for both the formal and the informal sectors and a positive impact on human health in the early part of this century.

2.8 CONCEPTS IN SOLID WASTE MANAGEMENT

Broadly, the material flow stream of solid waste from generation to ultimate disposal comprises the following:

- Generation
- Collection or transportation
- Processing
- Disposal

Accordingly, solid waste management encompasses the full range of activities for these streams, from the generation of used material to their disposal (Beede and Bloom, 1995; Lardinois, 1996). Resource recovery includes all activities of waste segregation, collection and processing which are carried out taking into consideration the economic viability of the material (Baud and Schenk, 1994).

2.8.1 RECYCLING

Recycling involves processing waste through remanufacture and conversion of parts in order to recover an original raw matter (Beukering, 1994). The early studies reveal that recycling in the past was mostly industrial and based on financial considerations to reduce production cost, unlike the current emphasis on recycling as a way of reducing waste in the environment and preserve dwindling resources (Cointreau *et al.*, 1984).

A well-run recycling programme, whether private or public can divert a significant percentage of municipal, institutional and business waste from disposal and can help control waste management costs by generating revenue through the sale of recyclable materials (USEPA, 1995). The importance of recycling in waste management is that, it prevents the emission of many greenhouse gases and water pollutants, saves energy, supplies valuable raw materials to industry, creates jobs and reduces the need for new landfills and combustors. In order to design an efficient recycling program, a system approach is the key. The public must be relied on to participate in the process by separating uncontaminated recyclable materials.

2.8.2 COMPOSTING

A study by Richard *et al.* (2002) argued that, composting is the controlled aerobic decomposition of organic matter by the action of micro- organisms and small invertebrates. Also according to them, composting could be regarded more as a recycling than a treatment method because its purpose is to convert the fermentable organic content of wastes into a soil conditioner and no specific land allocation is required for final disposal of this product. The types of composting are windrow composting, vermicomposting and static pile composting which are controlled by making the environmental conditions optimum for the waste decomposers to thrive.

Decomposition is performed primarily by aerobic bacteria. The rate of compost formation is controlled by the composition and constituents of the materials (that is, their Carbon/ Nitrogen (C/N) ratio, the temperature, the moisture content and the amount of air (Richard *et al.*, 2002).

2.8.3 INCINERATION

Incineration is the most common thermal treatment process. This is the combustion of waste in the presence of oxygen into heat, gas, steam and ash, inside a specially engineered and purposed-built incinerator. After incineration, the waste are converted to carbon dioxide, water vapour and ash.

- This method may be used as a means of recovering energy to be used in heating or the supply of electricity. In addition to supplying energy, incineration technologies have the advantage of reducing the volume of the waste, rendering it harmless, reducing transportation costs and reducing the production of the greenhouse gas methane. However, it is said to be a disputed method of waste disposal due to issues such as emission of gaseous pollutants and cost involved in maintaining it. Incinerators can also cause air pollution problems unless they are designed, equipped and operated to meet air pollution control requirements.

Waste-to-energy is a facility that burn waste in a furnace or boiler to generate heat, steam and or electricity. Modern combustion technologies maintain the advantages of incineration without its numerous disadvantages, while providing a clean energy source. Installation of a “boiler” such as the Rotary Cascading Bed Combustor (RCBC) allows the consumption of waste as fuels for the generation of electricity. The fly ash by-product is inert and can be mixed with compost.

2.8.4 LANDFILLING

Landfill is a fully engineered disposal option that avoids the harmful effects of uncontrolled dumping by spreading, compacting and covering the waste on land that has been carefully engineered before use.

Four basic conditions considered in preparing a landfill are:

1) Full or partial hydrogeological isolation
2) Formal engineering preparations

3) Permanent control

4) Planned waste emplacement and covering (Rushbrook and Pugh, 1999)

Sanitary landfills are designed to greatly reduce or eliminate the risks that waste disposal may pose to the public health and environmental quality. If properly designed and well-managed, landfills can be a hygienic and relatively inexpensive method of disposing of waste materials. They are usually placed in areas where land features act as natural buffers between the landfill and the environment. In addition to the strategic placement of the landfill, other protective measures are incorporated into its design. The bottom and sides of landfills are lined with layers of clay or plastic to keep the liquid waste known as leachate, from escaping into the soil.

Sanitary landfills rely on bull dozers as their main piece of equipment for spreading and grading refuse and for daily soil cover. However, it has been very difficult for a lot of waste management authorities to establish new landfills due to the difficulty in acquiring land for landfills and opposition from adjacent land owners and environmentalists.

2.8.5 WASTE REDUCTION

Waste reduction and reuse of products are both methods of waste prevention. Source reduction, which is also known as "waste prevention" (USEPA, 1995) eliminates the production of waste at the source of usual generation and reduce the demands for large scale treatment and disposal facilities. Methods of waste reduction include manufacturing products with less packaging, encouraging customers to bring their own reusable bags for packaging, encouraging the public to choose reusable products such as cloth napkins and reusable plastic and glass containers, backyard composting and sharing and donating any unwanted items rather than discarding them. These can help reduce waste disposal and handling costs by avoiding the costs of recycling, municipal composting, landfilling and combustion (USEPA, 1995).

All the methods of waste prevention mentioned require public participation. In order to get the public onboard, training and educational programmes need to be undertaken to educate the public about their role in the process. Also the government may need to control the types and amount of packaging used by manufacturers and make the reuse of shopping bags mandatory.

2.9 POLICY, LEGAL AND INSTITUTIONAL FRAMEWORK FOR SOLID WASTE MANAGEMENT

2.9.1 POLICY FRAMEWORK

Research shows that Ghana has a comprehensive national policy for solid waste management, which addresses solid waste management in the district, municipality and metropolitan areas. The National Environmental Sanitation policy was prepared by the Ministry for Local Government and Rural Development and approved by the cabinet of Ghana on April 8, 1999. By adopting the strategic objectives for environmental sanitation, it is expected that by the year 2020, all solid waste generated in urban areas will be regularly disposed off in adequately controlled landfills or by other environmentally acceptable means (African Development Bank, 2002).

The manual for the preparation of District Waste Management Plans

The purpose of the manual is to assist the District Assemblies and other relevant stakeholders in the planning and management of waste, leading to the preparation of integrated, systematic, consistent and strategic waste management plans. The manual is not intended to be a reference for the very detailed and specific problems that may occur in assessing waste management. It is intended to complement the professional judgement and experience of the user, as well as to provide general reference information for all stakeholders in waste management.

2.9.2 LEGAL FRAMEWORK

Government of Ghana has over the years put in place a legal and regulatory framework for solid waste management operations in the District Assemblies. These instruments include:

- National Environmental Policy, 1991
- Local Government Act, 1990 (Act 462)
- Environmental Protection Agency Act, 1994 (Act 490)
- Water Resources Commission Act, 1996 (Act 522)
- National Building Regulations, 1996 (L.I 1930)
- Environmental Sanitation Policy, 1999
- Environmental Assessment Regulations, 1999 (L.I. 1652) as shown in Table 2.4

Tab 2. 4 Annotated Summary of Legislations Affecting Solid waste Management

ACT 462	ACT 490	L.I. 1652	ACT 656
• Affirming Government commitment to decentralization	• EPA setting nationwide environmental standards.	• Selection and acquisition of site for proposed landfills being a function of the District Assembly.	• Affirming the District Assembly responsibility for solid waste management.
• Establishing the District Assembly as the institution functionally responsible for solid waste management in the district.	• Administering procedures for granting permits and certificates for all national activities, including landfill operations.	• EPA approving procedures for EIA in any proposed landfill undertaking.	• Placing the District Health Management Team (DHMT), also responsible for the district solid waste management activities, under the Ghana Health Service.
• Bringing into ambit of the Assemblies to pass the necessary by-laws to provide policies and regulatory framework for carrying out solid waste management functions		• EPA issuing an Environmental permit to allow construction to start after successful EIA. • Prior to commissioning operations, EPA approving an Environmental Management Plan • EPA requiring annual environmental reports to secure Environmental Permits to continue landfill operations.	

Source: Kesse *et al.*, 2005.

2.9.3 INSTITUTIONAL FRAMEWORK

The institution responsible for management of solid waste is the District or Municipal Assemblies. The institution is resourced from institutions such as Ministry of local government and Rural Development, Environmental Protection Agency (EPA), Ministry of Health and Regional Coordinating Council. Environmental Health Directorate are responsible for effective solid waste management in the district level (Ghana National Environmental Guideline, 2002).

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1STUDY AREA OF EJISU-JUABEN MUNICIPALITY

The Ejisu-Juaben Municipality lies in the central part of the Ashanti Region occupying a large area of 637.2km² with Ejisu as its district capital. It lies within latitudes 1º15'N and 1º45'N and longitude 6º15W and 7º00W. The municipality shares boundaries with six municipals in the region. They include: Sekyere East and Afiagya Kwabre to the North and North-West respectively; the Bosomtwi and Asante Akim South municipals to the South; the Asante Akim North to the East and the Kumasi Metropolitan Assembly to the West (Ejisu-Juaben Municipal Assembly, 2014)

Figure 3. 1 shows the districts in the Ashanti region, Ghana with Ejisu-Juaben municipality shown as shaded portion.

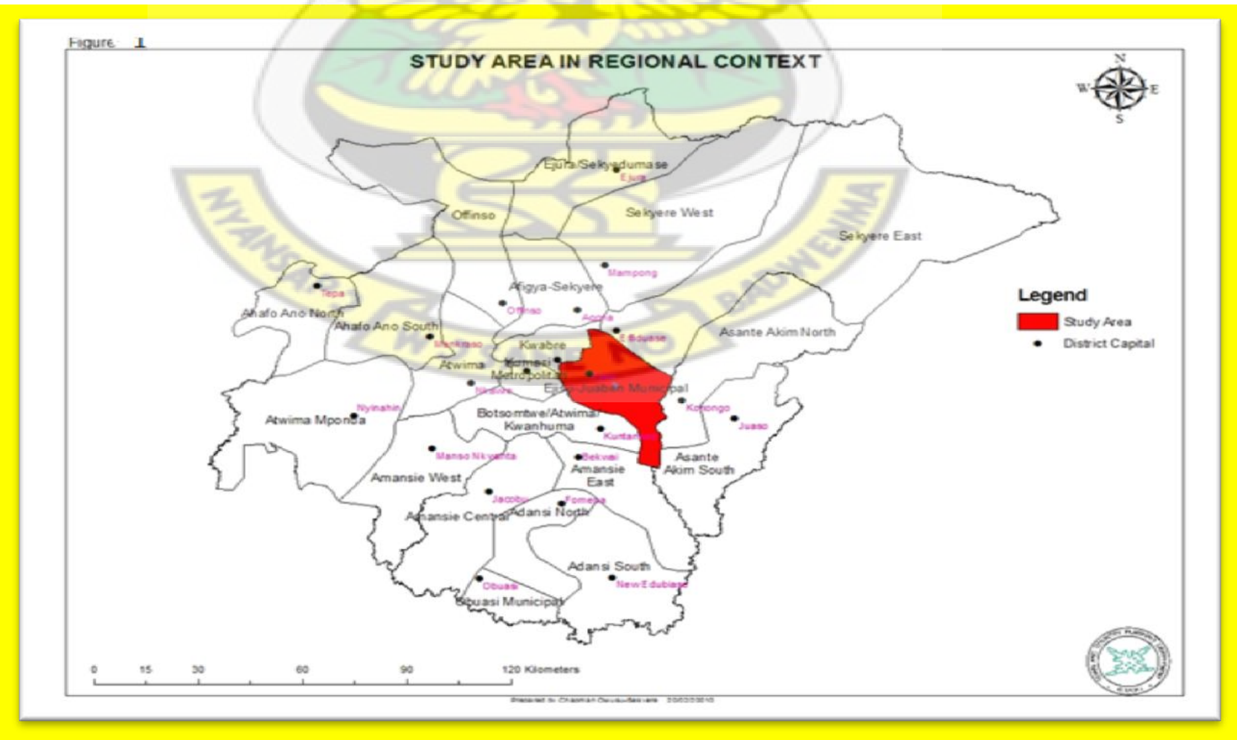

Fig 3. 1 Districts in the Region with Ejisu District shaded

The Municipal Assembly has bi-modal rainfall pattern. The major rainfall periods begin from March to July. The average annual rainfall for the major season is between 1200mm-1500mm per year. The minor rainfall periods begin in September and tapers off in November with minor annual rainfall of 900mm-1120mm per year. Mean annual temperatures in the municipal area are lowest around 25ºC in August and highest around 32ºC in March (Ejisu-Juaben Municipal Assembly, 2014). The 2010 Population and Housing Census showed that the population in the municipality was 143,762 comprising 68,648 (47.8%) males and 75,114 (52.2%) females with annual growth rate of 2.5%. The population of agricultural households according to the 2010 population census was 15,549 and accounted for 47% of the total household in the municipality. Bonwire located in the municipal area has globally become synonymous with the Kente festival.

