COMMERCIAL SOLID WASTE GENERATION AND COMPOSITION ANALYSIS: ARADA SUBCITY, ADDIS ABABA

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COMMERCIAL SOLID WASTE GENERATION AND COMPOSITION ANALYSIS: ARADA SUBCITY, ADDIS ABABA

A thesis submitted to the school of Graduate Studies of Addis Ababa University in partial fulfillment of the requirements for the degree of Master of Science in Environmental science

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Declaration

I hereby declare that I am the sole author of this thesis and has not been presented for any degree in any university and all the resource of material used for the thesis have been duly acknowledged.

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ACRONYMS

AACG	Addis Ababa City Government
AACA	Addis Ababa City Administration
AAHB	Addis Ababa Health Bureau
AASBPDA	Addis Ababa Sanitation Beautification and Park development Agency
AAAMPSC	Addis Ababa City Administration Master Plan Study Section
CSA	Central Statistical Authority
CIWMB	California Integrated Waste Management Board
EMA	Ethiopia Map Agency
MAA	Municipality of Addis Ababa
SPSS	Statistical Package for Social Science
PHW	Potentially Hazardous Waste
WHO	World Health Organization

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Abstract

Solid waste should be characterized by their sources, types of wastes produced, as well as generation rates and composition. Accurate information in these characteristics is necessary to establish proper waste management systems and for regulatory, financial, and institutional decisions making. The lack of timely information about the generation and composition of solid waste in Addis Ababa is one of the reasons among many for unsatisfactory solid waste management in Addis Ababa.

This research was conducted in Arada Sub City, Addis Ababa, Ethiopia to determine the commercial solid waste, domestic and commercial solid waste generation rates and their physical and chemical composition in order to contribute to decision support in planning and development of municipal solid waste management systems.

The study was carried out by classifying the whole commercial establishments population in Arada Sub City in two five strata. Commercial solid waste generation and composition data were collected and solid waste management related survey was also conducted. The collected data was analyzed using Statistical Package for Social Science 10 (SPSS 10) software. Hand sorting was used for classifying the collected waste in to the following fourteen fractions: Paper, Plastic, Glass, Metal, Food waste, Textiles/leather, Rubber, Wood, Yard waste, Inorganic, Electronics, Potentially hazardous Waste, Special waste, and particles less than 10mm. Proximate, ultimate and calorific value were also determined in selected commercial solid waste fractions such as food waste, yard waste, paper and textile.

The study result shows that in Arada Sub City the estimated commercial solid waste generation rate per employee per day is 1.6 Kg and 4.9 lt by weight and volume respectively. And the average commercial solid waste density is 323.4 Kg/m^3. Total commercial and residential solid waste generation rate per capita per day by weight and by volume in Arada Sub City is 0.55 Kg and 1.97 lt, respectively. And the density of commercial and residential solid waste is 277.7 Kg /m^3.

The percentage composition of commercial solid waste fractions clearly shows that food waste takes the largest proportion of commercial solid waste and followed by paper, yard and plastic waste consecutively, by weight and volume. This study also indicates the presence of potentially hazardous waste in the studied area i.e. 0.36 % by weight and 0.2 % by volume from the total commercial solid waste generated per day.

The result shows that due to inadequate solid waste management system, Arada Sub City has faced a problem related to solid waste collection and disposal. The existing infrastructure for solid waste collection in Arada Sub City is not proportional to the amount of solid waste generated from commercial and residential source. In addition the number of municipal containers and trucks for collection and transportation of waste is not adequate.

If composting and recycling are exercised in Arada sub city there is a possibility to reduce the amount of commercial solid waste going to be disposed in the landfill from Arada Sub City by 98.04 %. The energy value of food waste, yard waste, paper and cardboard from commercial source is higher than their respective energy value from residential source. The C: N ratio of the waste is also suitable for compost making.

Thus based on the generation rate and composition of solid wastes in Arada Sub City integrated solid waste management system which combines a range of solid waste treatment options like source reduction, composting, recycling and waste to energy transformation is recommended.

1. Introduction

1.1 Background

Solid waste management is in crisis in many of the world's largest urban areas as populations attracted to cities continues to grow and this has led to ever increasing quantity of domestic solid waste while space for disposal decrease (World Bank, 1999).

The quantity of waste generated in Addis Ababa is increasing because of rapid population growth and urbanization. This has outpaced the financial and a manpower resource of municipalities to deal with provision and management of services of solid waste (AASBPDA, 2003). In most cities and towns of developing world, inappropriate handling and disposal of municipal solid waste is the most visible cause of environmental degradation, i.e., air pollution, soil contamination, surface and ground water pollution, etc., resulted from improper disposal of municipal solid wastes (WHO, 1996).

In adequate solid waste management in Addis Ababa has resulted in the accumulation of waste on open lands, in drains and in the residential areas, causing a nuisance and foul-smelling pools, environmental pollution through leachates from piles (water and soil pollution) and burning of waste (air pollution), clogging of drains. This situation is believed to result in poor environmental conditions, which in turn present a formidable threat to health. There is thus a need for improved waste management system of the city.

The base of successful planning for a municipal solid waste management system is reliable information about the generation rate and composition of waste being generated. The generation and composition of waste determines the decisions for appropriate management system. It is thus a prerequisite for solid waste program mangers to have detailed information about the composition and generation of solid waste to set appropriate management system or plan.

Data on the composition, the volume and weight of waste generated and collected in Addis Ababa is limited. Very limited surveys and studies have been carried out in early 1980s and mid 1990s by Nurconsult, Louis Berger Company, Addis Ababa University and the French Mission and the estimates of waste generated per capita per day varies in volume from 0.40 to 1.23 lit/capita/day, in weight from 0.11 to 0.25 kg/capita/day and in density from 205 to 370 kg/m^3 (MAA, 2002; Yami Birke, 1999).

As we know demographic dynamics, socio-economic changes and consumption patterns are the main factors that affect the municipal solid waste generation and composition, which in turn affects the waste management system. Therefore, conducting studies on generation and composition of solid waste at the present demographic and socioeconomic conditions is very essential.

Recently, Yitayal beyene (2005) studied the domestic solid waste generation rate and composition of Arada Sub City and the estimated waste generation rate for Arada Sub City was 0.11 Kg/capita/day. However, additional information likes commercial, institutional,

Street sweepings, industrial and hospital solid wastes generation rate and composition studies are essential in order to provide full information for Arada Sub City and Addis Ababa at large.

Thus, this research was conducted to determine the generation and composition analysis of commercial solid waste in Arada Sub City and the result will have paramount importance in providing relevant information that is basic to design appropriate solid waste management system in the city of Addis Ababa.

1.2. Description of the study Area

Arada sub city is one of the central sub city of Addis Ababa and is located 9^0 01' 12'' (471000 m) and 9^0 03(476000 m) North latitude, and 38^0 44' 9.6'' (997000 m) and 38^0 46'58'' (100,100 m) East longitude. Addis Ababa has a total area of 540 Km^2 (54,000 Ha) (Tilaye Nugussie and Mesfin Tilaye, 1998) of which 11.56 Km^2 (1156 Ha) area is defined by Arada sub city (AAAMPSC, 2004).

The altitude of Arada sub city ranges between 2300m and 2,500m.a.s.l (EMA, 1982). The lowest and the highest annual average temperature of Addis Ababa, Arada Sub city, are about 10^0c and 25^0c (Tilaye Nugussie and Mesfin Tilaye, 1998).

The climate is divided in to three distinct seasons. The period of heavy rains (*Kiremt*) occurs between June and September, The dry period (*Bega*) is between October and January, and the small rains (*Belg*) occurs between March and May (MAA, 2002).

According to CSA (1995), Arada Sub City, one of the 10 Sub City of Addis Ababa, has about 37,897 and 297,942 housing unit and population, respectively. Based on the information extracted from Addis Ababa Trade and Industry Bureau data base in May (2005), there are around 13,396 commercial establishments or centers in Arada Sub City and among which 48.78 % of them are retailers shops, 20.58 % of them are business centers, 20.24 % of them are Bar and Restaurants, 5.87 % of them are wholesalers shops and 4.53 % of them are Repair service providers.

Table1: Commercial establishment category, total number, and sample size.

NO,	**Commercial establishments category**	**Total Number in Arada Sub City**	**Weight given proportionally %**
1	Retail Trade Shops	6535	48.78
2	Wholesale Trade Shops	786	5.87
3	Bar and Restaurants	2711	20.24
4	Business centers	2757	20.58
5	Repair Services	607	4.53
Total		13396	100

Given that the information on generation and composition of solid waste in this area is scarce, out dated and growth in commercial sector in Arada Sub City is fast this research was focused on the solid waste generation and composition from commercial establishments.

1.3 Solid Waste Management.

1.3.1 Solid waste and its sources

Solid Waste comprises all the wastes arising from human and animal activities that are normally solid and that are discarded as useless or unwanted (Tchobanoglous *et al.*, 1977). Similarly, solid wastes means any garbage, refuse, sludge, and other discarded solid materials, including solid waster materials resulting from industrial, commercial, and agricultural operations, and from community activities, but does not include solid or dissolved materials in domestic sewage or other significant pollutants in water resources, such as silt, dissolved or suspended solids in industrial wastewater effluents, dissolved materials in irrigation return flows or other common water pollutants (U.S. Code of Federal Regulations-cfr part 243,1995).

In Ethiopia according to Region 14 Administrative Hygiene and environment sanitation regulation, proclamation (1994), solid waste is described as follows; “solid waste comprises refuses from residential, commercial, or any institutes as yard sweeping, food remains, ash and chat leftover, papers, glasses, metals, plastic, grass, and vegetables, bone of animals, dead animals and other materials that cause poor environmental situation.”

The sources of solid wastes are residential, commercial, institutional, construction and demolish, municipal services, industrial, treatment plants sites and agricultural (Tchobanoglous., *et al*., 1977). Similarly, according to Urban Development Sector Unit East Asia and Pacific Region (1999), the source and type of solid waste are summarized in Table 2 as follows.

Table 2: Source and type of solid waste

Table 1: Sources and Type of solid waste		
Source	Typical waste generation	Type of solid wastes
Residential	Single and multi family dwelling	Food wastes, paper, cardboard, plastics, textiles, leather, yard wastes, wood, glass, metals, ashes, special wastes (e.g., bulky items, consumer electronics, white goods, batteries, oil, tires), and household hazardous wastes.
Industrial	Light and Heavy manufacturing, fabrication, construction sites, power and chemical plants.	Housekeeping wastes, packaging, food wastes, construction and demolition materials, hazardous wastes, ashes, special wastes.
Commercial	Stores, hotels restaurants, markets, office buildings, etc	Paper, card board, plastics wood food, waste glass metals, special wastes hazardous wastes.
Institutional	Schools, hospitals, prisons, government centers.	Same as commercial
Construction and demolition	New construction sites, road repair, renovation sites, demolition of buildings	Wood steel concrete and dirt, etc.
Municipal services	Street cleaning, landscaping, parks, beaches, other recreational areas, water and waste water treatment plants	Street sweepings, landscape and tree trimmings; general waste from parks, beaches, and other recreational areas; sludge.
Process	Heavy and light manufacturing, refineries, chemical plants, power plants, mineral and extraction processing	Industrial process waste, scrap materials, off-specification products, slog, tailings.
All the above should be included as “municipal solid waste”		
Agriculture	Crops, orchards, vineyards, dairies, feedlots, farms	Spoiled food wastes, agricultural wastes, hazardous wastes (e.g., pesticides)

Source: Urban Development Sector Unit East Asia and Pacific Region. (1999). What a Waste: Solid Waste Management in Asia

According to Norconsult (1982), the percentage of waste generated from domestic waste is 76 %, Commercial waste 9 %, Hotels 3 %, Industrial waste 5 %, Street sweeping 6 %, Hospitals 1 %. This data was generated before two decades and the percentage contribution of each solid waste source might have changed through time due to the change in demographic and socioeconomic conditions of the citizens. Therefore, further study is needed to generate more valid data for current and future planning.

There are six functional elements associated with solid waste management, namely: Waste generation, on-site handling and storage, collection, transfer and transport, processing and recovery, and disposal of solid wastes. These elements are discussed here in relation to Addis Ababa City particularly Arada Sub City, Thus, this information is useful to find out those managemental elements that must be improved so as to get a good result from the solid waste management activities in Arada sub city.

1.3.2 Generation of Solid Wastes

Having knowledge on the sources and types of solid wastes together with data on the composition and generation rates, is the basic to the design and operation of the functional elements associated with the management of solid wastes. Waste generation rates of developed countries are higher than the developing ones and attribute to the difference in technological advances. Cities like New York have generation rate of 18 liter/capita/day while most cities in developing countries have les than 1 litter/capita/day (AAHB, 1997).

The volume or rate of residential solid waste produced varies from day to day, month to month, season to season and from household to household. Market day's yields more wastes than other days of the week. Residential wastes rate usually peak during holyday season such as New Year, Christian holidays like Meskel, Christmas, and Easter, and Muslim holydays like Maulid, Eid ul-fitir or Ramadan, and Eid ul-adha or Arefa. People generate more waste during dry season than wet season. High income household generate twice as much as waste than low income group, this is because low income household consumes fewer resources and tend to recycle (Girma Kebede, 2004).

According to the report released by Addis Ababa Sanitation, Beautification and Park Development Agency (2003) the daily waste generation of Addis Ababa city was 0.252 kg/capita/day and daily waste production of the city was 2,297 m^3 or 851 tones. By the same authority, of the daily solid waste generated in Addis Ababa, 65% (1,482 m^3) is collected, 5% recycled and 5% composted. The remaining 25% is simply dumped on open sites, drainage channels, rivers and valleys as well as on the streets.

Nurconsult (1982) reported that the weighed mean per capita/day generation of Addis Ababa as 0.4 liter and 0.15 Kg and 370 weighted mean density in kg/m^3. After Norconsult study different researchers like Sturdy Gordon in 1994 and 1995 conducted study. Sturdy Gordon reported that the weighed mean per capita/day generation as 0.65 liter and 0.221 Kg in 1994 and 1.23 liter and 0.252 Kg in 1995 (AAHB, 1997).

1.3.3 Composition of solid waste

1.3.3.1 Physical composition

Information and data on the physical composition of solid waste are important in the selection and operation of equipment and facilities, in assessing the feasibility of resources and energy recovery, and in the analysis and design of disposal facilities (Tchobanoglous., *et al*., 1977). The composition of solid waste is the prime consideration before considering any process for its disposal or combustion or recycling. According to Hall *et al*., (1993) solid waste composition analysis is important because.

•The nature of the waste influences the mode of collection.

•The lives of landfill sites can only be estimated. Since changes in composition, density and output per person per week affect site life of landfill.

•The design and operation of waste disposal plant (e.g. incinerators) and waste derived fuel plants is controlled by the nature of the waste.

•An assessment can be made of the materials available for recycling or reuse and an estimate can be made of heavy metals or other biologically active substances that may affect the future use of reclaimed land of which waste has been deposited or which may need to be legislated for in the future.

1.3.3.2 Chemical Composition

Information on the chemical composition of solid waste is important in evaluating alternative processing and recovery options. If solid wastes are to be used as fuel, the most important properties to be known are (1) proximate analyses, which include moisture content (loss at 105^0C for 1 hr),

Volatile matter (additional loss in ignition at 950^0C), ash-residue (residue after burning), and fixed carbon (reminder). (2) Ultimate analysis, which include percent of Carbon, Hydrogen, Oxygen, Nitrogen, Sulfur ash and (3) heating value (energy value) (Tchobanoglous et al., 1977).

In general, data for developing countries reveals that organic (C, H, N) comprises about 40-50 %, inorganic substance (P, K) 20-30%, moisture about 30-40 % by weight, with less than 1000 Kcal of heat value (Abera Kumie, 1997).

1.3.4 On-site handling and storage

On site handling refers to the activities associated with the handling of solid waste until they are placed in the containers used for their storage before collection. Factors that must be considered in the onsite storage of solid wastes include (1) the type of container to be used, (2) the container location, (3) public health and aesthetics, and (4) the collection method to be used (Tchobanoglous *et al*., 1977).

The Addis Ababa Sanitation, Beautification and Park Development Agency provide individual containers for few institutions, hotels, fabrics, offices, commercial establishments, garages, health centers. Information about the on-site handling and storage system commercial establishments in Addis Ababa is not available.

1.3.5 Collection, transfer and transport of waste

The term collection includes not only the gathering or picking up of solid wastes from the various sources, but also the transportation of these wastes to the location where the contents of the collection vehicles are emptied (Tchobanoglous *et al*., 1993).

Currently in Arada sub city there are 79 municipal containers with 8 m^3 carying capacity and 96 municipal containers with 1.1m^3 carying capacity and there are 9 truckes which is being used with Gulele Sub City (AASBPDA, 2003).

There are three broad types of refuse collection systems in Addis Ababa namely door-to-door, block, and communal containers collections that are facilitated by three types of collection vehicles, i.e., side load trucks, closed compacting type trucks, and container lift trucks (AAHB, 1997). In the first system, people dispose of there solid wastes in to side-loading trucks, twice a week, at a predetermined time and day. It is the responsibilities of the people to bring the waste with their containers and unload it in to the truck. The side- loading and compacting trucks are usually designed to serve for door-to-door collection system where container transfer stations are lacking and road accessibility is not limited. In such collection system the disposing people and the truck along accessible street collection points meet at a defined time.

In the second method (Block collections) large waste containers ranging from 0.1-8 cubic meters are placed near blocked houses or buildings. The containers are emptied on the average every seven days (Tilaye Nigussie., *et al*., 1998). On the other hand according to ENDA (1999), the objective of the concerned authority is to service communal containers in every 2 or 3 days, however containers are actually emptied every 3 weeks on average.

There are 72 trucks for transportation of collected solid waste for Addis Ababa city; out of 72 only 35 - 40 trucks work daily because of the average age (more than 5 year) maintenance difficulties, negligence of drivers, lack of preventive maintenance, low quality of maintenance, and frequent vehicle accidents during traffic congestion (AASBPDA, 2003).

According the information collected from Arada Sub City solid waste management division, on average only four or five trucks are on work every day out of nine trucks assigned for Arada and Gulele Sub City together. The rest are on maintenance due to their long service period. So the average total transportation capacity of the Arada and Gulele sub city together is not more than 180 m^3 per day. In addition, in Arada Sub-City there is Micro and Small Enterprises engaged in primarily collection or pre-collection from commercial units to municipal container.

According to Fikru Tesema (2001) collection and transportation system of the Agency are becoming the most inefficient part of the services due to the lack of spare trucks and effective and efficient maintenance services services. Fikru further added that to make the collection and transportation system sustainable, truck and garage problems should be solved.

1.3.6 Processing and recovery of waste

Solid wastes or selected components of solid wastes, depending on local conditions, may be of value as a source of raw material for industry, fuel for production of power, or material that can be used for the reclamation of land.

Processing techniques are used in solid waste management systems to improve the efficiency of operations, to recover resources or usable materials and to recover conversion products and energy (Tchobanoglous *et al*., 1977).

Only 10 % of the total solid waste generated in Addis Ababa is composted and recycled (AASBPDA, 2003). Very little is done at the waste generating sources and community levels to reduce the volumes of waste through efficient sorting, recycling and composting activities. Most of the sorting and recycling of waste at the moment is done by the informal sector.

Like in most developing countries, recycling in Ethiopia is practiced informally. The collection of recoverable waste is highly organized with its huge network of dealers and wholesalers throughout the country. Then there are craftsmen who recycle metal, wood, rubber, clay to provide essential goods to great number of customers nation wide (ENDA 1999).

Processing and recovery of wastes are used to improving efficiency of solid waste management system, recovery of material and resources and recovery of conversion products and energy

1.3.6.1 Improving efficiency of solid waste management system

Various processing system are available to improve the efficiency of solid waste management systems. To reduce the storage requirements both incinerator and baling can be used. At the disposal places solid wastes can be compacted to use the available site effectively. Shredding can also be used to reduce storage volume during transportation and used to improve the efficiency of disposal sites. The selection of processing techniques for these purpose depends on the components of the overall waste management system and, in some cases, is situation-specific.

1.3.6.2 Recovery of material and resources

As a practical matter components that are most amenable to recovery are those for which market exists and which are present in the wastes in sufficient quantity to justify their separation. Materials that have been recovered from solid waste include paper, cardboard, plastic, glass, ferrous metal, aluminum and other non-ferrous metal.

In recycling, waste materials are processed industrially and then reformed into new or similar products. Recycling includes pre-consumer waste, such as factory cuttings or shavings, as well as post-consumer waste items, including cardboard, newspapers, plastic bottles, and aluminum cans. Although recycling is often viewed as a resource conservation activity, it may offer greater return for many products in terms of energy savings (Ohio State University, 2005).

According to Addis Ababa Health Bureau report (1997), there has been very little, less than10% by weight wastes to be recycled like paper, glass, metals, plastics, rubber, bone and wood.

Similarly, the same report states that plastics, rubber, glass metals and combustible materials used as traditional fuel are wastes recovered informally in the landfill and at their source of generation by some 200 scavengers.

Recycling is a better alternative to either dumping or burning wastes and saves money, energy, raw materials and land spaces, Moreover, it encourages individual awareness and responsibility for the waste generated . In spite of these facts, recycling practices and their importance are discouraged or disregarded by the society at large, by the municipal services and by other local authorities in Addis Ababa (ENDA, 1999).

Composting is a process in which compostable matter (e.g. compostable waste) biologically decomposes to a complex and stable material (Ecorecycle, 2003), which is very useful for agriculture and landscaping. Various types of compostable wastes are suitable for composting. Primary compostable wastes from households are mostly food waste, residuals of raw materials for cooking, and garden waste. These compostable materials are easily degradable and can be composted to produce soil-conditioning fertilizer.

According to Addis Ababa Environmental Health Bureau (1997), composting with methane gas harvesting for energy recovery has been considered as one alternative for Addis Ababa's waste recovery since the refuse comprises 30% -35% by weight organic matters mainly kitchen wastes and abandoned vegetables and grasses. In spite of this fact, composting for energy recovery has not yet been tried. Moreover, composting waste reduces the amount of waste going to the landfill,

and thus, increases the landfill's lifespan. This reduces expenditures on building another landfill for a while, and reduces pollution caused by landfilling activity.

1.3.6.3 Recovery of conversion products and energy

Combustible organic matter can be converted to intermediate products and ultimately to energy in a number of ways, including (1) incineration or direct combustion in power boilers, (2) pyrolysis to produce a synthetic gas or liquid fuel, and (3) biodegradation with and without sewage sludge to generate methane.

Incinerating of waste and use the heat for energy. Although many combustibles are recyclable, there is often a higher total value (due to processing costs) in burning the waste for energy than in recycling. Incineration reduces the volume of refuse by up to 90 percent, leaving behind only ash, and resulting in less need for landfill space (Ohio State University, 2005).

So as to get these benefits from processing one can use the following five processing techniques: (1) Mechanical volume reduction or compaction, (2) Chemical volume reduction or incineration, (3) Mechanical size reduction or shredding, (4) Component separation manual and mechanical, (5) Drying and dewatering or moisture content reduction. Physical, chemical and biological transformation of solid wastes for recovery of conversion products and energy are summarized in the following Table 3.

Table 3: Transformation process in solid waste management

Process	**Method**	**Principal conversion products**
Physical		
Separation	Manual and / or Mechanical	Individual components found in MSW
Volume reduction	Force or pressure	Original waste reduced in volume
Size Reduction	Shredding, Grinding or Milling	Change in size and shape
Chemical		
Combustion	Thermal oxidation	Co_2, So_2, Oxidation products and ash
Pyrolysis	Destructive distillation	Variety of gases, tar and/ or oil
Gasification	Starved air combustion	Gases and innerts
Biological		
Aerobic composting	Aerobic biological conversion	Compost, Humus like material
Anaerobic digestion	Anaerobic biological conversion	Methane, Co_2, trace gas and humus
Anaerobic composting	Anaerobic biological conversion	Methane, Co_2

Source: Extracted from Tchobanoglous et al 1977, 1993.

1.3.7 Solid Waste Disposal

While it is possible through reduction, reusing, recycling and incineration of municipal solid wastes to significantly reduce the amounts of wastes that need to be land filled, it is not possible to totally eliminate the land burial of municipal solid wastes. Ultimately, something must be done with the solid wastes that are collected and of no further use and with the residual matter after solid wastes have been processed and the recovery of conversion products and / or energy has been accomplished. And disposal of wastes is the ultimate fate of non-reversible and non-recyclable wastes. The safe and reliable long-term disposal of solid waste residues is important component of integrated waste management (Tchobanoglous *et.al.*, 1977).

Modern sanitary land filling is not a common practice in Ethiopia. Some developing countries use simple land filling methods just dumping wastes in low-lying areas, which are prone to flooding. During rainy season, possibility of surface water contamination increase due to flooding of these low lying-areas. The ground water pollution is also another threat posed by dumping of wastes as leachate may infiltrate and join the aquifer. In general, the open space dumping which has been practicing by the Addis Ababa city is major problem to the environment.

In Addis Ababa, there is currently one landfill site at Repi in the South West of the city in Kolfe Keraniyo Kifleketema located 13 kms away from the city center. It has a surface area of 25 hectares. According to Region 14 Administrative Health Bureau (1997) The Repi landfill site was commissioned more than 35 years ago. The only factors that were considered in selecting this site were hauling distance and the availability of the land. There was no evaluation of underlying soil structure and topography, climatological condition, surface water hydrology or the geologic and hydro-geologic conditions of the area.