3.2 MATERIALS

The following materials were used for the assessment:

- A weighing scale
- Sorting containers
- Leather gloves
- Nose mask
- Trash bags
- Digital camera

3.3 METHODS

3.3.1 WASTE CLASSIFICATION

Waste composition analysis was sorted in Ejisu, Atia and Donaso:

The composition of the waste that was sorted are:

- Food, garden and yard waste
- Plastics
- Metals
- Papers
- Wood
- Textiles
- Glasses
- Others (ash and sand).

This waste stream classification has been used by SENES Consultants Ltd. (1999) and Bolaane and Ali (2004).

3.3.2 SAMPLING DESIGN

Stratified random sampling was used for sampling the population in order to avoid bias. The population was divided into various identifiable groups with different socio-economic status which reflected the main variables expected. The strata considered in the towns were:

- High Class Residential
- Medium Class Residential
- Low Class Residential

3.4 SELECTING A HOUSEHOLD FOR THE STUDY

In carrying out the research, the methodology used by Gomez *et al.* (2008) was employed. It involved sorting and weighing directly from household where solid wastes were generated. According to Tchobanoglous and Kreith (2002) this is an established method for characterizing solid waste.

Preliminary random survey of the household solid waste in Ejisu, Atia and Donaso was undertaken. Households were randomly selected within each of these stratas in proportion to their size in the actual population.

According to the method recommended by Sharma and McBean (2007), thirty (30) samples are adequate when samples are taken from various solid waste generating sources. A total of ninety (90) households were selected for the preliminary samples from the three (3) towns in order to obtain the standard deviation and the mean. The number of households was selected proportionally depending on the population and the total number of households in each category. Seventy-five (75) households were selected from Ejisu, ten (10) from Atia and five (5) from Donaso. Accordingly, fifty-seven (57) were selected from high socio-economic status, fourteen (14) from the middle socio-economic status and nineteen (19) from the low socio-economic status. The data from this initial survey was then used to determine more precisely the actual size of the samples that would be required for the actual sampling as shown in Appendix A (page 55-57).

3.5 DETERMINATION OF THE NUMBER OF SAMPLES

The choice of number of samples was solely influenced by solid waste collection procedure and the heterogeneity of the solid waste. Moreover, Al-Khatib *et al.* (2010) cited that in the literature there is no specific method used for specifying the number of samples for solid waste characterization.

A total of one hundred and five (105) households were selected from the three (3) towns for the three (3) socio-economic statuses of High, Middle and Low. Eighty-seven (87) households were selected from Ejisu, eleven (11) from Atia and seven (7) from Donaso. Accordingly, sixty-seven (67) were selected from high socio-economic status, sixteen

(16) from the middle and twenty-two (22) from the low socio-economic status as shown in Table A.4 in the Appendix A (page58 -62).

3.6 SAMPLE SORTING PROCEDURE

Sorting was done for individual selected households since the analysis of solid waste composition in the various households was of interest. Each of the selected households was provided with trash bags. The trash bag was to be put into their waste collection bins for the collection of every solid waste generated. Each household waste was poured unto a wooden bench, sorted into food, yard and garden waste; plastics; metals; paper; wood, glass; textiles and other components and the weight of each of the component waste materials noted for onward analysis. Sorting was based on the types found most often and those most commonly reported in previous studies (Gomez *et al.,* 2008). The waste was collected bi-weekly and the sorting procedure was repeated for another week; -the average weight of each component was determined. The procedure adopted was the same for all waste found in the one hundred and five (105) households.

3.7 DETERMINATION OF HOUSEHOLD WASTE IN EJISU, ATIA AND DONASO

The household waste data collected from Ejisu, Atia, and Donaso were used to determine the following in the respective towns as shown in Appendix B (Page 63-77):

- Mean per family of household waste collected.
- Mean per person per week of household waste collected
- Waste generation rate of household waste collected
- Total household waste produced per day
- Total household waste produced in a year

3.7.1 DETERMINATION OF MEAN PER FAMILY OF HOUSEHOLD WASTE SORTED IN EJISU, ATIA AND DONASO

The mean per family of household waste sorted in the three towns was calculated using the relation:

Mean/ Family = $\frac{Weekly\ totals\ of\ each\ household\ waste\ collected}{Total\ number\ of\ households\ selected}$

This method has been used by Mensah (2008) for Household Waste Characterization in Atwima Nwabiagya District Assembly.

3.7.2 DETERMINATION OF MEAN PER PERSON PER WEEK OF HOUSEHOLD WASTE SORTED IN EJISU, ATIA AND DONASO

The determination of mean per person per week of household waste sorted in the three towns was calculated using the relation:

Mean/Person/Week = $\frac{Mean\ per\ family \times Total\ number\ of\ households\ selected}{Total\ number\ of\ persons\ in\ the\ households}$

This method has been used by Mensah (2008) for Household Waste Characterization in Atwima Nwabiagya District Assembly.

3.7.3 DETERMINATION OF WASTE GENERATION RATE OF HOUSEHOLD WASTE SORTED IN EJISU, ATIA AND DONASO

The waste generation rate of waste sorted in the three towns was calculated using the relation:

Waste generation rate = $\frac{(Weekly\ totals\ of\ each\ household\ waste\ collected\ per\ observation\ period)}{Total\ number\ of\ persons\ in\ the\ households}$

This method has been used by Fobil (2001) for Waste Generation Characteristics in Accra.

3.7.4 DETERMINATION OF TOTAL HOUSEHOLD WASTE PRODUCED PER DAY IN EJISU, ATIA AND DONASO

The total household waste produced in the three towns was calculated using the relation:

Total Waste/Day = Waste generation rate × Population

This method has been used by Mensah (2008) for Household Waste Characterization in Atwima Nwabiagya District Assembly.

3.7.5 DETERMINATION OF TOTAL HOUSEHOLD WASTE PRODUCED IN A YEAR IN EJISU, ATIA AND DONASO

The total household waste produced in a year in the three towns was calculated using the relation:

Total waste in a year = Total waste/ Day × Number of days in a year

This method has been used by Bolaane and Ali (2004) for Sampling Household Waste at Source.

3.7.6 DETERMINATION OF PERCENTAGE COMPOSITION OF HOUSEHOLD WASTE SORTED IN EJISU, ATIA AND DONASO

The percentage composition of the household waste sorted in the three towns was computed using Statistical Package for Social Sciences (SPSS). This was done to compare the quantity of each household waste component collected and their relative proportion in the waste stream.

3.7.7 COMPARISON OF HOUSEHOLD WASTE GENERATION RATES IN EJISU, ATIA AND DONASO

The rate at which each of these household waste component was generated in the three towns was computed. The analysis was done to compare the rate at which each of these household waste component is generated in their respective towns.

3.7.8 COMPARISON OF HOUSEHOLD WASTE PRODUCED PER DAY IN EJISU, ATIA AND DONASO

The quantity of each of these household waste component produced in their respective towns was computed. The quantity of each household waste component was computed to compare the volume of waste produced in a day in each of these towns.

3.7.9 CLASSIFICATION OF WASTE INTO BIODEGRADABLES, RECYCLABLES, TEXTILES AND OTHERS (SAND FROM SWEEPING AND ASH) IN EJISU, ATIA AND DONASO

The various household waste components were classified as biodegradables, recyclables, textiles and others in the waste stream:

Biodegradables: Wood, food-yard and garden waste.

Recyclables: Plastics, metals and paper

Textiles: Textiles.

Others: Ash and sand

These groupings of household waste categories were determined using Statistical Package for Social Sciences (SPSS) in the respective towns.

3.7.10 DETERMINATION OF GENERAL HOUSEHOLD WASTE TYPES IN EJISU-JUABEN MUNICIPALITY

The classification of waste into biodegradables, recyclables, textiles and others for the entire three towns was computed to provide the general household waste categories in the municipality using Statistical Package for Social Sciences (SPSS).

3.8 FORECAST OF THE AMOUNT OF WASTE THAT WOULD BE GENERATED IN 2022

Using the mean daily weight of the waste generated, a projection of the amount of waste produced for the years 2014 to 2022 (8 years' time) was done for each town by multiplying the mean daily weight by the number of days in each of these years as shown in Appendix C (page 78-86): Table C.1 to C.8.

The determination of projected household waste from sample towns was calculated to provide future information on the solid waste composition and quantification for the design of equipment for handling, recycling, composting and calculating the size of landfill for appropriate waste management options.

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

4.1 Table 4.1.1, 4.1.2 and 4.1.3 present percentage composition of waste sorted in the study area.

Table 4.1. 1 Percentage composition of the waste sorted in Ejisu

Waste Component	Percentage (%)
Food, Yard And Garden Waste	63.36
Plastics	4.71
Metals	3.64
Paper	2.16
Wood	2.20
Glass	2.18
Textiles	1.65
Others	20.06
Total	**100**

Others basically include sand from sweepings and ash

The largest component in the waste as presented in Tab 4.1.1 was food, garden and yard waste component of 63.36% contributing to the high percentage composition of biodegradable. Results show that, the average generation rate per household was 0.481 kg/person/day collected from eighty-seven (87) households with a total weight of 1,806.35 kg (Appendix E, Table E.1), this figure compares favourably with 0.40-0.60kg/person/day reported by Cointreau-Levine (1994).

Table 4.1. 2 Percentage composition of the waste sorted in Atia

Waste Component	Percentage (%)
Food, Yard And Garden Waste	69.65
Plastics	3.73
Metals	2.08
Paper	2.014
Wood	3.16
Glass	1.48
Textiles	1.26
Others	16.59
Total	**100**

Others basically include sand from sweepings and ash

Atia is a rural community unlike Ejisu. The largest component in the waste as presented in Tab 4.1.2 was food, garden and yard waste component of 69.65% contributing to the high percentage composition of biodegradable. Results show that, the average generation rate per household was 0.4573 kg/person/day collected from eleven (11) households with a total weight of 342.54 kg (Appendix E, Table E.2). This was also observed by Cointreau-Levine (1994) in Washington.

Table 4.1. 3 Percentage composition of the waste sorted in Donaso

Waste Component	Percentage (%)
Food, Yard And Garden Waste	69.46
Plastics	2.26
Metals	1.50
Paper	1.46
Wood	2.07
Glass	2.70
Textiles	0.17
Others	20.3
Total	**100**

Others basically include sand from sweepings and ash

Donaso possessed characteristics typical of rural settings. The largest component in the waste as presented in Tab 4.1.3 was food, garden and yard waste component of 69.46% contributing to the high percentage composition of biodegradable. Results show that, the average generation rate per household was 0.372 kg/person/day collected from seven (7) households with a total weight of 140.553kg (Appendix E, Table E.3). This figure compared favourably with studies by Bolaane and Ali (2004) who reported that the average waste generation rate for Gaborone was 0.33 kg/person/day.

Table 4.2. 1 Presents the overall percentage composition of waste sorted in the three sampled towns.

Waste Component	Percentage (%)
Food, Yard And Garden Waste	67.49
Plastics	3.57
Metals	2.41
Paper	1.88
Wood	2.48
Glass	2.11
Textiles	1.03
Others	18.98
Total	**100**

Others basically include sand from sweepings and ash

Ejisu, Atia and Donaso (peri-urban communities) possessed characteristics typical of rural and urban settings. Household wastes were subjugated by food-yard and garden waste with compositions of 63.36%, 69.65% and 69.46% conforming to an observation by Beukering *et al*. (1999) who noted that waste in rural settings has high organic content and susceptible to rapid decay. The results published by Buenrostro and Bocco (2003) reported that, foodscraps in Morelia accounted for 50.95%. The reason for the higher generation rates computed for the food-yard and garden waste in the Ejisu-Juaben Municipality could be attributed to the fact that most inhabitants are farmers with an abundance of food. Therefore the inhabitants tend not to bother about the wastage of foodstuffs hence accounting for the highest biodegradable waste in the municipality. This indicates that the community's waste has a large amount of organics and therefore suggests that it is a potential for use as compost.

The observed amount of plastics 3.57% including polythene bags in the sampled waste in the studied communities could be attributed to the fact that, most of the inhabitants who work mainly in Ejisu use polythene bags rather than glass as their means of packaging hence explains why glass recorded low levels in the waste. The inhabitants served as beneficiaries of the plastic carriers for the various items purchased from these urban areas. This can also be evident in a study conducted by Gomez *et al.* (2008), where waste composition for plastics and glass accounts for 18% and 6% respectively which indicates that plastic consumption outweighs that of glass.

Wood is used as a source of fire for domestic purposes in the communities and is therefore not disposed off in wastes. This could explain for the unusually low amount of wood recorded; 2.48% in the studied communities.

4.3 Composition of Waste Types in the Study Communities

Figures 4.3.1, 4.3.2 and 4.3.3 present the composition of waste types in the study area.

In order to best manage the solid waste in the Ejisu-Juaben municipality, there is a need for classifying the waste into biodegradables, recyclables, textiles and others (ash and sand).

The various household waste components were classified as biodegradables, recyclables, textiles and others in the waste stream:

Biodegradables: Wood, food-yard and garden waste.

Recyclables: Plastics, metals and paper

Textiles: Textiles.

Others: Ash and sand

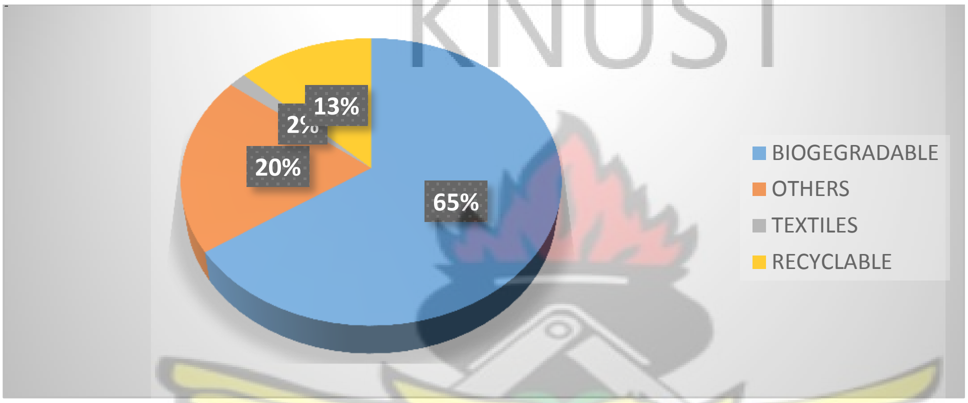

Fig 4.3. 1 General Household Waste Types in Ejisu

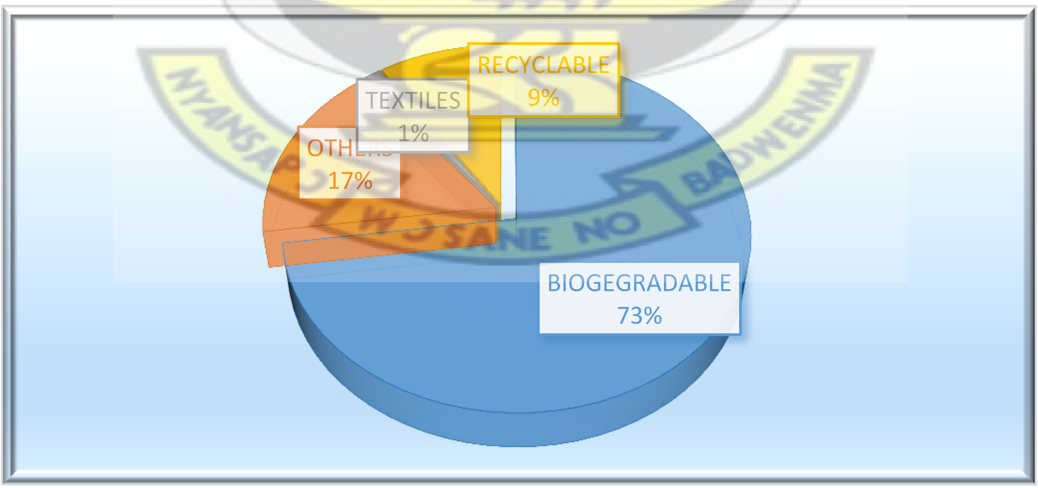

Fig. 4.3.2 General Household Waste Types in Atia

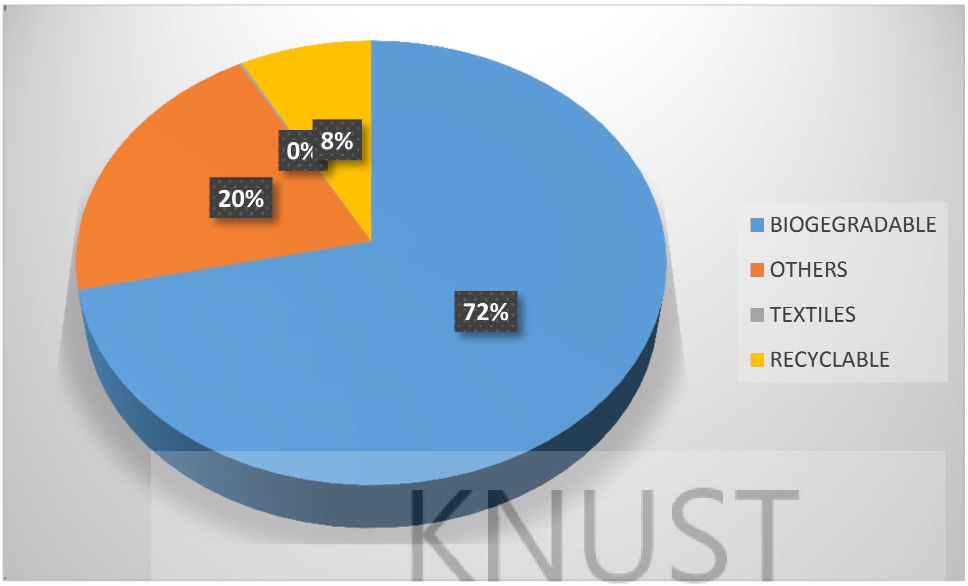

Fig 4.3. 3 General Household Waste Types in Donaso

4.4 GENERAL HOUSEHOLD WASTE FOR THE MUNICIPALITY

4.4 Figure 4.4.1 presents the overall composition of waste type in the three sampled towns.

Results show that the largest component in the entire waste was food-garden and yard waste component contributing to the high percentage composition of biodegradables of 67%. Conforming to an observation by the Kumasi Metropolitan Assembly (2009), biodegradable waste component in Accra and Kumasi accounted for 65% and 64% of total waste generated. This is an indication that the Ejisu-Juaben municipality's waste contains large amount of organics and therefore has a potential for use as compost. Asomani-Boateng (2002) also reported that biodegradable waste component can be improved for reuse as fertilizer by composting to enrich agricultural production. The 12% recyclable waste in the entire waste suggests that revenue could be generated if recycling management practices are adopted. Waste recycling is often undertaken as a survival strategy when the urban poor are unable to obtain formal employment, and when non-waste resources are scarce or unaffordable (Cointreau and de Kadt, 1991).

Despite these environmentally and socially beneficial aspects of waste recycling, it has some constraints, which include poor health and living conditions for the urban poor who deal in waste picking (Furedy, 1992).

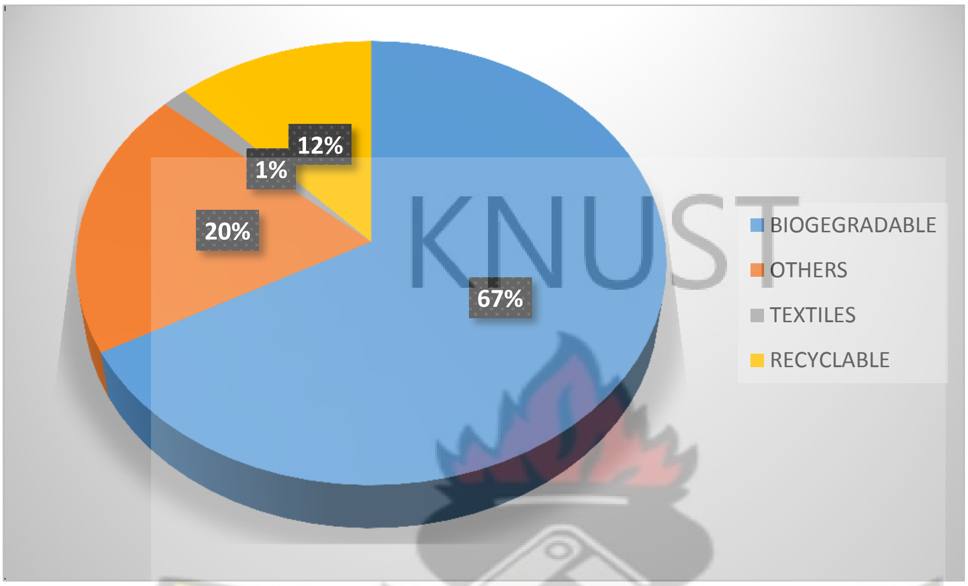

Fig 4.4. 1 General Household Waste Types in Ejisu Jaubeng District

4.5 COMPARISM OF WASTE GENERATION RATES IN THE MUNICIPALITY

4.5 Figure 4.5.1 presents the waste generation rate of various waste components in Ejisu, Atia and Donaso.

The average waste generation rate from Ejisu, Atia and Donaso was 0.4367 kg/person/day. A similar rate was also reported by Kaseva and Mbuligwe (2005) in a study on waste generation, reporting that the average waste generation rates of 0.34 kg/person/day accounts for low-income areas and 0.42 kg/person/day for planned areas in Dar es Salaam.

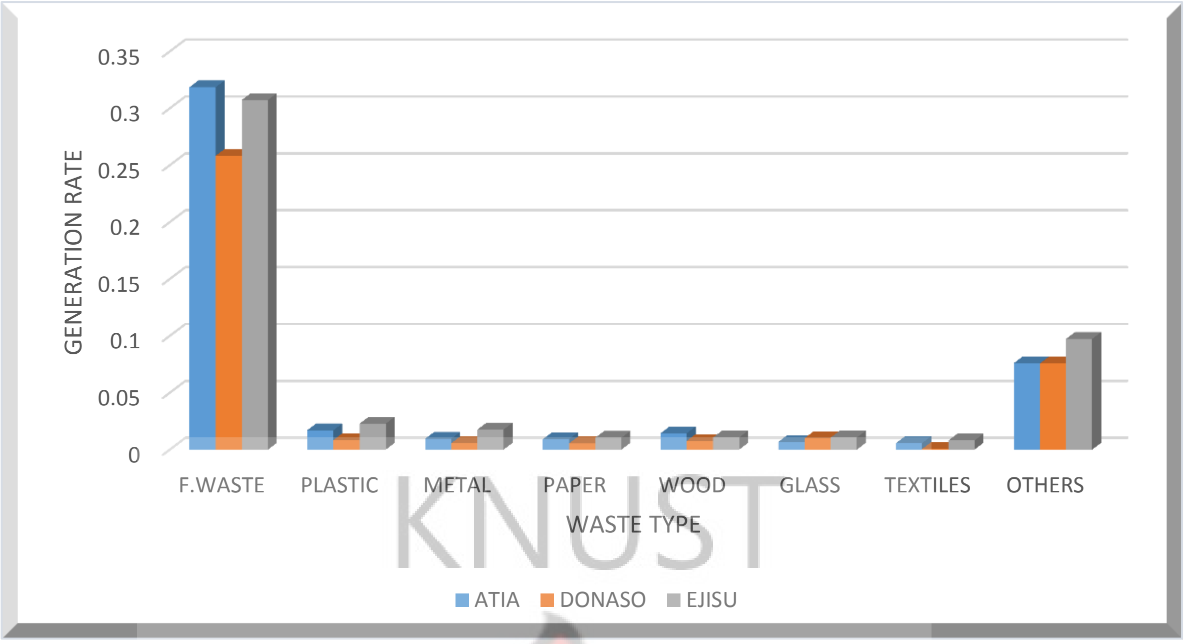

Fig 4.5. 1 Comparison of Waste Generation Rates in Ejisu, Atia and Donaso

CHAPTER FIVE

5.0 CONCLUSION AND RECOMMENDATION

5.1 CONCLUSION

- Solid waste in the Ejisu-Juaben Municipality is of biodegradable, recyclable and of textile backgrounds and contains food-yard-and-garden waste (67.49%), plastics (3.57%), metals (2.41%), paper (1.88%), wood (2.48%), glass (2.11%), textiles (1.03%), sand and ash (18.98%).