The major problems associated with the disposal site are: The site is over filled, surrounded by housing areas and institutions, nuisance and health hazard for people living nearby, more than 200 - 300 human scavengers per day work continuously and obviously living nearby the site and interfering the operation of the work for collection of salvageable materials such as wood, scrap metals and discarded food, no daily cover with soil, no leachate containment or treatment, no rainwater drain-off, no odor or vector control, no fence, no weigh bridge and inaccurate weighing of waste and poor record keeping, no liners, no gas venting, hence there is frequent fires,

operated very close to rivers and streams, poor road conditions leading to the site and no proper and adequate access road, indiscriminate disposal of hazardous and industrial wastes, no proper maintenance of the bull dozers and compactor. The present method of disposal is crude open dumping: hauling the wastes by truck, spreading and leveling by bulldozer and compacting by compactor or bulldozer (AASBPDA, 2003).

These types of disposal operations can pose health hazards as well as pollution of the air and water (Mantell, 1975). The wastes are exposed to wind and rain, as well as rat, houseflies, birds and other vermin. There are also people who spend their time sorting through the garbage for edible or recyclable materials in a very risky way to health.

1.4. Objective

1.4.1 General objective

This study was planned to determine the commercial solid waste, domestic and commercial solid waste generation rates per employee per day and per capita per day by weight and volume, to investigate the physical and chemical composition of commercial solid waste and to find out the generation and composition of solid waste generated in different commercial establishments like retail trade shop, wholesale trade shop, bar and restaurants, business centers, and repair services in Arada Sub City in order to contribute to decision support in planning and development of municipal solid waste management systems.

1.4.2 Specific objectives

1. To determine the commercial solid waste generation rate per employee per day.
2. To determine the domestic and commercial solid waste generation rate per capita per day.
3. To determine the density of commercial solid waste.
4. To determine the density of domestic and commercial solid waste.
5. To characterize the chemical and physical composition of the commercial solid waste.
6. To find out the generation and composition of solid waste generated in different commercial establishments like retail trade shops, wholesale trade shops, bar and restaurants, business centers, and repair services.
7. To generate base line data for development of municipal solid waste management systems.

2. Materials and Methods

2.1. Sample size determination

Since the study focus was on commercial solid waste, the sampling system attempted to exclude other manufacturing activities, residential, industrial and institutional. Note that commercial solid wastes are wastes that originate in wholesale, retail, or service establishments, such as offices buildings, stores, markets, theaters, hotels and warehouses and other non-manufacturing activities, excluding residential and industrial wastes (Tchobanoglous *et al*., 1977; Girma Kebede, 2004 and U.S. Code of Federal Regulations-cfr part 243, 1995).

Based on the information extracted from Addis Ababa trade and industry bureau data base in May (2005), there are 13396 registered commercial establishments. By taking in to considerations the following three factors like similarities of commercial sectors in trade kind (Retail trade, Wholesale trade and Services), expected waste types and definition of commercial solid waste those 13396 different trade fields were categorized in to five groups or strata or categories. By doing so all sources of commercial solid waste that are described in the definition are considered or incorporated in one of the five groups or strata. Their respective percentage proportion in Arada Sub City is presented in Table 1. Moreover the sub sectors of each main stratum or commercial sectors are also summarized in Annex 2.

For this study the selected sampling method was stratified random sampling due to variability of the nature of the population under investigation. In this sampling method a heterogeneous unit,

was divided into non-overlapping groups called strata. Each stratum was defined, so that internally it is relatively homogeneous (that is, the variability within each stratum was less than the variability observed over the entire population).

According to SENES (1999); CIWMB (1990) and USEPA (2002) the strategy behind creating strata is to create homogeneous groups so that the variability is better controlled. Therefore, the groupings created in this planning stage should attempt to consolidate waste generators that are expected to have similar waste compositions.

The value of each stratum was determined based on proportional allocation. In proportional allocation, the sampling effort in each stratum is directly proportional to the size of the stratum. Then random sampling was conduct within each stratum. This information is summarized in Table 4 as follows.

Table 4: Pre categorized or grouped commercial centers

NO,	Commercial units Category Name	Total Number in Arada Sub City	Weight given proportionally %	Sample size
1	Retail Trade shops	6535	48.78	29
2	Wholesale Trade shops	786	5.87	5
3	Bar and Restaurants	2711	20.24	13
4	Business centers	2757	20.58	14
5	Repair services	607	4.53	6
Total		13396	100	67

Source: Extracted from the database of Addis Ababa trade and industry bureau, 2005.

The minimum number of samples to be collected should be determined based on the level of precision that is desired in the results. The other input in the determination of the number of samples was the variability of the results between samples. Where the variability may not be well known, estimates of the variability can be used or this information on the variability can come from literature surveys, pilot studies, previous waste composition studies, of waste composition completed in other jurisdictions (SENES, 1999; CIWMB, 1990 and USEPA, 2002). According to these authors the number of samples required to achieve a precision objective can be calculated using the following equation,

$$n = \frac{z^2_{\alpha/2}\,\delta^2}{E^2}$$

Where:

n = the number of samples

z = the z-statistic for the desired confidence level and the number of samples;

δ = the standard deviation of the population (from previous studies, or in other comparable countries)

E = the precision requirement or allowable error (i.e. one half the range of the confidence interval).

A key assumption for use of the sample size equations is that the need of some prior estimate of the total study error, measured as the population standard deviation (δ) or population variance (δ^2). So an estimate of the standard deviation was needed to calculate the number of sample that I should use; yet I was not able to derive that estimate without any samples. To resolve this seemingly paradoxical question, I used one available option, I Used data from a study of a similar site or waste stream. The standard deviation of the population from Arada sub city is 0.056 (Yitayal beyen, 2005).

The standard deviation of the population from Botswana is 0.143 (Bolaane, et al., 2004). The standard deviation of the population from USA is 0.1632 (CIWMB, 1990). The desired level of precision was defined and then examined in terms of available budget and resources. The selected Confidence level and Allowable error was 99 % and 5 % respectively.

$n_1 = [2.57 \times 0.056 \div 0.02]^2 = 51.78 = 52$

$n_2 = [2.57 \times 0.143 \div 0.05]^2 = 54.03 = 55$

$n_3 = [2.57 \times 0.1632 \div 0.05]^2 = 70.37 = 71$

So the minimum number of sample size that should have been used was 60 commercial centers or units, which is the average of the three n-values computed above using different population standard deviation sources. However, 67 commercial centers were used as sampling units.

According to SENES (1999); CIWMB (1990) and USEPA (2002) precision objectives are unlikely to be met for all waste categories due to the high variability for some categories: estimates of the number of samples should be reviewed relative to study cost and objectives before conducting the survey. However, the precision objective of this study was met as planned.

2.2 Identification of commercial centers for sampling

To identify representative sampling commercial centers for each commercial groups sub sectors random number was assigned and using simple random table randomization was done for each group separately and finally the 67 selected sampling unit commercial centers were identified.

After identifying the sampling unit commercial centers the responsible person was convinced about the study by explaining to them the benefit of the study. At the same time questionnaires were also filled during field survey. Instead of the non cooperative selected commercial housing unit other commercial center were selected randomly.

2.3 Preparation of the Sorting Area

The selected sorting area was half walled hall to protect the team from bad smell or odor, birds, insects and the weather. All sorting and associated working areas were ventilated. The half walled hall has a sealed concrete floor and adequate lighting. The area was easily accessible by the hand push cart used to transport the waste samples.

Plate 1: Half walled hall solid waste sorting area

The following tasks were performed in the sorting area for the analysis:

♦The 14 containers were clearly labeled with signs corresponding to each of the primary waste categories.

♦Each container was weighed empty and the weight recorded.

♦Equipment was laid out according to ease and safety of working.

2.4 Collection and sorting of commercial waste

Each participating commercial centre were provided with two or more plastic bags for their daily solid waste based on the amount of solid waste that they have been generating daily. This was to prevent both the overloading of bags and the handling of excess weight of materials. Waste was placed into clearly marked large plastic sacks so as to identify the bags as being from an individual property. This was also allowing the waste to be assigned to a particular business category for recording and interpreting data. Those plastic bags were collected and transported to the analysis site using a pushcart.

Plate 2: Collection of commercial solid waste

Plate 3: Sorting of commercial solid waste

The sampling program was extended over eight successive days. A waste collected on the first day was discarded, as it has been seen the period they represent was doubtful. Wastes collected from the second to the eight days represent one week's solid waste production. The waste was collected each morning for sorting and weighting at Arada health station. The collected waste

was first weighed to obtain the weight of waste for each commercial center. Weighing was carried out three times and an average value was taken. This procedure has been followed throughout the study period.

Waste was sorted into 14 containers by predetermined components of paper, plastic, glass, metal, food, textile, rubber, wood, yard, inorganic, electronic wastes, potentially hazardous waste, special waste, inorganic particles less than 10 mm size. After sorting of the oversized material was finished, the table was shaken to ensure that everything below 10 mm has fallen through. The material below 10 mm, which was fallen to the ground, was shoveled up and its weight and volume was measured.

Periodically, during the analysis the 14 plastic containers were weighed and then emptied. The plastic containers were weighed (three times as before) to record the amount of waste sorted in each predetermined categories. Since solid waste density was needed as part of the study, the volume of the waste was measured and recorded at this point just by lift and drop the plastic or wood bucket container five times to allow the waste to settle. Finally fourteen plastic containers were emptied into disposal facilities provided and these processes were continued until all waste analyzed.

2.5 Proximate, ultimate and calorific value analysis

For Proximate (Volatile matter content, Free carbon remain, and Ash content after combustion), ultimate (C, H, N, S) and Calorific value analysis commercial solid waste samples were collected on 8/05/06. To select commercial centers for solid waste sample collection for proximate, ultimate and calorific value analysis, 20 commercial centers out of 67 commercial centers were used.

To get representative result in the analysis, the number of commercial centers in each commercial category was made proportional to their proximate percentage in 67 sampled commercial centers. Then, 1 Kg food waste, 1 Kg paper, 0.8 Kg yard waste and 0.8 Kg textile were collected. Then after the sample collection it was taken immediately for analysis to Geological Survey of Ethiopia, Central Geological Laboratory-Hydrocarbon division.

Procedures used for analysis are summarized as follows. The laboratory sample consisted of four sub-samples: putrescibles (food waste), Yard waste, papers (paper, cardboard) and textiles. The quantity of each fraction was 800 g to 1 Kg. For the temporary storage and transport of each sample to the laboratory, waterproof plastic bags were used. The time interval between collection and arrival at the laboratory was 3 hour. For the preparation of laboratory samples, necessary safety equipment like gloves was used. Size reduction of materials was achieved using knives and scissors. Volatile matter was determined after 6 minutes of ignition of wastes at $950\ ^{0}$ C and ash content was determined after burning of solid waste for 3 h at 750^{0} C.

The calorific value of solid waste samples was determined by using a bomb calorimeter. Elemental or ultimate analysis was performed using a Vario El elemental analyzer.

2.6 Statistical Data analysis

SPSS (Statistical Package for Social Science) was used for the analysis of commercial solid waste generation and composition data. Questionnaire was also summarized as per the required condition. The average commercial solid waste generation rate by weight and volume per commercial sector and per employee were calculated for the following commercial categories; retail trade shops, wholesale trade shops, bar and restaurants, business centers, and repair services. Per capita Commercial and domestic solid waste generation rate of Arada sub city by weight and volume were also calculated. The percentage compositions of waste fractions or components in all commercial categories or groups were calculated and presented in table, bar and graphs.

2.7 Materials and instruments

To carry out the analysis a number of items of equipment like hand protective plastic gloves for handling, hand push cart for transport of waste, scales capable of weighing up to 100kg, smaller range scales for detailed analysis, wood container with 11.895 m^3, 4.13075 m^3, 139.968 m^3, 94.392 m^3 for volume measurements, three 1m^2 wire mesh or Sieve / screen to separate waste with less than 10 mm particle size, 10mm thick blue plastic sheets to cover the floor, plastic bag for collection and sorting of solid wastes, trash bag for collection of already processed wastes, video and digital cameras to record the research process and field observation were used.

2.8 Limitation of the study

The population number for this study was taken from Addis Ababa Trade and industry bureau. This bureau has a data only for those who have registered. However, there might be commercial establishments who have not yet registered so that those who have not registered are not included in this study because it is not possible to access them by the time and budget resource of this research.

There are also some major limitations of the method that may affect the results of this study in some ways. First, waste generation rate and composition depend on external factors, such as climate, seasons, and location. So the result may vary if repeated in different climate season and location.

The chemical analysis was intended to do in all commercial solid wastes categories or components. However, due to budget constraint it was done only in four fractions like food, yard, paper and textiles wastes.