- The volumes of household waste produced in a day in Ejisu, Atia and Donaso were 8,925.635kg, 843.822kg and 324.384kg and they are expected to increase within eight (8) years to 52,726.739kg, 4,563.7kg and 2,500.238kg respectively in the year 2022.

- The multi-class nature of waste generated in the district compels the use of the integrated approach to manage solid waste in the district. This would allow the waste to be effectively managed since the benefits of the various practices (including compost formation and recycling) could be maximized. This would lessen the menace caused by solid waste and improve the economic value of compost and recyclable solid wastes in the municipality.

5.2 RECOMMENDATION

- A study should be conducted to collect information on resident willingness to source-separate their waste.

- A study covering the wet and dry seasons should be conducted to enable a better effect of time and seasons to be established for more effective waste management practice for the municipality.

. Peri-urban areas like Ejisu-man new sites, Serwaa Akura, Ejisu government bungalows and high residential areas within the municipality could be encouraged to operate house-house and communal collection services for onward transfer.

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APPENDICES

Appendix A

DETAILED RESULTS

SELECTING A HOUSEHOLD FOR THE STUDY

Table A.1: SUMMARY OF DATA ON THE POPULATION AND HOUSEHOLD IN EJISU-JUABEN MUNICIPALITY

LOCALITY	HIGH CLASS RESIDENTIAL	MIDDLE CLASS RESIDENTIAL	LOW CLASS RESIDENTIAL	TOTAL NUMBER OF HOUSEHOLD	TOTAL POPULATION
EJISU	1741	329	382	2452	18391
ATIA	34	96	191	321	1629
DONASO	113	7	50	170	872
TOTAL	1888	432	623	2943	20892

PRELIMINARY SURVEY DETERMINATION

A total of 90 households were selected from Ejisu, Atia and Donaso. Households were randomly selected within each of these stratas in proportion to their size in the actual population.

Total Number of Households = 2452 + 321 + 170

= 2943

NUMBER OF HOUSEHOLD SELECTED IN EJISU

$\frac{2452}{2943} \times 90$

= 75 samples were taken from Ejisu

s

NUMBER OF HOUSEHOLD SELECTED IN EACH STRATA

High Class Residential: $\frac{1741}{2452} \times 75 = 53$

Middle Class Residential: $\frac{329}{2452} \times 75 = 10$

Low Class Residential: $\frac{382}{2452} \times 75 = 12$

NUMBER OF HOUSEHOLD SELECTED IN ATIA

$\frac{321}{2943} \times 90$

= 10 samples were taken from Atia

NUMBER OF HOUSEHOLD SELECTED IN EACH STRATA

High Class Residential: $\frac{34}{321} \times 10 = 1$

Middle Class Residential: $\frac{96}{321} \times 10 = 3$

Low Class Residential: $\frac{191}{321} \times 10 = 6$

NUMBER OF HOUSEHOLD SELECTED IN DONASO

$\frac{170}{2943} \times 90$

= 5 samples were taken from Donaso

NUMBER OF HOUSEHOLD SELECTED IN EACH STRATA

High Class Residential: $\frac{113}{170} \times 5 = 3$

Middle Class Residential: $\frac{7}{170} \times 5 = 1$

Low Class Residential: $\frac{50}{170} \times 5 = 1$

Table A.2: SUMMARY OF PRELIMINARY HOUSEHOLD SELECTED AT EJISU, ATIA AND DONASO

LOCALITY	High Class Residential	Middle Class Residential	Low Class Residential	Total Household
Ejisu	53	10	12	75
Atia	1	3	6	10
Donaso	3	1	1	5
Total	57	14	19	90

DETERMINATION OF ACTUAL SAMPLE SIZE

The mean and standard deviation calculated for the one week preliminary studies in the Ejisu-Juaben Municipality were 19.5339 and 11.2272.

SAMPLE SIZE CALCULATION

Cochran's (1977) sample size formula was used to determine the sample size

$$n = \frac{z_{\alpha/2}.\delta}{\epsilon}^{2}$$

Where n is the sample size

$z_{\alpha/2}$ is the critical value at the vertical boundary for the area of $\alpha/2$ in the right tail of the standard normal distribution.

δ is the population standard deviation

ϵ is the permissible error margin

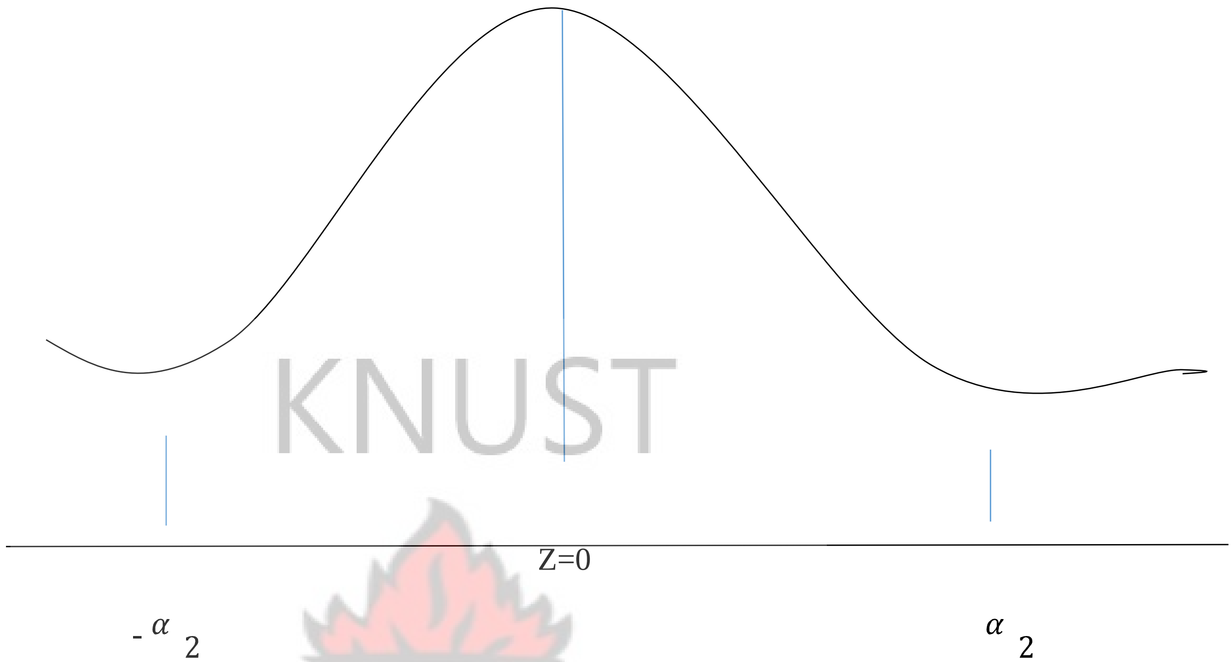

Fig A.1. The standard normal distribution curve

- Assuming a 1% error and 99% probability for the weights:

Permissible error margin (ϵ) = Error margin (%) × mean

ϵ = 0.01 × 19.5339

= 0.19534

From the normal distribution table, $\boldsymbol{z_{\alpha/2}}$ = 2.575

Therefore putting ϵ into the equation below

$$n = \frac{z_{\alpha/2}.\,\delta}{\epsilon}\ ^{2}$$

$$n=[\frac{2.575 \times 11.2272}{0.19534}]$$

n = 21904 households

- Assuming a 5% error and a 95% probability for the weights:

ϵ = 0.05 × 19.5339

ϵ = 0.9767

From the normal distribution table, $z_{\alpha/2} = 1.96$

Putting ϵ into the equation:

n = $[\frac{1.96 \times 11.2272}{0.9767}]$

n = 508 households

- Assuming a 10% error and a 90% probability for the weights:

ϵ = 0.1 × 19.5339

ϵ = 1.9534

From the normal distribution table, $z_{\alpha/2}$= 1.645

n= $[\frac{1.645 \times 11.2272}{1.9534}]$

n= 89 households

- Assuming 15% error and 85% probability for the weights:

ϵ = 0.15 × 19.5339

ϵ = 2.9301

From the normal distribution table, $z_{\alpha/2}$= 1.44

n= $[\frac{1.44 \times 11.2272}{2.9301}]$

n = 31 households

- Assuming 20% error and 80% probability for the weights:

$\epsilon = 0.2 \times 19.5339$

$\epsilon = 3.9068$

From the normal distribution table, $z_{\alpha/2} = 1.29$

$n = [\frac{1.29 \times 11.2272}{3.9068}]$

n = 14 households

Table A.3: SUMMARY OF THE SAMPLE SIZES

Confidence Limit, P (%)	Error Margin, ϵ (%)	Critical Value, $z_{\alpha/2}$	Permissible error margin (ϵ)	Sample size, n(households)
99	1	2.575	0.19534	21904
95	5	1.96	0.9767	508
90	10	1.645	1.9534	89
85	15	1.44	2.9301	31
80	20	1.29	3.9068	14

From the above calculation it can be inferred that confidence level, P (%) values higher than 95% resulted in too large sample size. This poses a difficulty in the sampling and sorting processes due to time and financial constraints. On the basis of using probability value of 90%, sample size of 105 households were used for the selected towns (Ejisu, Atia and Donaso) in Ejisu-Juaben municipality and is justified within a confidence limit between 90% and 95%.

DETERMINATION OF THE NUMBER OF SAMPLES

A total of 105 households were selected from Ejisu, Atia and Donaso. Households were randomly selected within each of these stratas in proportion to their size in the actual population.