3 RESULTS AND DISCUSSION

3.1 Waste handling and storage at sources

As one part of the research survey was conducted to assess functional elements associated with waste management, mainly: on-site handling and storage. In Arada sub city collection and transportation and disposal of solid wastes are being carried out by both private and governmental organization. In Arada sub-city there are 32 Micro and Small Enterprises engaged in primarily collection or pre-collection from commercial and household units to municipal containers. There are also some organizations who are engaged in the collection and transportation and even disposal of solid wastes at Repi disposal site using their own truck.

During survey sixty seven people from various commercial establishments were asked different question (See Annex 3). The respondent's responses are summarized in Table 5, 6,7,8,9.

Table 5: Type of solid waste storage

Type of solid waste storage	Number	Percent
Metallic containers	14	20.89
Metallic container and Basket	4	5.97
Metallic container and plastic bag	3	4.48
Cardboard	2	2.99
Cardboard and Plastic bag	3	4.48
Cardboard and Basket	1	1.49
Basket	21	31.34
Plastic bag	13	19.4
Any material available	1	1.49
None	5	7.46
Total	67	100

Again in the same survey sixty seven people from various commercial establishments were asked the question: which commercial wastes are reused by your commercial center? As can be seen from table 6, In Arada Sub city peoples used to reuse material like cardboard, metals, fragmented Aluminum metals, auto spare parts, plastic bottle, left over food and papers.

Table: 6 Type of reused solid waste.

Type of solid waste reused	Number	Percent
Cardboard and metals	2	2.99
Fragmented Aluminum metals and auto spare parts	1	1.49
Auto spare parts	1	1.49
Cardboards	4	5.97
Plastic bottle	2	2.99
Left over food	2	2.99
Papers	7	10.45
Paper plastic and cardboards	1	1.49
None	47	70.15
Total	67	100

As indicated in Table 7 some peoples used to sell materials like Cans, Plastic bottles, Glass, Cardboard, Metals, Gold and silver dusts, Leather and shoe sols. Most of them sold their waste for “Korales” in English “Who have got any metals? “

Table 7: Type of sold solid waste

Type of solid waste sold	Number	Percent
Cans and plastic bottles	1	1.49
Cans, Plastic bottle and Glass	1	1.49
Cardboard	2	2.99
Metals	2	2.99
Gold and silver dusts	1	1.49
Leather and shoe sols	1	1.49
None	59	88.06
Total	67	100

As can be seen from the summary of the results in Table 8 in Arada sub city burning of solid wastes is not being practiced in large scale. Out of 67 respondents only 8 of them are being burning their wastes and out of 8 only two of them have prepared places for burning of solid wastes.

Table: 8 Solid waste burning practices.

Burning system	Number	Percent
Burning with prepared places	2	3
Burning with out prepared places	6	9
No burning practice at all	59	88
Total	67	100

Respondents also have been raising some critics and giving suggestion and possible solution by their own perception on solid waste collection and disposal system of Arada sub city which are summarized in table 9. 10.45 % of the respondent said we are not satisfied with the present system. And they provide the inequality between the amounts of waste generated in the sub city and the capacity of those private and governmental collectors to collect and dispose all the generated waste as the reason. And as a solution they said that the private and governmental organizations who participated in the sector should increase their capacity to clean the city.

Further more the respondent said there should be more communal containers in the near distances. As they said the shortage of communal containers results for the throwing of solid wastes on the street and the over flow of solid wastes around the municipal containers. If municipal containers are available as required those who can’t afford to pay for pre-collectors may use it rather than throwing their wastes on the street, ditches and riverbanks.

According to those respondents pre-collectors should work with truck to increase their capacity in order to facilitate their services. Moreover they said that governmental or any non governmental organization should help those pre collectors to increase the collection and disposal capacity because most of them are not capable to provide reliable services with the help of truck.

There are also some respondent who are satisfied with the present collection system. However, as they said the frequency collection should be increased and every individual even those who do not have the money to pay for the services given by pre-collectors should be served by those pre-collector otherwise they will forced to throw their wastes on the street, open areas and rivers. Those who can not afford to pay for the service charge should get the service as well in order to reduce the waste disposal practice in the open areas, ditches, river side.

Table 9: Recommended waste collection system by studied commercial centers

Recommended waste collection system	Reason	Number	Percent
Pre-collectors should work with truck to facilitate their services and Governmental or any non governmental organization should help them to do so.	The amount of waste is above the capacity of those collectors	5	7.46
We are satisfied with the present collection system		38	56.72
We are satisfied with the present collection system but there should be more focus on the street waste collection system.	It needs frequent cleaning	2	2.99
I am not satisfied with the present waste collection system	The amount of waste is above the capacity of those private and governmental collectors. Thus the private and governmental organizations who participated in the sector should increase their capacity to clean the city.	7	10.45
There should be more communal containers in the near distances	Those who can't afford to pay the service charge may use it rather than throwing on the street.	5	7.46
Wastes should be collected according to there nature	It helps to reuse and recycle them.	1	1.49
Every individual even those who do not have money to pay should be served by those pre-collector.	They will dispose in the river and street.	1	1.49
The waste collection service charge should be reduced as per the volume or weight of waste discharged.		1	1.49
The collection frequency should be increased and there should be more communal containers in the near distances.		2	2.99
The frequency of collection system should be increased.		2	2.99
No recommendation		1	1.49
There should be awareness creation work with the collection practices at the same time.		1	1.49
If private containers provided it would be better		1	1.49
Total		67	100

3.2 Field observation

While walking in Arada sub city inadequate solid waste management can be observed through accumulation of waste like papers and plastics on the street, open lands, in drains and in the commercial area like Atakilt tera (plate 4,5,6,7,). And this results a nuisance. Obnoxious odors originating from decomposing solid wastes, semi-liquid and liquid wastes which are accumulated in the ditch are disgusting all citizens. Overflowing of wastes from communal containers is also observed during the field observation.

Plate 4: Overflowing of wastes from municipal containers

Plate 5: Disposed solid waste in the rive bank

Plate 6: Disposal of solid waste in the riverbanks

Plate 7: Accumulation of waste on the street

3.3 Solid waste generation rate

3.3.1 Generation rate in weight

The mean daily weight generation of each commercial housing unit is obtained by direct measurements of solid wastes collected during the study period. The mean daily weight generation of each commercial housing unit in their respective categories are presented as follows.

Table10: The data structure of the study in weight (Kg)

	GROUPS					
	Retailer shops	Bar and Restaurants	Business centers	Repair services	Wholesalers shops	
	.352857	45.26999	.098514	1.257143	14.65457	
	10.09743	23.09114	.400571	1.760286	15.28743	
	.162857	15.46257	.025714	.041429	104.3057	
	.551429	13.95073	.338857	.788857	77.16000	
	15.71571	13.30500	.739429	6.021429	130.0200	
	.705714	117.2386	1.506429	4.480000		
	.130000	3.438573	.398571			
	.771714	73.65572	1.648571			
	.490000	26.43572	.946000			
	.401429	14.08429	.171429			
	.268571	70.70000	.794286			
	.238571	37.37400	.518571			
	.218571	5.350001	.561714			
	.335714		.764286			
	.392857					
	.421429					
	.720000					
	1.224286					
	2.881429					
	.350000					
	.428857					
	9.345714					
	6.638571					
	2.745714					
	2.667143					
	3.541429					
	1.175143					
	127.1886					
	10.99414					
TOTAL	201.155879	459.356334	8.912942	14.349144	341.4277	1025.201999
REPLICATION	29	13	14	6	5	67
MEAN	6.9364	35.3351	0.6366	2.3915	68.2855	15.30152237
GRAND MEAN						15.30152237

A, B, C, D, E stands for bar and restaurants, retailers shops, business centers, wholesalers shops and repair services, respectively. As can be seen in the data structure of the research those experimental units (Commercial housing units) are stratified proportionally in order to make the sample representative of the population. And such data structures can be analyzed in completely randomized design in unequally replication.

From the above data the following Table 11 is extracted in order to show clearly the mean weight of commercial solid waste generation rate in Arada Sub City per commercial center and per employee.

Table 11: Solid waste generation rate per day, per commercial unit and per employee

Group	Average Number of employee	Mean weight of Solid waste generation per day per commercial unit in Kg	Mean weight of Solid waste generation per day per employee in Kg	Total solid waste generation per day in Kg
A	14.08	35.35	2.51	95793.46
B	4.04	6.94	1.717	45329.44
C	18.43	0.64	0.035	1755.11
D	5.60	68.29	12.19	53672.4
E	9.17	2.39	0.26	1451.64
Total	9.57	15.30	1.59	204978.89

As observed from the above table the commercial solid waste generation rate of Arada sub city is 1.59 Kg per employee per day. The per employee per day commercial solid waste generation rate of group A, B, C, D and E are 2.5 Kg, 1.7 Kg, 0.035 Kg, 12.19 Kg and 0.26 Kg respectively.

Table 12: The Analysis of variance of mean generation rate by weight

Source of variation	Degree of freedom	Sum of square	Mean of square	F-Value		
				Calculated	Tabulated	
					0.05	0.01
Total	66	65086.4786				
Between groups	4	25294.11	6323.5275	9.85	2.522	3.632
With in groups	62	39792.36	641.81			

As can be seen in the above table 12 F-calculated or computed value is greater than F-tabulated at 1 % significant level there is a strong significance difference between groups mean daily weight generation rate. And because of unequal replication the standard error and the coefficient of variances are calculated separately for each group in order to know the magnitude of the deviation relative to their respective mean and the result is presented as follows.

Table 13: Standard error and coefficient of variances of each group

Groups	Standard error	Coefficient of variances
B	4.7	67.8
A	7.3	20.6
C	6.8	1063.6
E	10.3	432.9
D	11.3	16.6

From Table 13 it can be seen that the presence of higher variation in the mean daily weight generation with in group C (Business centers) and lower with in group D (Wholesalers shops). This indicates the presence of homogeneity with in the sample population in wholesalers and

heterogeneity with in the sample population of business services. This standard error indicates that if study is going to be conducted in the future in the same solid waste stream the sample size for those who have higher standard error should be increased.

The ANOVA table 12 shows the presence of strong significance differences in the mean daily weight generation rate among the five groups. And then by doing further analysis using List of Significant Differences (LSD) procedure the differences between each means are observed as follows whether they are significantly different or not.

Table 14: LSD for comparing all possible pair of means from completely randomized design in unequal replication involving five groups using alphabetic notation.

Group	Mean daily weight generation rate	LSD at 0.05 and 0.01
D	68.2855	a
A	35.3351	a
B	6.9364	b c
C	0.6366	b d
E	2.3915	d c

The mean daily solid waste generation rate of group B (Retail Trade shops) and C (Business centers) are not significantly different from each other. And again and E (Repair Services) with B (Retail Trade shops) and C (Business centers) are not significantly different from each other. The mean daily solid waste generation rate of group A and D are not significantly different from each

other at 0.01 significant levels. However, the mean daily solid waste generation rate of group A and D are significantly different from each other at 0.05 significant levels.

Mean solid waste generation per day from total sample is 1025.202 Kg
Mean solid waste generation per day per commercial centers is 15.3015 Kg
Mean solid waste generation per day per employee is 1.599 Kg
Total number of commercial units in Arada sub city is 13396
Estimated total number of employee in commercial units is 128,199.72
Total solid waste generation per day from commercial centers in Arada sub city becomes 204,978.89 Kg.
Total solid waste generation per day from residential source in Arada sub city is 49t (Yitayal, 2005). And then by sum up these two results we can say that the total Commercial and Residential solid waste generation rate per day in Arada sub city is 253.99135t. According to the 1993/94-population census, the population of Arada sub city was estimated to be 297,942 at a growth rate of 3.79 %. Thus the present population of Arada sub city can be estimated as follows.

$P'' = P(1+r)^{t}$
Where;
P'' = the present population
P = the previous population before t years
r = Growth rate of the population
t = year interval in between P and P''.
$P'' = 297942(1+0.0379)^{12}$
P" = 465583.8124
Then the per capita commercial and residential solid waste generation rate is equal to the division of the total commercial and residential solid waste generated per day with the total number of population, so the per capita commercial and residential solid waste of Arada Sub city becomes 0.55 Kg.

3.3.2 Generation rate in Volume

The mean daily generation of each commercial housing unit by volume is obtained by direct measurements of solid wastes collected during the study period. The mean daily generation of solid waste in volumes in cubic centimetre of each commercial housing unit in their respective categories groups are presented as follows.

Table 15: The data structure of the study in volume measurements (cm^3)

	GROUPS					
	B	A	C	D	E	
	4902.43	158093	1951.93	3813	30444.25	
	2859.75	49613.21	2977.77	5588.36	544.71	
	2995.93	186704	3903.79	158099.5	3475.07	
	2088.07	87742.26	5076.43	165507	1634.14	
	3041.75	20922.75	2542	200589.8	21515.79	
	1316.39	108720	4357.71		22114.79	
	5858.21	60412.43	7685.25			
	6628.61	57190.29	1997.29			
	7258.46	55695.07	4666.21			
	36425.11	484056.7	6084.32			
	36714.64	37378	6808.93			
	47255.68	137344.5	3865.54			
	2185.68	131381.1	17278.25			
	2315.04		15691.39			
	125779.5					
	64562.07					
	30715.5					
	27425.18					
	25915.18					
	7536.46					
	248436.8					
	34776.32					
	14870.5					
	7120.79					
	118566					
	16341.43					
	2678.18					
	7302.36					
	3132.11					
TOTAL	897004.13	1575253.31	84886.81	533597.66	79728.75	3170470.66
REPLICATION	29	13	14	5	6	67
MEAN	30931.1769	121173.3315	6063.344	106719.532	13288.125	47320.4576
GRAND MEAN						47320.4576

A, B, C, D, E stands for bar and restaurants, retailers shops, business centers, wholesalers shops and repair services, respectively.

From the above data table 16 is extracted in order to clearly show the mean volume of commercial sold waste generation rate in Arada sub city per commercial center and per employee in meter cubic and liter.

Table16: Solid waste generation rate per Commercial center, Employee and Total per day from each group in volume

Group	Mean volume of Solid waste generation per day per commercial unit in cubic centimeter	Mean volume of Solid waste generation per day per employee in cubic meter	Mean volume of Solid waste generation per day per employee in liter	Total volume of solid waste generation per day in cubic meter
A	121173.33	0.0086	8.606	328.50
B	30931.18	0.0077	7.656	202.14
C	6063.34	0.0003	0.328	16.72
D	106719.53	0.0191	19.057	83.88
E	13288.13	0.0015	1.449	8.07
Total	47320.46	0.0049	4.944	633.91

As we can see from the above table the commercial solid waste generation rate of Arada sub city is 4.95lt or 0.0049m^3 per employee per day by volume. The per employee commercial solid waste generation rate of group A, B, C, D and E are 8.6 lt, 7.7 lt, 0.33 lt, 19.1 lt, 1.45 lt respectively.

Table 17: Analysis of variance for mean generation rate by volume

Source of variation	Degree of freedom	Sum of square	Mean of square	F-Value		
				Calculated	Tabulated	
					0.05	0.01
Total	66	414582942167.5				
Between groups	4	127115375481.8	31778843870.5	6.85	2.522	3.632
With in groups	62	287467566685.7	46366573656.2			

Since F-calculated or computed value is greater than F-tabulated at 1 % significant level there is a strong significance difference between groups mean daily generation by volume. And because of unequal replication the standard error and the coefficient of variances are calculated separately for each group in order to know the magnitude of the deviation relative to there respective mean and the result is presented as follows.

Table 18: Standard error and coefficient of variances of each group

Groups	Standard error	Coefficient of variances
B	8742.999	28.27
A	13058.334	10.78
C	12583.33	207.53
E	19221.35	144.65
D	21055.93	19.73

In this table the higher variation in the mean daily generation by volume with in group C (Business centers) and lower with in group A (Bar and restaurants) can be observed. And this indicates the presence of homogeneity with in the sample population in bar and restaurants and heterogeneity with in the sample population of business centers.

As observed in the ANOVA table 17 strong significance differences exist in the mean daily generation rate in volume among the five groups. And then by doing further analysis using List of Significant Differences (LSD) procedure the differences between each means are observed as follows weather they are significantly different or not.

Table 19: LSD for comparing all possible pair of means from completely randomized design in unequal replication involving five groups using alphabetic notation.

Group	Mean daily weight generation rate	LSD at 0.05 and 0.01 significant level
D	68.2855	a
A	35.3351	a
B	6.9364	b c
C	0.6366	b d
E	2.3915	d c

The mean daily solid waste generation rate by volume of different groups denoted with the same letter are not significantly different from each other. However, the mean daily solid waste generation rates are significantly different from each other for those groups which are denoted by different letters.

Mean solid waste generation per day from total sample is 3,170,470.7 cm^3

Mean solid waste generation per day per commercial centers is 47,320.5 cm^3

Mean solid waste generation per day per employee is 4,944.666 cm^3

Total number of commercial units in Arada sub city is 13,396

Estimated total number of employee in commercial units is 128,199.72

Total solid waste generation per day from commercial centers in Arada sub city becomes 633,907,641.7 cm^3

Total solid waste generation per day by volume from residential source in Arada sub city is 280,812.3 lt per day (Yitayal, 2005). And then by sum up these two results (Residential and Commercial) we can say that the total Commercial and Residential solid waste generation rate per day in Arada sub city is 914,719.9 lt per day.

According to the 1993/94 population census, the population of Arada sub city was estimated to be 297942 at a growth rate of 3.79 %. Thus the present population of Arada sub city can be estimated as follows.

$P'' = P(1+r)^{t}$

$P'' = 297942(1+0.0379)^{12}$

$P'' = 465583.8124$

P'' = the present population

P = the previous population before t years

r = Growth rate of the population

t = year interval in between P and P''.

Per capita commercial and residential solid waste generation rate by volume is equal to the division of the total volume commercial and residential solid waste generated with the total number of population, so the per capita volume commercial and residential solid waste of Arada Sub city becomes 1.97 lt.

The commercial solid waste density can be easily calculated just by dividing the commercial solid waste generation rate weight by volume and becomes 323.4 Kg/m^3 per cubic meter. Similarly the Residential and commercial solid waste density becomes 277.7 Kg/ m^3.

As can be seen the final results of generation rate of domestic and commercial solid waste in Addis Ababa, Arada Sub City is 0.55Kg per capita per day by weight and 1.97lt per capita per day by volume. And this result shows the significant difference as compared to former studies in Addis Ababa.

As discussed, in Arada Sub City there are 79 municipal containers with 8 m^3 carring capacity and 96 municipal containers with 1.1m^3 carring capacity and there are 9 truckes which are being used with Gulele sub city. And these materials are now serving 465,583.8124 people in the sub city (AASBRDA, 2003). This means that all containers together can accommodate 737.6 m3 of solid waste. However, the volume of solid waste from commercial and residential source is1.97 lt or 914.7 m^3 per capita per day.

From these figure we can see that the daily solid waste generated from commercial and domestic source (914.7 m^3) is by far greater than the carrying capacity of the available municipal containers. The present number of municipal containers can collect only 80.64 % of the total solid waste generated from commercial and residential source per day.

And similarly if all wastes that are generated from commercial and domestic and collected in municipal containers have to be transported to the only disposal site (Repi) the existing transportation capacity of the Arada Sub City has to be increased. This is believed to enable the department to cope up with the ever-increasing demand for handling solid waste management of the city.

Table 20: Summery of commercial solid waste generation rate and density

Generation rate	Business categories				
	A	B	C	D	E
Kg / employee / day	2.51	1.72	0.04	12.19	0.26
lt / employee / day	8.61	7.66	0.33	19.06	1.45
m^3 / employee / day	0.009	0.008	0.0003	0.019	0.001
Density (kg / lt)	0.29	0.22	0.11	0.64	0.180
Density (kg / m^3)	291.61	224.25	104.87	639.88	180.11
Kg / employee / day	1.599				
lt / employee / day	4.945				
m^3 / employee / day	0.005				
Density (kg / lt) / employee / day	0.323				
Density (kg / m^3) / employee / day	323.4				
Kg / capita / day	0.546				
lt / capita / day	1.965				
m^3 / capita / day	0.002				
Density (kg / lt) / capita / day	0.278				
Density (kg / m^3) / capita / day	277.7				

According to Norconsult, (1982) the percentage contribution of waste generated from domestic waste 76 %, commercial waste and hotels 12 %, industrial waste 5 %, street sweeping 6 %, hospitals 1%. The total commercial and domestic solid waste generation rate per day in Arada Sub City is 253.99 t. From this total amount of solid waste generated commercial centers and domestic independently generates 204.98 t and 49 t respectively per day in Arada Sub City. From this information the percentage contribution of domestic and commercial sources for the total domestic and commercial solid waste generation rate become 19.3 % and 80.7 % respectively.

As clearly observed in figure 1 the percentage contribution of each solid waste source might have changed through time due to the change in socioeconomic and demographic conditions of the citizens.

Figure 1: Trends in commercial and domestic solid waste generation

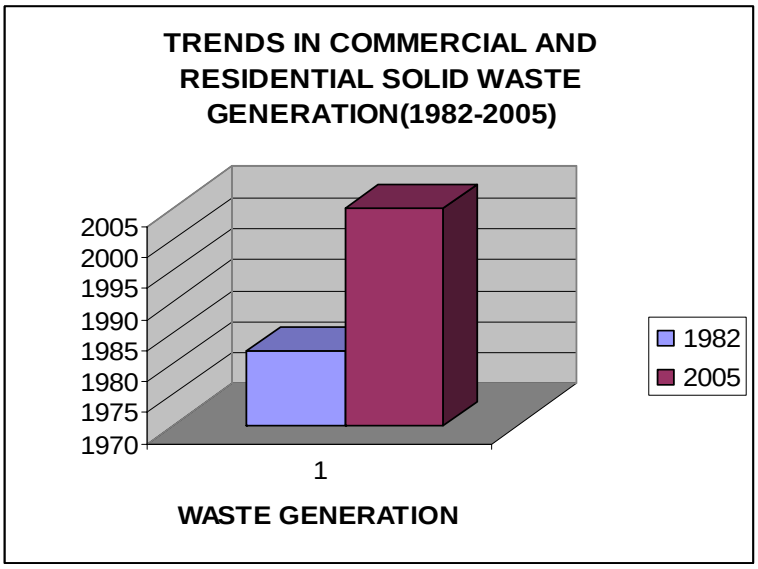


Table 21: Addis Ababa solid waste generation rate in different years

Generation rate	The study was conducted by					
	Norconsult, 1982 wet season	Sturdy Gordon, 1994 Wet season	Sturdy Gordon, 1995, Dry season	Abera Kumie, 1997	French Mission Wet season	The result of this study
gm/capita/day	150	221	252	-	200	546
liter/capita/day	0.4	0.65	1.23	0.45	0.65	1.97
Density, Kg/ m^3	370	336	205	-	308	277.66
Sources	Addis Ababa Administration Health Bureau (1997).					

As can be seen from these studies, which were conducted in different years by different bodies before ten years, the per capita per day solid waste generation in Addis Ababa was in between 150 gm and 252 gm and 0.4 and 1.23 liter. However, the result of this paper 0.55 Kg and 1.97 liter per capita per day and it shows a big difference with those studies.

This variation is mainly due to the change in socio economic and demographic condition of the citizens. This increase in weight and volume of solid waste generated in a given area through time is supported by different authors in similar studies like (Girma Kebede, 2004). Similarly according to this author due to the difference in socio economic and demographic differences, the quantity of solid waste produced or generated per capita per day varies from country to country. Table, which compares the waste generated per capita per day in Arada sub city, Addis Ababa with cities in different countries, are given in table 22.

Table 22: A comparison of waste generated in Addis Ababa with cities in different countries.

Country/ City	Generation per capita per day		Density Kg /m^3
	Lt.	Kg	
UK*	6.4	0.845	132
Middle east*	4.7	1.0	211
Moscow*	1.37	0.548	400
New York*	18	1.8	100
Humbug*	5.6	0.85	150
Rome*	4.6	0.69	150
Singapore*	4.9	0.87	175
Jakarta*	3.0	0.6	200
Kampala*	1.78	0.8	450
American cities*	1.0	1.0-2.0	100-150
Addis Ababa, Arada sub city**	**1.965**	**0.55**	**277.66**
Asian cities*	0.73	0.415	570
Indian cities*	1.12	0.4-0.5	350-500
Developing countries*	-	-	300-500
Cairo, Egypt*	1.5	0.5	330
Kano Nigeria*	1.8	0.46	250
Lahore, Pakistan*	1.0	0.5	500
Calcutta*	1.0	0.51	500

** The data is taken from this paper research result.
* The data is taken from Addis Ababa Administration Health Bureau (1997).

So based on the above table the commercial and residential solid waste generation rate per capita per day in Addis Ababa, Arada Sub City (0.55 kilogram) is highly comparable with other major cities in developing countries such as Jakarta, Indonesia (0.60 Kilogram/person/day), Lahore, Pakistan (0.5), Calcutta, India (0.51), Cairo, Egypt (0.50), and Kano, Nigeria (0.46).

However, the per capita per day commercial and domestic solid waste generation of Arada Sub City in Addis Ababa is lower than countries or cities like UK, Middle east, Moscow, New York, Humbug, Rome, Singapore, Jakarta, Kampala, American cities solid waste per capita per day generation rate.