From Table 1, Total Number of Household = 2452 + 321 + 170

= 2943

NUMBER OF HOUSEHOLD SELECTED IN EJISU

$\frac{2452}{2943} \times 105$

= 87 samples were taken from Ejisu

NUMBER OF HOUSEHOLD SELECTED IN EACH STRATA

High Class Residential: $\frac{1741}{2452} \times 87 = 62$

Middle Class Residential: $\frac{329}{2452} \times 87 = 12$

Low Class Residential: $\frac{382}{2452} \times 87 = 13$

NUMBER OF HOUSEHOLD SELECTED IN ATIA

$\frac{321}{2943} \times 105$

= 11 samples were taken from Atia

NUMBER OF HOUSEHOLD SELECTED IN EACH STRATA

High Class Residential: $\frac{34}{321} \times 11 = 1$

Middle Class Residential: $\frac{96}{321} \times 11 = 3$

Low Class Residential: $\frac{191}{321} \times 11 = 7$

NUMBER OF HOUSEHOLD SELECTED IN DONASO

$\frac{170}{2943} \times 105$

= 6 samples were taken from Donaso

NUMBER OF HOUSEHOLD SELECTED IN EACH STRATA

High Class Residential: $\frac{113}{170} \times 6 = 4$

Middle Class Residential: $\frac{7}{170} \times 6 = 1$

Low Class Residential: $\frac{50}{170} \times 6 = 2$

Table A.4: **A SUMMARY OF ACTUAL SAMPLE SIZES**

LOCALITY	High Class Residential	Middle Class Residential	Low Class Residential	Total
Ejisu	62	12	13	87
Atia	1	3	7	11
Donaso	4	1	2	7
Total	67	16	22	105

Appendix B

DETERMINATION OF HOUSEHOLD WASTE PARAMETERS IN EJISU

DETERMINATION OF MEAN PER FAMILY IN EJISU

The mean per family of household waste sorted in Ejisu was calculated using the relation:

Mean/ Family = $\frac{Weekly\ totals\ of\ each\ household\ waste\ collected}{Total\ number\ of\ households\ selected}$

Table B.1: Determination of mean/family in Ejisu

Household waste component	Weekly totals of household waste component (kg)	Total number of households (Total number of households selected)	Mean/Family
Food, garden and yard waste	1144.61	87	13.16
Plastics	85.256	87	0.98
Metals	65.93	87	0.76
Papers	39.055	87	0.45
Wood	39.78	87	0.46
Textiles	39.45	87	0.45
Glasses	29.84	87	0.34
Others (ash and sand)	362.43	87	4.17

DETERMINATION OF MEAN/PERSON/WEEK IN EJISU

The determination of mean per person per week of household waste sorted in Ejisu was calculated using the relation:

Mean/Person/Week = $\frac{Mean\ per\ family \times Total\ number\ of\ households\ selected}{Total\ number\ of\ persons\ in\ the\ households}$

Table B.2: Determination of mean/person/week in Ejisu

Household waste component	Weekly totals of household waste component (kg)	Mean/Family	Total number of households	Total number of persons in the house	Mean/Person/Week
Food, garden and yard waste	1144.61	13.16	87	532	2.152
Plastics	85.256	0.98	87	532	0.160
Metals	65.93	0.76	87	532	0.124
Papers	39.055	0.45	87	532	0.074
Wood	39.78	0.46	87	532	0.075
Textiles	39.45	0.45	87	532	0.074
Glasses	29.84	0.34	87	532	0.056
Others (ash and sand)	362.43	4.17	87	532	0.682

DETERMINATION OF WASTE GENERATION RATE IN EJISU

The waste generation rate of waste sorted in Ejisu was calculated using the relation:

Waste generation rate = $\frac{(Weekly\ totals\ of\ each\ household\ waste\ collected\ per\ observation\ period)}{Total\ number\ of\ persons\ in\ the\ households}$

Table B.3: Determination of waste generation rate in Ejisu

Household waste component	Weekly totals of household waste component	Observed period (week)	Total number of persons in the house	Waste generation rate
Food, garden and yard waste	1144.61	7	532	0.307
Plastics	85.256	7	532	0.023
Metals	65.93	7	532	0.018
Papers	39.055	7	532	0.010
Wood	39.78	7	532	0.011
Textiles	39.45	7	532	0.011
Glasses	29.84	7	532	0.008
Others (ash and sand)	362.43	7	532	0.097

DETERMINATION OF TOTAL HOUSEHOLD WASTE PRODUCED PER DAY IN EJISU

The total household waste produced in Ejisu was calculated using the relation:

Total Waste/Day = Waste generation rate × Population

Table B.4: Determination of total household waste produced per day in Ejisu

Household waste component	Waste generation rate	Population	Total waste per day
Food, garden and yard waste	0.307	18391	5646.037
Plastics	0.023	18391	422.993
Metals	0.018	18391	331.038
Papers	0.010	18391	183.91
Wood	0.011	18391	202.301
Textiles	0.011	18391	202.301
Glasses	0.008	18391	147.128
Others (ash and sand)	0.097	18391	1789.927

DETERMINATION OF TOTAL HOUSEHOLD WASTE PRODUCED IN A YEAR IN EJISU

The total household waste produced in a year in Ejisu was calculated using the relation:

Total waste in a year = Total waste/ Day × Number of days in a year

Table B.5: Determination of total household waste produced in a year in Ejisu

Household waste component	Total waste per day	Number of days in a year	Total waste in a year
Food, garden and yard waste	5646.037	365	2060803.505
Plastics	422.993	365	154392.445
Metals	331.038	365	120828.87
Papers	183.91	365	67127.15
Wood	202.301	365	73839.865
Textiles	202.301	365	73839.865
Glasses	147.128	365	53701.72
Others (ash and sand)	1789.927	365	653323.355

DETERMINATION OF MEAN PER FAMILY IN ATIA

The mean per family of household waste sorted in Atia was calculated using the relation:

Mean/ Family = $\frac{Weekly\ totals\ of\ each\ household\ waste\ collected}{Total\ number\ of\ households\ selected}$

Table B.6: Determination of mean/family in Atia

Household waste component	Weekly totals of household waste component (kg)	Total number of households (Total number of households selected)	Mean/Family
Food, garden and yard waste	238.58	11	21.689
Plastics	12.79	11	1.163
Metals	7.14	11	0.649
Papers	6.9	11	0.627
Wood	10.85	11	0.986
Textiles	5.09	11	0.463
Glasses	4.33	11	0.394
Others (ash and sand)	56.86	11	5.169

DETERMINATION OF MEAN/PERSON/WEEK IN ATIA

The determination of mean per person per week of household waste sorted in Atia was calculated using the relation:

$$\text{Mean/Person/Week} = \frac{Mean\ per\ family \times Total\ number\ of\ households\ selected}{Total\ number\ of\ persons\ in\ the\ households}$$

Table B.7: Determination of mean/person/week in Atia

Household waste component	Weekly totals of household waste component (kg)	Mean/Family	Total number of households	Total number of persons in the house	Mean/Person/Week
Food, garden and yard waste	238.58	21.689	11	107	2.230
Plastics	12.79	1.027	11	107	0.106
Metals	7.14	4.993	11	107	0.513
Papers	6.9	4.825	11	107	0.496
Wood	10.85	22.143	11	107	2.276
Textiles	5.09	2.424	11	107	0.249
Glasses	4.33	9.021	11	107	0.927
Others (ash and sand)	56.86	5.169	11	107	0.531

DETERMINATION OF WASTE GENERATION RATE IN ATIA

The waste generation rate of waste sorted in Atia was calculated using the relation:

$$\text{Waste generation rate} = \frac{(Weekly\ totals\ of\ each\ household\ waste\ collected\ per\ observation\ period)}{Total\ number\ of\ persons\ in\ the\ households}$$

Table B.8: Determination of waste generation rate in Atia

Household waste component	Weekly totals of household waste component	Observed period (week)	Total number of persons in the house	Waste generation rate
Food, garden and yard waste	283.58	7	107	0.379
Plastics	12.79	7	107	0.017
Metals	7.14	7	107	0.010
Papers	6.9	7	107	0.009
Wood	10.85	7	107	0.014
Textiles	5.09	7	107	0.007
Glasses	4.33	7	107	0.006
Others (ash and sand)	56.86	7	107	0.076

DETERMINATION OF TOTAL HOUSEHOLD WASTE PRODUCED PER DAY IN ATIA

The total household waste produced in Atia was calculated using the relation;

Total Waste/Day = Waste generation rate × Population

Table B.9: Determination of total household waste produced per day in Atia

Household waste component	Waste generation rate	Population	Total waste per day
Food, garden and yard waste	0.379	1629	617.391
Plastics	0.017	1629	27.693
Metals	0.010	1629	16.29
Papers	0.009	1629	14.661
Wood	0.014	1629	22.806
Textiles	0.007	1629	11.403
Glasses	0.006	1629	9.774
Others (ash and sand)	0.076	1629	123.804

DETERMINATION OF TOTAL HOUSEHOLD WASTE PRODUCED IN A YEAR IN ATIA

The total household waste produced in a year in Atia was calculated using the relation;

Total waste in a year = Total waste/ Day × Number of days in a year

Table B.10: Determination of total household waste produced in a year in Atia

Household waste component	Total waste per day	Number of days in a year	Total waste in a year
Food, garden and yard waste	617.391	365	225347.715
Plastics	27.693	365	10107.945
Metals	16.29	365	5945.85
Papers	14.661	365	5351.265
Wood	22.806	365	8324.19
Textiles	11.403	365	4162.095
Glasses	9.774	365	3567.51
Others (ash and sand)	123.804	365	45188.46

DETERMINATION OF MEAN PER FAMILY IN DONASO

The mean per family of household waste sorted in Donaso was calculated using the relation:

Mean/ Family = $\frac{Weekly\ totals\ of\ each\ household\ waste\ collected}{Total\ number\ of\ households\ selected}$

Table B.11: Determination of mean/family in Donaso

Household waste component	Weekly totals of household waste component (kg)	Total number of households (Total number of households selected)	Mean/Family
Food, garden and yard waste	97.63	7	13.947
Plastics	3.19	7	0.456
Metals	2.11	7	0.301
Papers	2.053	7	0.293
Wood	2.92	7	0.417
Textiles	3.8	7	0.543
Glasses	0.25	7	0.036
Others (ash and sand)	28.6	7	4.086

DETERMINATION OF MEAN/PERSON/WEEK IN DONASO

The determination of mean per person per week of household waste sorted in Donaso was calculated using the relation:

Mean/Person/Week = $\frac{Mean\ per\ family \times Total\ number\ of\ households\ selected}{Total\ number\ of\ persons\ in\ the\ households}$

Table B.12: Determination of mean/person/week in Donaso

Household waste component	Weekly totals of household waste component (kg)	Mean/Family	Total number of households	Total number of persons in the house	Mean/Person/Week
Food, garden and yard waste	97.63	13.947	7	54	1.808
Plastics	3.19	0.456	7	54	0.059
Metals	2.11	0.301	7	54	0.039
Papers	2.053	0.293	7	54	0.038
Wood	2.92	0.417	7	54	0.054
Textiles	3.8	0.543	7	54	0.070
Glasses	0.25	0.036	7	54	0.005
Others (ash and sand)	28.6	4.086	7	54	0.530

DETERMINATION OF WASTE GENERATION RATE IN DONASO

The waste generation rate of waste sorted in Donaso was calculated using the relation:

$$\text{Waste generation rate} = \frac{(\textit{Weekly totals of each household waste collected per observation period})}{\textit{Total number of persons in the households}}$$

Table B.13: Determination of waste generation rate in Donaso

Household waste component	Weekly totals of household waste component	Observed period (week)	Total number of persons in the house	Waste generation rate
Food, garden and yard waste	97.63	7	54	0.258
Plastics	3.19	7	54	0.008
Metals	2.11	7	54	0.006
Papers	2.053	7	54	0.005
Wood	2.92	7	54	0.008
Textiles	3.8	7	54	0.010
Glasses	0.25	7	54	0.001
Others (ash and sand)	28.6	7	54	0.076

DETERMINATION OF TOTAL HOUSEHOLD WASTE PRODUCED PER DAY IN DONASO

The total household waste produced in Donaso was calculated using the relation:

Total Waste/Day = Waste generation rate × Population

Table B.14: Determination of total household waste produced per day in Donaso

Household waste component	Waste generation rate	Population	Total waste per day
Food, garden and yard waste	0.258	872	224.976
Plastics	0.008	872	6.976
Metals	0.006	872	5.232
Papers	0.005	872	4.36
Wood	0.008	872	6.976
Textiles	0.010	872	8.72
Glasses	0.001	872	0.872
Others (ash and sand)	0.076	872	66.272

DETERMINATION OF TOTAL HOUSEHOLD WASTE PRODUCED IN A YEAR IN DONASO

The total household waste produced in a year in Donaso was calculated using the relation:

Total waste in a year = Total waste/ Day × Number of days in a year

Table B.15: Determination of total household waste produced in a year in Donaso

Household waste component	Total waste per day	Number of days in a year	Total waste in a year
Food, garden and yard waste	224.976	365	82116.24
Plastics	6.976	365	2546.24
Metals	5.232	365	1909.68.
Papers	4.36	365	1591.4
Wood	6.976	365	2546.24
Textiles	8.72	365	3182.8
Glasses	0.872	365	318.28
Others (ash and sand)	66.272	365	24189.28

Appendix C

DETERMINATION OF PROJECTED POPULATION IN THE THREE TOWNS; EJISU, ATIA AND DONASO

The available data on the municipal assembly population as at 2014 with a growth rate of 2.5% is shown below.