3.3.3 Composition of Arada sub city commercial solid waste

3.3.3.1 Physical composition

Table 23: Percentage composition of commercial solid waste fractions.

Waste fraction or categories	Percent by weight	Percent by Volume
FOOD	88.41	75.32
PAPER	3.79	7.6
YARD	2.19	7.77
PLASTIC	1.76	4.7
METAL	0.99	1.12
LESS TEN PARTICLE SIZE	0.77	1.6
GLASS	0.62	0.31
POTETIALLY HAZARDOUS WASTE	0.36	0.2
INORGANIC	0.31	0.2
TEXTIL	0.25	0.46
WOOD	0.23	0.5
SPECIAL WASTE	0.15	0.14
ELECTRONICS	0.14	0.04
RUBBER	0.03	0.04
Total	100	100

As can be observed from the above Table 23 from the percentage composition of commercial solid waste fractions by weight and by volume food waste takes the largest proportion followed by paper, yard and plastic waste consecutively. Figuratively, Food waste share 88.4 %, 75.32 % of the total waste generated in commercial sectors and paper contributes about 3.8 % , 7.6 % yard is about 2.2 %, 7.8 % and plastic is 1.7 %, 4.7 % and the rest as a whole contributes 3.8 %, 4.58 %by weight and by volume respectively for the total commercial solid waste generated in Arada sub city

As can be seen from table 23 from the total commercial solid waste generated in Arada sub city 94.87 % by weight and 91.65 % by volume is compostable solid waste like food, paper, yard, textile and wood. Only 5.13 % by weight and 8.35 % by volume of the total commercial solid waste generated is non compostable. This information shows that the presence of great potential for compost production in Arada Sub City and indicates the possibilities of reducing burdens by diverting to compost areas on the existing the only landfill in Addis Ababa.

Figure 2: Percentage composition of commercial solid waste fractions by volume

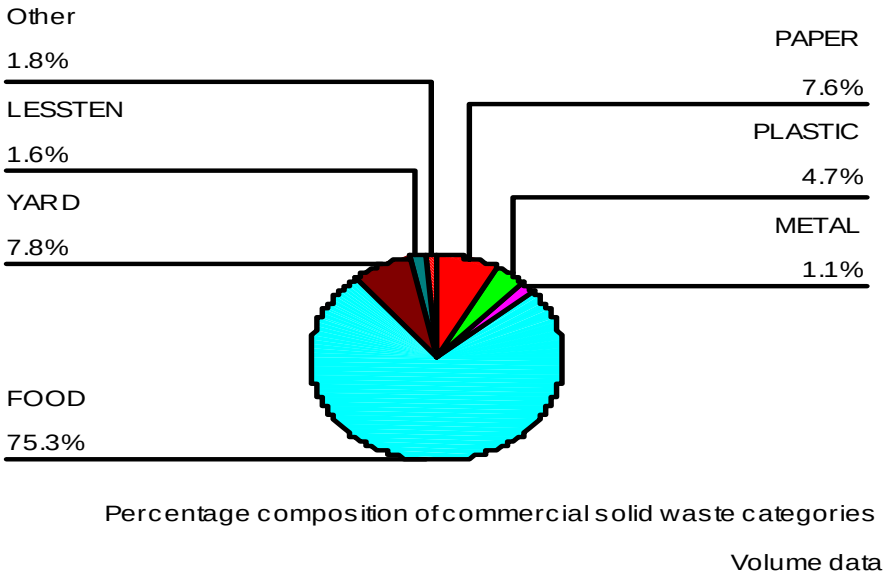


Figure 2 shows the percentage composition of commercial solid waste categories or fractions by volume and it shows that food waste takes the largest proportion of commercial solid waste and followed by yard, paper, and plastic, in organic particle less than 10mm and metals consecutively. Figuratively, Food waste has 75.3 % of the total waste generated in commercial sectors and paper contributes about 7.6 %, yard is about 7.8 % and plastic is 4.7 %, less than 10mm sizes contribute about 1.6 %, metals 1.1 % and the rest as a whole contributes 1.8 % for the total commercial solid waste generated in Arada sub city by volume.

Table 23 also shows that the presence of potentially hazardous waste in the studied area 0.36 % by weight and 0.2 % by volume from the total commercial solid waste generated per day. During the study potentially hazardous wastes like soap, detergents and detergents containers, perfumes,

oil containers, oiled textiles and papers, cosmetics containers, oil cleaner, oil filter, break oil, dry cell, disinfectants are observed. Medical wastes like discarded or used syringes and different tablets have also been observed during sorting of commercial solid waste.

Commercial solid wastes produce hazardous waste related to the service they provide: for example solvents from photographic and dry cleaning shops, cleaning solvent from auto repair garages, ink from printing shop, paints and thinners from hardware shops (Girma Kebede 2004).

As observed from table 23 only about 1.6 % by weight of all commercial solid waste is less than 10mm size. And from this result we can understand that this solid waste need much more time to be degraded in the landfill and this by it self is not good for countries like Ethiopia with single landfill. This study also indicates the need of size reduction during aerobic composting to increase biochemical reaction rate and pyrolysis process for energy recovery.

From the total commercial solid waste about 7.67 % by weight and 14.73 % by volume is recyclable solid waste like metal, glass, paper, plastic, textile, rubber and wood. This figure shows the presence of recyclable materials in Arada Sub City commercial solid waste. Generally if composting and recycling are exercised in Arada sub city there is a possibility to reduce the amount of commercial solid waste going to be disposed in the landfill from Arada Sub City by 98.04 %.

Camille De Stoop (1998) wrote as if there is little room for profitable and viable investments as far as large-scale waste recovery is concerned. However, as can be seen from this research finding from the total solid waste generated in Arada Sub City there is a possibility to recover 98.04 % of the waste through composting and recycling. And this indicates the presence the potential for resource recovery in a large scale.

Since recycling and recovery of wastes are the elements of solid waste management system, the Addis Ababa Sanitation, Beautification and Park Development Agency should take in to consideration the benefit gained by applying this managemental elements both in reduction of the volume of the waste that need to be disposed of by the agency and conservation of the natural resources.

The comparison of Arada Sub City commercial solid waste composition with Domestic solid waste and to the other city or country solid waste composition is presented in Table 24. According to Tchobanoglous *et al*. (1977) the percentages of municipal solid waste components are vary with location, season, economic condition and this variation is also observed in the comparison of Arada Sub City commercial solid waste composition with domestic solid waste and to the other city or country solid waste composition which is clearly observed in table 24.

Similarly according to Cointreau (1984) urban solid waste in cities of developing countries differs from that of industrialized nations. The composition of the waste also differs not only from country to country but also with in a country depending on the source like residential, commercial, industrial and institutional.

As can be seen in table 25 even with in the same season and location the percentage composition of commercial solid waste fractions or composition from different commercial categories are different and this is mainly due to the variation of the activities of commercial establishments.

Table 24: The comparison of commercial, domestic and municipal solid waste from different source

	Arada sub city Addis Ababa		Addis Ababa and other cities			
Waste fraction or categories	Commercial solid waste Percent by weight	Residential solid waste Percent by weight	Addis Ababa Municipal solid waste Gordon,1995	Indian cities	US cities	Uk Cities
FOOD	88.41	59.17	-	-	-	-
PAPER & CARDBOARD	3.79	6.77	3.37	7.6	30	37
YARD	2.19	12.02	-	15.5	10	1
PLASTIC	1.76	5.75	1.98	-	-	-
METAL	0.99	0.662	1.18	0.6	10	9
LESS TEN PARTICLE SIZE	0.77	10.13	-	-	-	-
GLASS	0.62	0.604	0.8	0.6	10	9
POTENTIALLY HAZARDOUS WASTE	0.36	-	-	-	-	-
INORGANIC	0.31	-	-	-	-	-
TEXTI AND LEATHER	0.25	1.778	1.41	-	-	-
WOOD	0.23	1.51	2.29	-	-	-
SPECIAL WAASTE	0.15	-	-	-	-	-
ELECTRONICS	0.14	-	-	-	-	-
RUBBER	0.03	0.015	0.28	-	-	-
MIS. ORGANICS	-	1.546	-	-	-	-
COMBUSTIBLE	-	-	22.63	-	-	-
NON- COMBUSTIBLE	-	-	2.96	-	-	-
FINES< 10MM	-	-	28.04	-	-	-
10 <FINES <55MM	-	-	31.43	45.6	10	10
VEGETABLE	-	-	2.9	28.3	20	28
BONE	-	-	1.62	-	-	-
RUBBER AND PLASTIC	-	-	-	1.8	10	6
Total	100	100	100	100	100	100
Sources of information	Result of this Research	Yitayal Beyene, 2005	Addis Ababa Administration Health bureau, 1997.			

Table 25: Percentage composition of solid waste fractions from different Commercial Categories

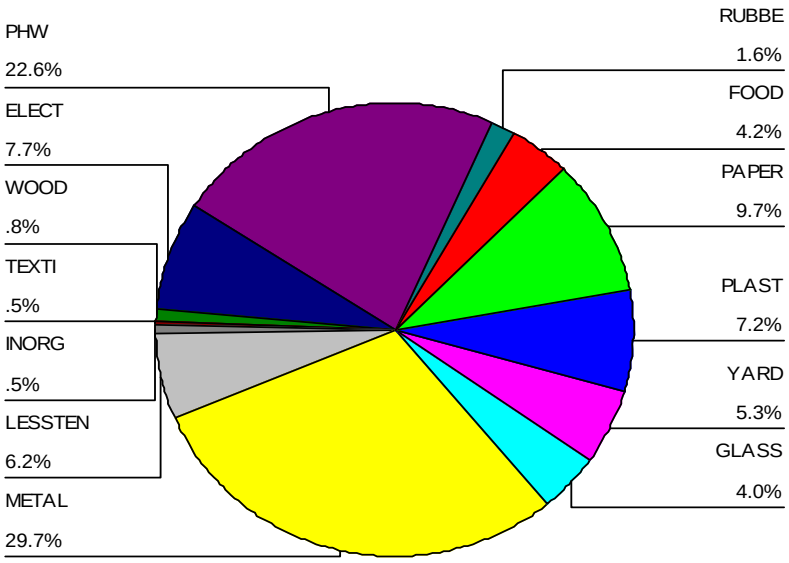
Waste fraction or categories	Commercial Centers Categories									
	Business centers		Retailers shop		Bar and Restaurants		Repair business services		Wholesaler shops	
	BV	BW	BV	BW	BV	BW	BV	BW	BV	BW
FOOD	15.5	35.27	64.97	88.38	80.4	83.62	1.82	4.2	98.2	99.85
PAPER	54.82	32.92	8.33	2.07	5.9	6.55	27.3	9.73	1.042	0.081
PLASTIC	11.1	5.69	3.79	0.57	5.9	3.28	10.41	7.1	0.7	0.052
YARD	0.64	0.24	18.59	6.53	4.91	1.87	2.16	5.34	0	0
GLASS	0.32	0.82	0.096	0.063	0.5	1.22	0.63	3.99	0.02	0.001
METAL	3.05	4.58	0.49	0.126	0.77	1.14	20.44	29.71	0.034	0.001
LESS TEN PARTICLE SIZE	1.98	7.184	1.53	0.724	0.79	1.07	29.95	6.16	0.01	0.004
INORGANIC	0.69	1.78	0.167	0.212	0.2	0.54	0.23	0.5	0	0
TEXTIL	10.56	10.26	0.142	0.062	0.2	0.317	1.25	0.52	0	0
WOOD	0.11	0.02	1.395	0.71	0.1	0.175	0.23	0.82	0	0
SPECIAL WASTE	0.11	0.02	0.395	0.52	0.05	0.11	0	0	0	0
ELECTRONIC	0	0	0.03	0.01	0.055	0.06	0.23	7.7	0	0
POTENTIALYH AZARDOUS WASTE	0.86	1.15	0.06	0.024	0.2	0.055	4.33	22.6	0	0
RUBBER	0.27	0.064	0.01	0.001	0.01	0.015	1.03	1.56	0	0
Total	100.	100	100	100	100	100	100	100	100	100

NB: BV and BW stand for generation of solid waste by weight and volume respectively.

Table 25 shows the percentage composition of metallic waste is higher in repair services commercial category that is 29.7 % and followed by potentially hazardous material that is 22.6 % and then paper, wood, electronic, plastics, less ten inorganic, yard, textile, inorganic, foods, and glass will follow consecutively.

This means there is a possibility to recycle higher amount of metals from such commercial establishments. There is also a possibility to reduce the higher amount of potentially hazardous waste that has been disposed in the landfill just by controlling potentially hazardous waste originated from this sector. This result can be clearly observed in figure 3.

Figure 3: Percentage composition of commercial solid waste by weight originated from Repair service providers

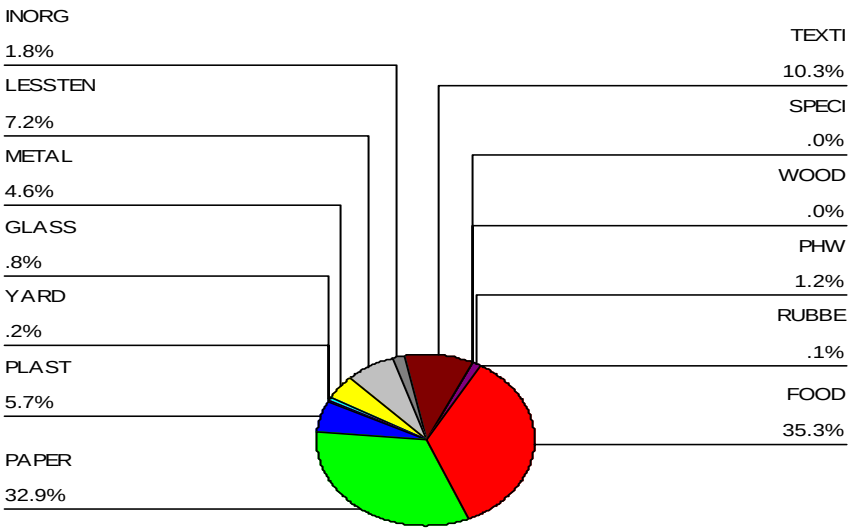


From Table 25 and figure 3 out of the total solid waste generated from repair services 20.61 % by weight is compostable solid waste like food, paper, yard, textile and wood. Majority of the waste around 53.43 % by weight of the total solid waste generated is recyclable like metal, glass, paper, plastic, textile, and rubber, wood. And about 29.27 % by weight of the total solid waste generated is combustible like paper, plastic, textile, rubber, wood, food and yard. This information shows that the presence of great potential for recycling, composting and combustion solid wastes from this sector.

As table 25 indicates the percentage composition of food waste is higher in business centers commercial establishments that is 35.3 % and followed by paper material that is 32.9 % and then textile glass less ten inorganic plastics, yard and inorganic will follow consecutively. This means there is a possibility to recycle higher amount of paper from such commercial establishments.

From the total commercial solid waste generated from business centers 78.709 % by weight is compostable solid waste like food, paper, yard, textile and wood. Waste around 54.35 % by weight of the total solid waste generated is recyclable like Metal, glass, paper, plastic, textile, rubber, wood. And about 84.46 % by weight of the total solid waste generated is combustible like paper, plastic, textile, rubber, wood, food and yard. This information shows that the presence of great potential for recycling, composting and combustion solid wastes from this sector. The above information can be clearly seen in the following Figures.

Figure 4: Percentage composition of solid waste by weight originated from Business centers



As observed from Table 25 the percentage composition of food waste is higher in bar and restaurants that is 83.62 % and followed by paper, plastic, yard, glass, and metal consecutively. This information shows that the presence of great potential for composting solid wastes from this sector.

Table 25 also shows that the percentage composition of food waste is higher in retailers' commercial establishments that is 88.38 % and followed by yard, paper, plastic, glass, and metal consecutively. This information shows that the presence of great potential for composting solid wastes from this sector. Knowing what materials different types of businesses typically dispose, can help them reduce waste, recycle more, and save money.

3.3.3.2 Chemical composition

In this study proximate and ultimate analysis were conducted for Food, Yard, Paper and Textile wastes and the result obtained from proximate and ultimate analysis is summarized as follows.

Table 26: Chemical composition of commercial solid waste generated from Arada Sub City

Components	Volatile matter (%)	Fixed carbon (%)	Ash (%)	Cal. Val (cal/gm)	N(%)	C(%)	H(%)	S(%)	C:N ratio
Food waste	74.59	13.90	2.39	4638	1.57	40.79	7.07	0.29	25.98
yard waste	63.585	15.43	10.25	4016	1.61	36.74	5.69	0.27	22.82
Textile	72.63	6.93	15.54	3289	0.27	41.19	6.15	0.30	152.56
Paper and cardboard	71.48	8.405	14.865	4950	0.20	32.72	4.91	0.12	163.60

As can be seen from the table 26 and 27 the energy value of food waste from commercial source is higher than their respective energy value from residential and typical residential municipal solid waste source. In addition, the energy value of food, yard, paper and card board wastes from commercial source is higher than their respective energy value from residential solid waste source. All this data shows the presence of possibilities to generate more energy from commercial solid waste.

As the physical composition analysis of the commercial solid waste result indicates from the total commercial solid waste generated in Arada sub city 94.87 % by weight and 91.65 % by volume is compostable solid waste like food, paper, yard, textile and wood. At the same time the chemical composition analysis result of Food and yard waste C and N ration testifies the possibility of making compost from this source for fertilizer. Moreover this is a good opportunity for the city like Addis Ababa where solid waste disposal site is a problem.

Table 27: Comparison of the chemical composition of commercial solid waste generated from Arada Sub City with the other findings.

Components	Volatile matter (%)			Fixed carbon (%)			Ash (%)			Cal. Val(cal/gm)		
	A	B	C	A	B	C	A	B	C	A	B	C
Food waste	74.59	65.53	21.4	13.90	14.2	3.6	2.39	19.43	5	1106.95	865.45	859.85
yard waste	63.585	63.31	30	15.43	16.96	7.3	10.25	10.15	10	958.455	884.65	3224.4
Textile	72.63	75.08	66.0	6.93	11.72	7.5	15.54	6.96	2.5	784.983	958.38	3224.4
Paper and cardboard	71.48	64.85	76.7	8.405	14.305	10.35	14.865	10.86	5.5	1181.4	807.64	3159.9
Total										4031.788	3516.12	10468.55

NB: Values under column A, B and C represents the data from this research paper, Yitayal Beyene (2004) and Tchobanoglous (1993) respectively. Values under column A represent the Commercial, B and C represent Domestic sources of solid waste.

Table 28: Comparison of the elemental composition of commercial solid waste generated from Arada Sub City with the other findings.

Components	Carbon (%)			Hydrogen (%)			Nitrogen (%)			Sulfur		
	A	B	C	A	B	C	A	B	C	A	B	C
Food waste	40.79	36.94	48.0	7.07	5.4	6.4	1.57	1.78	2.6	0.29	0.94	0.4
yard waste	36.74	37.94	47.8	5.69	5.7	6.0	1.61	1.53	3.4	0.27	0.38	0.3
Textile	41.19	40.52	55.0	6.15	6.13	6.6	0.27	0.62	4.6	0.30	0.3	0.15
Paper and cardboard	32.72	35.675	43.75	4.91	5.78	5.95	0.20	0.38	0.3	0.12	0.295	0.2

NB: Values under column A, B and C represents the data from this research paper, Yitayal Beyene (2004) and Tchobanoglous (1993) respectively. Values under column A represent the Commercial and B and C represent Domestic sources of solid waste.

4. Conclusion and Recommendation

4.1 Conclusion

This research was conducted in Arada Sub City, Addis Ababa, Ethiopia to determine the commercial solid waste, domestic and commercial solid waste generation rates and their physical and chemical composition in order to contribute to decision support in planning and development of municipal solid waste management systems.

As field observation and generation rate result indicated, Arada Sub City has a problem of solid waste collection and disposal. Inadequate solid waste management can be observed through overflowing of wastes from municipal containers and accumulation of waste like papers, plastics, and yard waste on the street, open lands, in drains and even in the commercial area like “Atakilt tera”.

The survey result and the generation rate data together indicates that the number of municipal containers in Arada Sub City is not proportional to the amount of solid waste generated from commercial and residential source. The present number of municipal containers can collect only 80.64 % of the total solid waste generated only from commercial and residential source per day with daily empitization program. Since those communal containers are emptied in a week or more the problem is aggravated.

Similarly if all collected wastes that are generated from commercial and domestic sources have to be transported to the only disposal site (Repi) the existing disposal capacity of the Arada Sub City has to be increased. This is believed to enable the department to cope up with the ever increasing demand for handling solid waste management of the city.

From the survey result it can be concluded that most commercial establishments have their own onsite solid waste storage containers. However, majority of commercial establishments have not been exercising reusing, selling and burning their wastes.

In Arada Sub City most of commercial establishments solid wastes are being collected from storage to municipal containers by Macro and Micro scale enterprises pre-collectors and majority of commercial establishments are satisfied with the service given by those pre-collectors. However, some commercial establishments who have much amount of solid waste complained about the limited capacity of pre-collectors.

The study result shows that the commercial solid waste generation rate by weight per employee per day of Bars and restaurants, Retailers shop, Business centers, Wholesaler shop and Repair services are 2.5 Kg, 1.7 Kg, 0.0345 Kg, 12.194 Kg and 0.261 Kg respectively. And the overall average commercial solid waste generation rate per employee per day by weight is 1.59 Kg.

The study result shows that the commercial solid waste generation rate by volume per employee per day of Bars and restaurants, Retailers shop, Business centers, Wholesaler shop and Repair services are 8.6 lt, 7.7 lt, 0.33 lt, 19.1 lt, 1.45 lt respectively. And the overall average commercial solid waste generation rate per employee per day by volume is 4.95 lt.

The study result shows that the commercial solid waste density from Bars and restaurants, Retailers shop, Business centers, Wholesaler shop and Repair services are 291.61 kg / m^3, 224.25 kg / m^3, 104.87 kg / m^3, 639.88 kg / m^3, 180.11 kg / m^3 respectively. And the overall average commercial solid waste density is 323.36 Kg per cubic meter.

Total solid waste generated from commercial centers by weight and volume in Arada Sub City is 204,978.89 Kg per day and 633.91 m^3 per day respectively.

The per capita per day commercial and residential solid waste generation rate by weight and by volume in Arada Sub City is 0.55 Kg and 1.97 lt respectively. The residential and commercial solid waste density becomes 277.65 Kg per cubic meter.

According to this study out of the total solid waste originated from commercial and domestic sources the percentage contribution of domestic source is 19.3 % and the rest 80.7 % is contributed by commercial source.

The percentage composition of commercial solid waste fractions by weight clearly shows that food waste takes the largest proportion of commercial solid waste by weight and followed by paper, yard and plastic waste consecutively. The percentage composition of commercial solid waste fractions by volume shows that food waste takes the largest proportion of commercial solid waste and followed by yard, paper, and plastic, inorganic particle less than 10mm and metals consecutively.

The percentage contribution of five groups or categories for the total commercial solid waste generated in Arada Sub City by weight shows that wholesalers contributes the greatest part 69.6 % and followed by bars and restaurants 22.6 % , retailers 5.5 % , business centers 3 % and repairers 2 %.

The total commercial solid waste generated in Arada Sub City 94.87 % by weight and 91.65 % by volume is compostable solid waste like food, paper, yard, textile and wood. Only 5.13 % by weight and 8.35 % by volume of the total commercial solid waste generated is non compostable. This information shows that the presence of great potential for compost production in Arada sub city and indicates the possibilities of reducing burdens by diverting to compost areas on the existing the only landfill in Addis Ababa.

This study also indicates the presence of potentially hazardous waste in the studied area commercial solid waste 0.36 % by weight and 0.2 % by volume from the total commercial solid waste generated per day. There is also a possibility to reduce the amount of potentially hazardous waste that has been disposed in the landfill just by controlling potentially hazardous waste originated from repair service sector because high amount of potentially hazardous waste is originated from such commercial establishments.

About 1.6 % by weight from all commercial solid waste is inorganic less than 10mm size particles. And from the total commercial solid waste about 7.67 % by weight and 14.73 % by volume is recyclable solid waste like metal, glass, paper, plastic, textile, rubber and wood.

If composting and recycling are exercised in Arada Sub City there is a possibility to reduce the amount of commercial solid waste going to be disposed in the landfill from Arada Sub City by 98.04 %. When these strategies are implemented, the diverse costs associated with solid waste management from natural resource utilization to air and water pollution will be reduced.

The energy value of food waste, yard waste, paper and cardboard from commercial source is higher than their respective energy value from residential and municipal source. The potential of energy production from commercial solid waste in Arada Sub city is very high. And similarly the chemical composition analysis result of commercial solid waste C and N ration testifies the possibility of making compost from this source for fertilizer and other purpose.

4.2 Recommendation

Based on the generation rates and composition of solid wastes in Arada Sub City integrated solid waste management system which combines a range of solid waste treatment options like source reduction or prevention, reusing, recycling, composting, and waste to energy transformation is recommended.

Since municipal containers and trucks for solid waste collection and transportation are insufficient for the sub city waste production, responsible body should look after this problem otherwise the sub city solid waste management division should look other solid waste disposal options like composting, recycling and energy production because as observed from the study result the composition of solid waste in the area is suitable for other disposal options other than landfilling.