Table C.1: EJISU-JUABEN MUNICIPAL ASSEMBLY POPULATION AS AT 2014

LOCALITY	TOTAL POPULATION
EJISU	18391
ATIA	1629
DONASO	872
TOTAL	20892

Based on this data, the population of the sampled towns were projected.

The determination of projected population in the sample towns was calculated using the relation:

$P\eta = Po\,(1+r)^{\eta}$

Where: $P\eta$ = Projected population

Po = Current population

r = Growth rate

η = Number of years

Table C.2: Projected Population Growth in the Ejisu-Juaben Municipality

Year	EJISU	ATIA	DONASO
2015	229889	2036	1090
2016	28736	2545	1363
2017	35920	3182	1703
2018	44900	3977	2129
2019	56125	4971	2661
2020	70156	6214	3326
2021	87695	7768	4158
2022	109619	9710	5198

FORECAST OF THE AMOUNT OF WASTE THAT WOULD BE GENERATED IN 2022

The mean daily weight of waste (waste/day) that would be generated in Ejisu was calculated using the relation:

Mean daily weight of waste generated (Waste/Day) = Waste generation rate × Projected Population

Table C.3: DETERMINATION OF MEAN DAILY WEIGHT (WASTE/DAY) THAT WOULD BE PRODUCED IN EJISU

Year	Projected Population	Waste Generation Rates for each household waste component							
		Food, garden and yard waste	Plastics	Metal	Paper	Wood	Glass	Textiles	Others
2015	229889	0.303	0.023	0.018	0.010	0.011	0.011	0.008	0.097
2016	28736	0.303	0.023	0.018	0.010	0.011	0.011	0.008	0.097
2017	35920	0.303	0.023	0.018	0.010	0.011	0.011	0.008	0.097
2018	44900	0.303	0.023	0.018	0.010	0.011	0.011	0.008	0.097
2019	56125	0.303	0.023	0.018	0.010	0.011	0.011	0.008	0.097
2020	70156	0.303	0.023	0.018	0.010	0.011	0.011	0.008	0.097
2021	87695	0.303	0.023	0.018	0.010	0.011	0.011	0.008	0.097
2022	109619	0.303	0.023	0.018	0.010	0.011	0.011	0.008	0.097
Waste/Day: 2015		69656.367	5287.447	4138.002	2298.89	2528.779	2528.779	1839.112	22299.233
Waste/Day: 2016		8707.008	660.928	517.248	287.36	316.096	316.096	229.888	2787.392
Waste/Day: 2017		10883.76	826.16	646.56	359.2	395.12	395.12	287.36	3484.24
Waste/Day: 2018		13604.7	1032.7	808.2	449	493.9	493.9	359.2	4355.3
Waste/Day: 2019		17005.875	1290.875	1010.25	561.25	617.375	617.375	449	5444.125
Waste/Day: 2020		21257.268	1613.588	1262.808	701.56	771.716	771.716	561.248	6805.132
Waste/Day:2021		26571.585	2016.985	1578.51	876.95	964.645	964.645	701.56	8506.415
Waste/Day: 2022		33214.557	2521.237	1973.142	1096.19	1205.809	1205.809	876.952	10633.043

Year	Number of days in a year	Total Waste/ Day for each household waste component							
		Food, garden and yard waste	Plastics	Metal	Paper	Wood	Glass	Textiles	Others
2015	365	69656.367	5287.447	4138.002	2298.89	2528.779	2528.779	1839.112	22299.233
2016	365	8707.008	660.928	517.248	287.36	316.096	316.096	229.888	2787.392
2017	365	10883.76	826.16	646.56	359.2	395.12	395.12	287.36	3484.24
2018	365	13604.7	1032.7	808.2	449	493.9	493.9	359.2	4355.3
2019	365	17005.875	1290.875	1010.25	561.25	617.375	617.375	449	5444.125
2020	365	21257.268	1613.588	1262.808	701.56	771.716	771.716	561.248	6805.132
2021	365	26571.585	2016.985	1578.51	876.95	964.645	964.645	701.56	8506.415
2022	365	33214.557	2521.237	1973.142	1096.19	1205.809	1205.809	876.952	10633.043
Waste/Year: 2015		25424573.96	1929918.155	1510370.73	839094.85	923004.335	923004.335	671275.88	8139220.045
Waste/Year: 2016		3178057.92	241238.72	188795.52	104886.4	115375.04	115375.04	83909.12	1017398.08
Waste/Year: 2017		3972572.4	301548.4	235994.4	131108	144218.8	144218.8	104886.4	1271747.6
Waste/Year: 2018		4965715.5	376935.5	294993	163885	180273.5	180273.5	131108	1589684.5
Waste/Year: 2019		6207144.375	471169.375	368741.25	204856.25	225341.875	225341.875	163885	19987105.625
Waste/Year: 2020		7758902.82	588959.62	460924.92	256069.4	281676.34	281676.34	204855.52	2483873.18
Waste/Year: 2021		9698628.525	736199.525	576156.15	320086.75	352095.425	352095.425	256069.4	3104841.475
Waste/Year: 2022		12123313.31	920251.505	720196.83	400109.35	440120.285	440120.285	320087.48	3881060.695

FORECAST OF THE AMOUNT OF WASTE THAT WOULD BE PRODUCED IN 2022 AT EJISU

The total waste that would be produced for eight (8) years in Ejisu was calculated using the relation:

Total waste in a year = Total waste/ Day × Number of days in a years

Table C.4: DETERMINATION OF WASTE THAT WOULD BE PRODUCED IN 2022 AT EJISU

FORECAST OF THE AMOUNT OF WASTE THAT WOULD BE GENERATED IN 2022

The mean daily weight of waste (waste/day) that would be generated in Atia was calculated using the relation:

Mean daily weight of waste generated (Waste/Day) = Waste generation rate × Projected Population

Table C.5: DETERMINATION OF MEAN DAILY WEIGHT (WASTE/DAY) THAT WOULD BE PRODUCED IN ATIA

Year	Projected Population	Waste Generation Rates for each household waste component							
		Food, garden and yard waste	Plastics	Metal	Paper	Wood	Glass	Textiles	Others
2015	2036	0.303	0.023	0.018	0.010	0.011	0.011	0.008	0.097
2016	2545	0.303	0.023	0.018	0.010	0.011	0.011	0.008	0.097
2017	3182	0.303	0.023	0.018	0.010	0.011	0.011	0.008	0.097
2018	3977	0.303	0.023	0.018	0.010	0.011	0.011	0.008	0.097
2019	4971	0.303	0.023	0.018	0.010	0.011	0.011	0.008	0.097
2020	6214	0.303	0.023	0.018	0.010	0.011	0.011	0.008	0.097
2021	7768	0.303	0.023	0.018	0.010	0.011	0.011	0.008	0.097
2022	9710	0.303	0.023	0.018	0.010	0.011	0.011	0.008	0.097
Waste/Day: 2015		616.908	46.828	36.648	20.36	22.396	22.396	16.288	197.492
Waste/Day: 2016		771.135	58.535	45.81	25.45	27.995	27.995	20.36	246.865
Waste/Day: 2017		964.146	73.186	57.276	31.82	35.002	35.002	25.456	308.654
Waste/Day: 2018		1205.031	91.471	71.586	39.77	43.747	43.747	31.816	385.769
Waste/Day: 2019		1506.213	114.333	89.478	49.71	54.681	54.681	39.768	482.187
Waste/Day: 2020		1882.842	142.922	111.852	62.14	68.354	68.354	49.712	602.758
Waste/Day:2021		2353.704	178.664	139.824	77.68	85.448	85.448	62.144	753.496
Waste/Day: 2022		2942.13	223.33	174.78	97.1	106.81	106.81	77.68	941.87

FORECAST OF THE AMOUNT OF WASTE THAT WOULD BE PRODUCED IN 2022 AT ATIA

Table C.6: DETERMINATION OF WASTE THAT WOULD BE PRODUCED IN 2022 AT ATIA

Year	Number of days in a year	Total Waste/ Day for each household waste component							
		Food, garden and yard waste	Plastics	Metal	Paper	Wood	Glass	Textiles	Others
2015	365	616.908	46.828	36.648	20.36	22.396	22.396	16.288	197.492
2016	365	771.135	58.535	45.81	25.45	27.995	27.995	20.36	246.865
2017	365	964.146	73.186	57.276	31.82	35.002	35.002	25.456	308.654
2018	365	1205.031	91.471	71.586	39.77	43.747	43.747	31.816	385.769
2019	365	1506.213	114.333	89.478	49.71	54.681	54.681	39.768	482.187
2020	365	1882.842	142.922	111.852	62.14	68.354	68.354	49.712	602.758
2021	365	2353.704	178.664	139.824	77.68	85.448	85.448	62.144	753.496
2022	365	2942.13	223.33	174.78	97.1	106.81	106.81	77.68	941.87
Waste/Year: 2015		225171.42	17092.22	13376.52	7431.4	8174.54	8174.54	5945.12	72084.58
Waste/Year: 2016		281464.275	21365.275	16720.65	9289.25	10218.175	10218.175	7431.4	90105.725
Waste/Year: 2017		351913.29	26712.89	20905.74	11614.3	12775.73	15967.655	11612.84	140805.685
Waste/Year: 2018		439836.315	33386.915	26128.89	14516.05	15967.655	15967.655	14515.32	140805.685
Waste/Year: 2019		549767.745	41731.545	32659.47	18144.15	19958.565	19958.565	14515.32	175998.255
Waste/Year: 2020		687237.33	52166.53	40825.98	22681.1	24949.21	24949.21	22682.56	220006.67
Waste/Year: 2021		859101.96	65212.36	40825.98	28353.2	31188.52	31188.52	22682.56	275026.04
Waste/Year: 2022		1073877.45	81515.45	63794.7	35441.5	38985.65	38985.65	28353.2	343782.55

FORECAST OF THE AMOUNT OF WASTE THAT WOULD BE GENERATED IN 2022

The mean daily weight of waste (waste/day) that would be generated in Donaso was calculated using the relation:

Mean daily weight of waste generated (Waste/Day) = Waste generation rate × Projected Population

Table C.7: DETERMINATION OF MEAN DAILY WEIGHT (WASTE/DAY) THAT WOULD BE PRODUCED IN DONASO

Year	Projected Population	Waste Generation Rates for each household waste component							
		Food, garden and yard waste	Plastics	Metal	Paper	Wood	Glass	Textiles	Others
2015	1090	0.303	0.023	0.018	0.010	0.011	0.011	0.008	0.097
2016	1363	0.303	0.023	0.018	0.010	0.011	0.011	0.008	0.097
2017	1703	0.303	0.023	0.018	0.010	0.011	0.011	0.008	0.097
2018	2129	0.303	0.023	0.018	0.010	0.011	0.011	0.008	0.097
2019	2661	0.303	0.023	0.018	0.010	0.011	0.011	0.008	0.097
2020	3326	0.303	0.023	0.018	0.010	0.011	0.011	0.008	0.097
2021	4158	0.303	0.023	0.018	0.010	0.011	0.011	0.008	0.097
2022	5198	0.303	0.023	0.018	0.010	0.011	0.011	0.008	0.097
Waste/Day: 2015		330.27	25.07	19.62	10.9	11.99	11.99	8.72	105.73
Waste/Day: 2016		412.989	31.349	24.534	13.63	14.993	14.993	10.904	132.211
Waste/Day: 2017		516.009	39.169	30.654	17.03	18.733	18.733	13.624	165.191
Waste/Day: 2018		645.087	48.967	38.322	21.29	23.419	23.419	17.032	206.513
Waste/Day: 2019		806.283	61.203	47.898	26.61	29.271	29.271	21.288	258.117
Waste/Day: 2020		1007.778	76.498	59.868	33.26	36.586	36.586	26.608	322.622
Waste/Day:2021		1259.874	95.634	74.844	41.58	45.738	45.738	33.264	403.326
Waste/Day: 2022		1574.994	119.554	93.564	51.98	57.178	57.178	41.584	504.206

FORECAST OF THE AMOUNT OF WASTE THAT WOULD BE PRODUCED IN 2022 AT DONASO

The total waste that would be produced for eight (8) years in Donaso was calculated using the relation:

Total waste in a year = Total waste/ Day × Number of days in a year

Table C.8: DETERMINATION OF WASTE THAT WOULD BE PRODUCED IN 2022 AT DONASO

Year	Number of days in a year	Total Waste/ Day for each household waste component							
		Food, garden and yard waste	Plastics	Metal	Paper	Wood	Glass	Textiles	Others
2015	365	330.27	25.07	19.62	10.9	11.99	11.99	8.72	105.73
2016	365	412.989	31.349	24.534	13.63	14.993	14.993	10.904	132.211
2017	365	516.009	39.169	30.654	17.03	18.733	18.733	13.624	165.191
2018	365	645.087	48.967	38.322	21.29	23.419	23.419	17.032	206.513
2019	365	806.283	61.203	47.898	26.61	29.271	29.271	21.288	258.117
2020	365	1007.778	76.498	59.868	33.26	36.586	36.586	26.608	322.622
2021	365	1259.874	95.634	74.844	41.58	45.738	45.738	33.264	403.326
2022	365	1574.994	119.554	93.564	51.98	57.178	57.178	41.584	504.206
Waste/Year: 2015		120548.55	9150.55	7161.3	3978.5	4376.35	4376.35	3182.8	38591.45
Waste/Year: 2016		150740.985	11442.385	8954.91	4974.95	5472.445	5472.445	3979.96	48257.015
Waste/Year: 2017		188343.285	14296.685	11188.71	6215.95	6837.545	6837.545	4972.76	60294.715
Waste/Year: 2018		235456.755	22339.095	13987.53	7770.85	8547.935	8547.935	6216.68	75377.245
Waste/Year: 2019		294293.295	22339.095	17482.77	9712.65	10683.915	10683.915	7770.12	94212.705
Waste/Year: 2020		367838.97	27921.77	21851.82	12139.9	13353.89	13353.89	9711.92	117757.03
Waste/Year: 2021		459854.01	34906.41	27318.06	15176.7	16694.37	16694.37	12141.36	147213.99
Waste/Year: 2022		574872.81	43637.21	34150.86	18972.7	20869.97	20869.97	15178.16	184035.19

APPENDIX D

A SUMMARY OF TOTAL PRELIMINARY WASTE SORTED AT EJISU, ATIA AND DONASO

Number of Household	FOOD,YARDAND GARDEN(kg)	PLASTIC (kg)	METAL (kg)	PAPER (kg)	WOOD (kg)	GLASS (kg)	TEXTILE (kg)	OTHERS (kg)	TOTAL (kg)
1	30.850	1.100	.400	.300	.100	.940	.640	4.300	38.630
2	11.450	1.600	.350	.250	.150	.100	.0	1.900	15.800
3	16.450	1.250	.630	.650	.130	.100	.240	.325	19.775
4	8.350	.150	.250	.300	.200	.0	.250	6.850	16.350
5	8.450	.400	.300	.340	.0	.200	.240	4.600	14.390
6	7.550	.150	.340	.0	.300	.0	.230	9.150	17.970
7	15.700	.750	.0	.260	.200	.100	.0	1.600	18.610
8	49.650	4.000	.260	.620	.027	.100	.010	5.900	60.567
9	38.800	2.850	.650	1.450	.028	.0	.0	13.100	56.878
10	21.100	.960	.250	.600	.0	.140	1.250	4.900	29.200
11	11.050	1.860	.220	.500	.250	1.400	.0	1.250	16.530
12	11.700	.500	.400	.650	.110	.0	.240	6.990	20.590
13	11.700	1.700	.250	.600	.640	.250	.290	8.150	23.580
14	6.300	1.560	.270	.350	.0	.0	.0	9.900	18.380
15	6.000	.300	.0	.450	.140	.100	.0	12.700	19.690
16	11.100	.800	.300	.350	.0	.0	1.250	.100	13.900
17	38.600	1.950	.0	.960	.200	.0	.0	2.700	44.410
18	18.850	1.950	.0	.150	.0	.100	.580	6.150	27.780
19	6.450	1.500	.0	.100	.080	.0	.0	4.850	12.980
20	6.350	1.250	.100	.500	.010	.250	.400	3.100	11.960
21	3.450	1.150	.0	.200	.0	.0	1.100	.900	6.800
22	1.550	.350	.0	.050	.250	.0	.0	2.800	5.000
23	13.700	.200	.0	.100	.130	.200	.040	7.000	21.370
24	3.800	.950	.100	.470	0.80	.0	.0	1.600	7.000

25	4.750	1.340	.0	.320	1.500	.0	1.300	7.050	16.260
26	3.890	.950	.0	.350	.0	.0	.0	.0	5.190
27	9.700	.980	.200	.500	.200	.140	.040	8.800	20.560
28	4.600	.850	.0	.450	.320	.0	.0	12.000	18.220
29	4.300	.400	.0	.200	.0	.0	.100	.900	5.900
30	9.100	.200	.150	.300	.420	.0	.0	4.200	14.370
31	12.750	1.600	.300	.520	.0	.840	.750	4.250	21.010
32	17.651	1.100	.250	.270	.0	.0	.0	1.800	21.071
33	9.951	1.400	.0	.370	.130	.0	.340	3.300	15.491
34	13.510	1.900	.250	.450	.0	.0	.290	7.150	23.550
35	19.451	1.100	.300	.450	.0	.0	.290	2.600	24.191
36	13.000	1.300	.310	.470	.280	.0	.290	8.150	23.800
37	4.000	.750	.400	.270	.0	.0	.0	1.700	7.120
38	5.300	2.300	.360	.420	.027	.0	.010	4.900	13.317
39	17.510	1.150	.350	.320	.0	.0	.0	12.100	31.430
40	7.300	2.000	.450	.300	.0	.140	1.690	4.800	16.680
41	18.951	1.050	.250	.420	.0	.0	.290	.500	21.461
42	9.750	1.350	.0	.520	.0	.240	.340	6.950	19.150
43	8.351	2.050	.700	.620	.530	.0	.390	7.150	19.791
44	19.861	1.150	.0	.420	.0	.0	1.440	8.900	31.771
45	6.600	2.350	.500	1.270	.130	.250	.0	11.700	22.800
46	13.300	.600	.0	.0	.0	.0	.0	.0	13.900
47	18.800	1.020	.250	.320	.0	.0	1.290	1.700	23.380
48	4.051	.800	.0	.0	.0	.0	.0	5.150	10.001
49	2.750	1.850	.750	.370	.080	.140	.590	3.850	10.380
50	10.750	1.100	.100	.300	.0	.750	.500	3.850	17.350
51	15.650	.600	.050	.0	.0	.0	.0	.700	17.000
52	7.950	.900	.0	.150	.050	.0	1.100	2.200	12.350
53	11.501	1.400	.050	.230	.0	.0	.050	6.050	19.281
54	17.451	.600	.100	.050	.0	.0	.0	1.500	19.701

55	11.000	.800	.100	.150	.050	.0	.0	7.050	19.150
56	2.000	.250	.200	.230	.200	.0	.0	.600	3.480
57	3.400	1.800	.160	.050	.0	.0	1.450	3.800	10.660
58	15.600	.650	.150	.250	.0	.0	.050	11.000	27.700
59	5.400	1.500	.250	.050	.400	.050	.100	3.600	11.350
60	16.961	.550	.050	.200	.100	.0	.0	.300	18.161
61	29.800	1.000	.300	.300	.200	.640	.0	2.100	34.340
62	10.480	1.500	.250	.150	.600	.0	.450	5.200	18.630
63	17.430	.250	.420	.240	.140	.0	.100	3.260	21.840
64	7.350	.150	1.240	.400	.250	.0	.200	5.600	15.190
65	8.125	.300	.200	.270	.0	.010	.0	5.200	14.105
66	6.560	.100	.310	.430	.400	.0	.230	9.300	17.330
67	15.100	.500	.160	.250	.200	.0	.010	4.500	20.720
68	48.550	.300	.0	.300	.014	.0	.0	6.200	55.364
69	37.800	.300	.500	.240	.100	.020	1.200	15.100	55.260
70	22.400	.590	.200	.300	.0	.0	.220	5.800	29.510
71	10.980	1.600	.100	.420	.400	.0	.0	3.200	16.700
72	11.900	.400	.300	.510	.200	.0	.140	7.100	20.550
73	6.300	1.500	.210	.320	1.000	.010	.0	8.880	18.220
74	11.700	1.400	.0	.200	.0	.0	.0	7.100	20.400
75	5.500	.200	.210	1.200	.240	.0	.050	13.200	20.600
76	38.100	.700	.0	.0	.0	.0	.0	.300	39.100
77	7.840	1.240	.200	.200	.800	.050	.0	3.700	14.030
78	8.950	1.830	.0	.0	.0	.0	.0	6.800	17.580
79	5.340	1.200	.0	.370	.100	.0	.040	5.200	12.250
80	6.400	1.800	.100	.200	.020	.0	.100	3.500	12.120
81	3.240	1.150	.0	.030	.0	.0	.0	1.200	5.620
82	11.400	.250	.0	.100	.260	.100	.300	3.200	15.610
83	13.400	.100	.0	.010	.140	.0	.0	8.000	21.650
84	3.200	.200	.0	.010	.100	.0	.0		3.510

85	3.600	.850	.010	.100	1.250	.010	1.200	1.590	8.610
86	4.500	1.240	.0	.200	.0	.0	.0	7.800	13.740
87	3.800	1.000	.100	.0	.500	.0	.0	.200	5.600
88	9.500	.960	.0	.050	.400	.0	.010	8.900	19.820
89	4.200	1.200	.0	.003	.800	.0	.0	12.650	18.853
90	5.010	.010	.0	.250	.0	.0	.0	.820	6.090

The mean and standard deviation calculated from the summary of the total preliminary waste sorted at Ejisu, Atia and Donaso using Statistical Package for Social Scientists (SPSS) was:

Mean = 19.5339

Standard Deviation = 11.2272

APPENDIX E

Table E.1: ONE WEEK WASTE SORTED IN EJISU

HOUSEHOLD IN EJISU	FOOD, YARD AND GARDEN WASTE (kg)	PLASTIC (kg)	METAL (kg)	PAPER (kg)	WOOD (kg)	GLASS (kg)	TEXTILES (kg)	OTHERS (kg)	TOTAL (kg)	FAMILY SIZE	WASTE GEN.
1	13	1.65	0.35	0.62	0.1	0.9	0.8	5.2	22.62	7	0.461633
2	18.23	1.2	0.3	0.3	0	0.2	0.24	1.92	22.39	6	0.533095
3	10.13	1.45	0.2	0.41	0.21	0	0.39	3.9	16.69	5	0.476857
4	13.32	1.1	0.25	0.35	0	2	0.28	8.13	25.43	6	0.605476
5	18.45	1.9	0	0.5	0.4	1.2	1.2	2.94	26.59	9	0.422063
6	14	1.4	0.4	0.43	0.28	0	0	9.23	25.74	5	0.735429
7	15.2	0.8	0.38	0.62	1.1	0	0	1.82	19.92	9	0.316190
8	5.7	2.4	0.45	0	0.05	0.2	0.57	5.2	14.57	4	0.520357
9	18.32	1.2	0	0.49	0	0	0	13.1	33.11	7	0.675714
10	16.3	2.3	0.39	0.39	0.21	0	1.57	5	26.16	5	0.747429
11	19.32	0	0.52	0.72	1.42	0	0	5.9	27.88	10	0.398286
12	11.75	1.5	0.45	0.42	1.23	0.24	1.82	7.2	24.61	4	0.878929
13	9.32	2	0	0.81	0.32	0	0.34	8	20.79	6	0.495
14	18.34	2.3	2.38	0.72	0.93	0	0.51	9	34.18	11	0.443896
15	7.2	1.45	0.24	0	0	0.15	0.43	10.2	19.67	5	0.562
16	17.3	3	0.98	0.53	0	0.32	0	0.2	22.33	8	0.39875
17	20.4	1	0	1.4	1.24	0.5	0.28	2.1	26.92	11	0.349610
18	8.2	0.9	3.2	0	0	0	0	5.6	17.9	4	0.639286
19	5.65	0	4.3	0.34	0.09	0.32	1.28	4.1	16.08	2	1.148571
20	9.83	2.3	0	0.8	0	0	1.42	2.8	17.15	7	0.35
21	16.1	1.9	0.89	1.2	0.24	1.2	0.83	0.6	22.96	8	0.41

22	8.5	0.8	2.4	0.1	0	0.5	0.54	2.4	15.24	5	0.435429
23	11.85	1.2	3	0.5	0.12	0	0.32	5.3	22.29	7	0.454898
24	18.32	0	1.2	0	1.2	0	0	3	23.72	8	0.423571
25	10.2	1.48	0	1.3	0	0	0.98	8.2	22.16	6	0.527619
26	1	1.2	0.16	1	0	0.32	0	0.8	4.48	4	0.16
27	9	0.8	0.2	0	0	2	0.45	3.4	15.85	2	1.132142
28	5	1.8	1.1	0.5	0.01	0.5	0	2	10.91	8	0.194821
29	8	0.25	0.75	0.24	0	0	0	0.09	9.33	2	0.666429
30	2	1	1.2	0	0.2	3	0.64	0.4	8.44	10	0.120571
31	3.1	0.3	0	1.25	0	0.25	0.38	0.5	5.78	2	0.412857
32	1.1	0.1	0	0.89	0.04	0	0	0	2.13	1	0.304286
33	1.4	1	3.2	0.36	0	0	0	0.9	6.86	3	0.326667
34	2	0	1.5	0	0	0	0.42	0.1	4.02	2	0.287143
35	4.3	1	0.3	0	0.32	0.14	0	0.24	6.3	4	0.225
36	29.98	0.98	0	0.4	0.3	0.5	0	4.2	*36.36*	2	*2.597143*
37	11.46	1.6	0.35	0.16	0.8	0	0.1	2	16.47	1	2.352857
38	18.35	0.25	0	0.25	0.24	0.2	0	3.1	22.39	3	1.066190
39	7.98	0	1.24	0.483	0.48	1	0	3.5	14.683	10	0.209757
40	9.32	0	0	0.34	0	2	0.15	4.2	16.01	4	0.571786
41	5.89	0.36	0	0.42	0.7	0	0	9.6	16.97	6	0.404048
42	14.65	0	0.52	0	0.4	0.1	0	2	17.67	11	0.229481
43	29.98	0.98	0	0.4	0.3	0.5	0	4.2	36.36	5	1.038857
44	11.46	1.6	0.35	0.16	0.8	0	0.1	2	16.47	8	0.294107
45	18.35	0.25	0	0.25	0.24	0.2	0	3.1	22.39	11	0.290779
46	7.98	0	1.24	0.483	0.48	1	0	3.5	14.683	4	0.524393
47	9.32	0	0	0.34	0	2	0.15	4.2	16.01	2	1.143571
48	5.89	0.36	0	0.42	0.7	0	0	9.6	16.97	10	0.242429

49	14.65	0	0.52	0	0.4	0.1	0	2	17.67	4	0.631071
50	32	1.2	0.45	0.42	1.1	0.41	1.2	5.3	42.08	6	1.001905
51	12.86	1.65	1	0.31	1.25	0.32	0.46	2	19.85	11	0.257792
52	18.49	1.42	0.83	0.85	0.43	0.85	0.39	0.46	23.72	5	0.677714
53	11.25	1.64	0.35	0.5	0.32	0.43	0.36	7.23	22.08	8	0.394286
54	9.84	1.34	0.42	0.35	0.2	0.1	0.98	5.2	18.43	11	0.239351
55	10.35	1.25	0.48	0.28	0.48	0.2	0.43	9.43	22.9	4	0.817857
56	18.62	1.32	0.29	0.39	1.36	0	0	1.84	23.82	2	1.701429
57	48.63	0.29	0	0.88	1.2	0.75	0.21	5	56.96	7	1.162449
58	40.25	0	0.69	1.75	0.98	0.84	0.3	14.35	59.16	6	1.408571
59	23.84	1.25	1.2	0.68	1.43	0.71	0	4.65	33.76	5	0.964571
60	12.45	1.43	1.43	0.49	2.1	0.48	0	1.4	19.78	6	0.470952
61	16.3	2.3	0.39	0.39	0.21	0	1.57	5	26.16	9	0.415238
62	19.32	0	0.52	0.72	1.42	0	0	5.9	27.88	5	0.796571
63	11.75	1.5	0.45	0.42	1.23	0.24	1.82	7.2	24.61	9	0.390635
64	9.32	2	0	0.81	0.32	0	0.34	8	20.79	4	0.7425
65	18.34	2.3	2.38	0.72	0.93	0	0.51	9	34.18	7	0.697551
66	7.2	1.45	0.24	0	0	0.15	0.43	10.2	19.67	5	0.562
67	17.3	3	0.98	0.53	0	0.32	0	0.2	22.33	10	0.319
68	20.4	1	0	1.4	1.24	0.5	0.28	2.1	26.92	4	0.961429
69	8.2	0.9	3.2	0	0	0	0	5.6	17.9	6	0.426190
70	5.65	0	4.3	0.34	0.09	0.32	1.28	4.1	16.08	11	0.208831
71	5.27	0.896	4	0.1	0.3	0	0	0.84	11.406	5	0.325886
72	9.75	0.5	0.98	0	0.45	0.6	0	0.53	12.81	8	0.229821
73	12.62	0.98	0	0.12	1.32	0.45	0.62	0.48	16.59	11	0.215455
74	15.48	1.54	1.5	1.2	0.95	0.24	1.82	0.65	23.38	4	0.835
75	7.98	0	1.24	0.483	0.48	1	0	3.5	14.683	2	1.048786

76	9.32	0	0	0.34	0	2	0.15	4.2	16.01	7	0.326735
77	5.89	0.36	0	0.42	0.7	0	0	9.6	16.97	6	0.404048
78	14.65	0	0.52	0	0.4	0.1	0	2	17.67	5	0.504857
79	11.46	1.6	0.35	0.16	0.8	0	0.1	2	16.47	6	0.392143
80	18.35	0.25	0	0.25	0.24	0.2	0	3.1	22.39	9	0.355397
81	7.98	0	1.24	0.483	0.48	1	0	3.5	14.683	5	0.419514
82	9.32	0	0	0.34	0	2	0.15	4.2	16.01	9	0.254127
83	29.98	0.98	0	0.4	0.3	0.5	0	4.2	36.36	4	1.298571
84	11.46	1.6	0.35	0.16	0.8	0	0.1	2	16.47	7	0.336122
85	18.35	0.25	0	0.25	0.24	0.2	0	3.1	22.39	5	0.639714
86	7.98	0	1.24	0.483	0.48	1	0	3.5	14.683	10	0.209757
87	9.32	0	0	0.34	0	2	0.15	4.2	16.01	4	0.571786
Total/week	**1144.61**	**85.256**	**65.93**	**39.055**	**39.78**	**39.45**	**29.84**	**362.43**	**1806.351**	**532**	**20.76265517**
Mean/family	13.16	0.98	0.76	0.45	0.46	0.45	0.34	4.17	20.77	6.11494	
Mean/week/person	2.152	0.160	0.124	0.074	0.075	0.074	0.056	0.682	3.397		
Per capital/day	0.307	0.023	0.018	0.010	0.011	0.011	0.008	0.097	0.485		
Total waste/day	5646.037	422.993	331.038	183.91	202.301	202.301	147.128	1789.927	8925.635		
Total waste/year	2060803.505	154392.445	120828.87	67127.15	73839.865	73839.865	53701.72	653323.355	3257856.775		

Table E.2: ONE WEEK WASTE SORTED IN ATIA

HOUSEHOLDS IN ATIA	FOOD, YARD AND GARDEN WASTE (kg)	PLASTIC (kg)	METAL (kg)	PAPER (kg)	WOOD (kg)	GLASS (kg)	TEXTILES (kg)	OTHERS (kg)	TOTAL (kg)	FAMILY SIZE	WASTE GEN.
1	32	1.2	0.45	0.42	1.1	0.41	1.2	5.3	42.08	14	0.429388
2	12.86	1.65	1	0.31	1.25	0.32	0.46	2	19.85	7	0.405102
3	18.49	1.42	0.83	0.85	0.43	0.85	0.39	0.46	23.72	9	0.375508
4	11.25	1.64	0.35	0.5	0.32	0.43	0.36	7.23	22.08	6	0.525714
5	9.84	1.34	0.42	0.35	0.2	0.1	0.98	5.2	18.43	5	0.526571
6	10.35	1.25	0.48	0.28	0.48	0.2	0.43	9.43	22.9	8	0.408929
7	18.62	1.32	0.29	0.39	1.36	0	0	1.84	23.82	11	0.309351
8	48.63	0.29	0	0.88	1.2	0.75	0.21	5	56.96	15	0.542476
9	40.25	0	0.69	1.75	0.98	0.84	0.3	14.35	59.16	13	0.650110
10	23.84	1.25	1.2	0.68	1.43	0.71	0	4.65	33.76	9	0.535873
11	12.45	1.43	1.43	0.49	2.1	0.48	0	1.4	19.78	10	0.282571
total/week	***238.58***	***12.79***	***7.14***	***6.9***	***10.85***	***5.09***	***4.33***	***56.86***	***342.54***	***107***	31.14
mean/family	21.689	1.163	0.649	0.627	0.986	0.463	0.394	5.169	31.14	9.727272727	
mean/week/person	2.230	0.106	0.513	0.496	2.276	0.249	0.927	0.531	7.328		
per capital/day	0.379	0.017	0.010	0.009	0.014	0.007	0.006	0.076	0.518		
Total waste/day	617.391	27.693	16.29	14.661	22.806	11.403	9.774	123.804	843.822		
Total waste/year	225347.715	10107.945	5945.85	5351.265	8324.19	4162.095	3567.51	45188.46	307995.03		

Table E.3: ONE WEEK WASTE SORTED IN DONASO

HOUSEHOLD IN DONASO	FOOD, YARD AND GARDEN WASTE (kg)	PLASTIC (kg)	METAL (kg)	PAPER (kg)	WOOD (kg)	GLASS (kg)	TEXTILES (kg)	OTHERS (kg)	TOTAL (kg)	FAMILY SIZE	Waste generation rate
1	29.98	0.98	0	0.4	0.3	0.5	0	4.2	36.36	13	0.39956
2	11.46	1.6	0.35	0.16	0.8	0	0.1	2	16.47	8	0.294107
3	18.35	0.25	0	0.25	0.24	0.2	0	3.1	22.39	11	0.290779
4	7.98	0	1.24	0.483	0.48	1	0	3.5	14.683	6	0.349595
5	9.32	0	0	0.34	0	2	0.15	4.2	16.01	8	0.285893
6	5.89	0.36	0	0.42	0.7	0	0	9.6	16.97	3	0.808095
7	14.65	0	0.52	0	0.4	0.1	0	2	17.67	5	0.504857
Total/week	**97.63**	**3.19**	**2.11**	**2.053**	**2.92**	**3.8**	**0.25**	**28.6**	**140.553**	**54**	0.054885
Mean/family	13.947	0.456	0.301	0.293	0.417	0.543	0.036	4.086	20.079	7.714285714	0.003746
Mean/week/person	1.808	0.059	0.039	0.038	0.054	0.070	0.005	0.530	2.603		
Per capital/day	0.258	0.008	0.006	0.005	0.008	0.010	0.001	0.076	0.372		
Total waste/day	224.976	6.976	5.232	4.36	6.976	8.72	0.872	66.272	324.384		
Total waste/year	82116.24	2546.24	1909.68	1591.4	2546.24	3182.8	318.28	24189.23	118400.11		

APPENDIX F

PHOTOS

PLATE F.1: A Refuse Dump at EJISU

PLATE F.2: A Refuse Dump at ATIA

PLATE F.3: A Refuse Dump at DONASO

PLATE F.4: A collection event at EJISU

PLATE F.5: The waste sorting and collection event

PLATE F.6: The waste sorting and data collection event