Majority of the respondents lack information about waste reduction and alternative disposal mechanisms of wastes other than landfilling. So the Arada Sub City solid waste management division should work more on awareness creation in the waste reduction, reusing at the source and alternative disposal mechanisms of wastes other than landfilling.

A commercial solid waste quantity and composition study should be conducted during a rainy season in order to get more year round data on waste generation and composition. Since Addis Ababa city is in demand of such timely solid waste generation and characterization study similar studies should be conducted in other sub cities and waste sources like institutions, industries and street too.

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ANNEX

ANNEX 1: DEFINITION OF TERMS

Agricultural solid wastes, Agricultural wastes and residues resulting from various urban agricultural activities-such as the harvesting of vegetables along some of the city's rivers, the production of dairy products, and the production of small animals for slaughter- are also on the increase, these wastes are indiscriminately thrown along roadsides and waterways and in open fields. No data are available on the amounts of solid wastes generated from urban agricultural activities.

Ash means a residue from the combustion of any solid or liquid material. This type does not include any subtypes. Examples: This type includes ash from fireplaces, incinerators, biomass facilities, waste-to-energy facilities, and barbecues. This subtype also includes ash and burned debris from structure fires.

Batteries mean any type of battery including both dry cell and lead acid. This type does not include any subtypes. Examples: This type includes car, flashlight, small appliance, watch and hearing aid batteries.

Commercial solid waste are wastes that originate in wholesale, retail, or service establishments, such as offices buildings, stores, markets, theaters, hotels and warehouses (Tchobanoglous *et al*., 1977).

Commercial solid Waste means any solid wastes generated by storoffices, restaurants, warehouses, and other non-manufacturing activities, excluding residential and industrial wastes (U.S. Code of Federal Regulations-CFR PART 243, 1995).

Construction solid wastes: the composition of such wastes may include concrete, stones, bricks, blocks, scrap wood, metals, plastics, broken glasses, plumbing and electrical parts, and dirt, Wastes from torn-down houses or buildings, crumbing streets and sidewalks, and other run-down structures also contribute to the growing volume of solid wastes in the city.

Electrical & Electronic Tools: drills, saws, equipment for turning, milling, sanding, grinding, sawing, cutting, shearing, drilling, making holes, punching, folding, bending; tools for riveting, nailing, screwing or removing rivets, nails, screws or similar uses; tools for welding, soldering or similar uses, tools for mowing & other gardening activities;

Film Plastic means flexible plastic sheeting. It is made from a variety of plastic resins including high-density polyethylene (HDPE) and low-density polyethylene (LDPE). It can be easily contoured around an object by hand pressure. Examples: This type includes plastic garbage bags, agricultural film, food bags, dry cleaning bags, grocery store bags, packaging wrap, and food wrap. This type does not include rigid bubble packaging.

Food waste means food material resulting from the processing, storage, preparation, cooking, handling, or consumption of food. This type includes material from industrial, commercial, or residential sources. Examples: This type includes discarded meat scraps, dairy products, egg shells, fruit or vegetable peels, and other food items from homes, stores, and restaurants.

Industrial solid waste Sources and types of solid wastes generated by industries are many metals, plastics, rubber, paper, scrap materials, cloth, glass, leather, clay, ashes, and ceramics. Many of the industrial solid wastes are considered hazardous because they may contain toxic substances. The dangers of toxic wastes include corrosively, explosivity, flammability, ignitability and reactivity, irritant (allergy response), mutagenicity, toxicity, and radioactivity (Tchobanoglous, *et.al* 1993: 100). Leading producers of hazardous industrial wastes include chemical, leather, metal, and printing manufactures.

Institutional solid waste: Institutional solid waste includes schools, hospitals, government offices, and prisons. In addition to the type of solid waste generated by commercial establishments, institutional wastes include the hazardous material of health care establishments such as discarded syringes, needles and chemical waste like the formaldehyde and phenols in disinfectants and the mercury in thermometer and blood pressure gauges.

Leaves and Grass means plant material, except woody material, from any public or private landscapes. Examples: This subtype includes leaves, grass clippings, plants, and seaweed. This subtype does not include woody material or material from agricultural sources.

Municipal solid waste —more commonly known as trash or garbage—consists of everyday items such as product packaging, grass clippings, furniture, clothing, bottles, food scraps, newspapers, appliances, paint, and batteries.

Paint means containers with paint in them. This type does not include any subtypes. Examples: This type includes latex paint, oil based paint, and tubes of pigment or fine art paint. This type does not include dried paint, empty paint cans, or empty aerosol containers.

Residential solid wastes contain putrescibles (rapidly decomposing) animal and vegetable matters resulting from the handing, preparation, cooking and consumption of foods, paper, cardboard, textiles, leather, wood, tin cans, yard wastes, grass, ash, and dirt. In addition, there are bulky household wastes, especially from well-to-do household, such as old furniture, appliances, and electronic gadgets. Residential wastes may include hazardous materials such as spent batteries, chlorine bleach, outdated medicines and medical bottles, detergents, paint products, and insecticides

Rock, Soil and Fines means rock pieces of any size and soil, dirt, and other matter. Examples: This type includes rock, stones, and sand, clay, soil and other fines. This subtype also includes non-hazardous contaminated soil.

Sewage Solids means residual solids and semisolids from the treatment of domestic waste water or sewage. This type does not include any subtypes. Examples: This type includes biosolids, sludge, grit, screenings, and septage. This subtype does not include sewage or waste water discharged from the sewage treatment process.

Solid Waste comprises all the wastes arising from human and animal activities that are normally solid and that are discarded as useless or unwanted (Tchobanoglous *et al*., 1977).

Solid Wastes means any Garbage, refuse, sludge, and other discarded solid materials, including solid waster materials resulting from industrial, commercial, and agricultural operations, and from community activities, but does not include solid or dissolved materials in domestic sewage or other significant pollutants in water resources, such as silt, dissolved or suspended solids in industrial wastewater effluents, dissolved materials in irrigation return flows or other common water pollutants(U.S. Code of Federal Regulations-CFR PART 243,1995).

Special Waste: Ash, Sewage Solids, Industrial Sludge, Treated Medical Waste, Bulky Items, Tires, Remainder/Composite Special Waste.

Street solid waste: This includes street sweepings, roadside litter, haphazardly thrown residential wastes, waste from municipal litter container, and increasing volume of paper, leaves, animal waste, plastics, wrappings, tins, rubber, leather, and broken glasses.

Textiles means items made of thread, yarn, fabric, or cloth. Examples: This subtype includes clothes, fabric trimmings, draperies, and all natural and synthetic cloth fibers. This subtype does not include cloth covered furniture, mattresses, leather shoes, leather bags, or leather belts.

Used Oil This type does not include any subtypes. Examples: This type includes spent lubricating oil such as crankcase and transmission oil, gear oil, and hydraulic oil.

Vehicle and Equipment Fluids means containers with fluids used in vehicles or engines, except used oil. This type does not include any subtypes. Examples: This type includes used antifreeze and brake fluid. This type does not include empty vehicle and equipment fluid containers.

ANNEX 2: DETAILED DESCRIPTION OF STRATA

Categorization of commercial establishments

NO,	Category
1	**Wholesale Trade Shops** Unfabricated textile, Fabricated textiles, Vegetables & fruits, Pepper & spices, Timber, Grain, Coffee and coffee husk, Bar salt, Paper chips, Food stuffs & sanitary goods, Yarn, Cotton & acrylic thread, Automobile spare parts, Tire, Kitchen utensils, Transmitters & music instruments, Vegetables & flowers seeds, Fabricated alcoholic & soft drink, Stationeries, Books & printed items, Sales of bus & trucks, Butter & honey, Paper & printing works, Fish trade, Incense, Bathroom & toilet materials, Agricultural & industrial products.
2	**Retail Trade shops** Apparel & accessory stores, Agricultural & industrial products, Art works, Automobile spare parts, Bag, Bar alt, Books & printed items, Butchery, Butter & honey, Canvas & plastics shoe, Cassette trade, Chat, Children clothes & dolls, Church materials, Coffee and Coffee husk, Coffins, Cosmetic, Cotton & acrylics thread, Eye glasses & spare parts, Fabricated alcoholic & soft drink, Flour-mill spare parts, Flowers & wreath, Fodder, Food stuffs & sanitary goods, Footwear's & other leather products, Furnishings and equipment stores like household & office furniture's, Garden supply, Gesho & malt, Grain, Hardware, Hen & egg, Hides & skins, Homemade food items, Sales of bus & trucks, Items for shoe production, Kitchen utensils, Local areke, Metal trade, Milk & dairy products, Packing & sales of orange juice, Packing & sales of tea, Paper chips, Photographic & cinematography equipment's & spare parts, Plastic tiles, Publishing & sales of video & tape cassettes, Ready made clothes & shoes, Ready made clothes & suitcases, Salvage, Second-hand household utensils, Souvenirs, Sponge mattress, Sport items, Stationeries, Super markets, Textile chips, Timber, Tools using for agriculture, Traditional household materials, Transmitters & music instruments, Tire, Unfabricated and fabricated building materials, Unfabricated and fabricated textiles, Used materials, Used metal, Used tires, Vegetables & flowers seeds, Vegetables & fruits, pepper & spices, Watch, Wood (atana), Yarn.
3	**Bar and Restaurants** like Restaurants, bar, Hotels / Lodging, Rooming Houses, Camps, Pastry, bakery, bakery & pastry, soft drink & packed foods, tej bet, fruits' & vegetables' juice, Snack bar, Pension, beverage grocery.
4	**Business centers** Computer service, Accounting services, Advertising, Art works, Audit service, Barberry, Bath & shower, Beauty salon, Book binding, Building cleaning, Car rent, Car wash, Caranbola game, Consultancy offices, Cloth cleaning & ironing, Communication service, Construction equipments rental, Event organizer, Flour mill, Interior commission agent, Interior trade auxiliary, Laundry, Packing, Plumbing, Printing & binding, Rental of various household or festivities, Rental of video films, Tapisserie, Theaters cinemas hall, Tour agents, Translation & secretarial services, Video game, Video recording, Wedding clothes & jewels rental,
5	**Repair services** Flour mill maintenance, Automobile spare parts, Brake repair, Charging of car battery, Computer assembly, Electric & electro mechanical maintenance, Electrical engineering, Electrical technical service, Electro mechanical, Fuel station gas, Garage, Industrial electrical engineering, Liquid petroleum, Motor cycle & cycle repair, Motor oils & lubricants, Production of spare parts & repair, Radiator repair, Radio, tape recorder, television repair, Refrigerator repair, Repair of medical equipments, Shoe repair, Tornatory, Typewriter & adding machines repair, Tire repair, Watch repair.

ANNEX 3: QUESTIONNAIRES AND REGISTRATION FORMAT

QUESTIONNAIRES AND REGISTRATION FORMAT

NAME OF BUSINESS---------- DATE----------

CONTACT ADDRESS----------

KEY CONTACT PERSON/TITLE ----------

PHONE----------

1. Number of employees----------

2. Number of customers per day----------

3. Which commercial wastes are reused and for what purpose?

   Reused wastes----------

   Purpose----------

4. Is there any organization and /or person who buy wastes for reuse purpose? If yes, for whom do you sell----------, which waste materials? ----------

   ---------- ----------

5. Where do you put your daily-generated wastes? ----------

6. Who is responsible for the disposal of collected solid wastes at the disposal place/ container? ---------- Why? ----

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   ----

7. How far are the waste disposal place/ containers from the commercial unit? ----------

8. Do you burn collected commercial waste? If yes ----------

Do you have prepared place for this purpose? ----------

9. Are there any governmental and / or non governmental organizations that monitor whether commercial household wastes properly collected and disposed at the appropriate place or not? If yes, what kind of punishment is given for those who don't collect and dispose their commercial wastes properly? ----------

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10. What kind of commercial waste collection and disposal systems do you suggest? ------

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ANNEX 4: WASTE CHARACTERIZATION ANALYSIS DATA SHEET

WASTE CHARACTERIZATION ANALYSIS DATA SHEET

NAME OF BUSINESS----------

CONTACT ADDRESS----------

SAMPLE ADDRESS / IDENTIFICATION CODE: ----------

SAMPLING DATE: ----------

GROUP NUMBER: ----------

TOTAL WEIGHT OF SAMPLE COLLECTED: ----------

No	Material Categories	Day 1		Day 2		Day 3		Day 4		Day 5		Day 6		Day 7		Day 8	
		W	V	W	V	W	V	W	V	W	V	W	V	W	V	W	V
1	**PAPER**																
2	**PLASTIC**																
3	**GLASS**																
4	**METAL**																
5	**FOOD WASTE**																
6	**TEXTILES/LEATHER**																
7	**RUBBER**																
8	**WOOD**																
9	**YARD WASTE**																
10	**INORGANIC**																
11	**ELECTRONICS**																
12	**PHW**																
13	**SPECIAL WASTE**																
14	**Less than 10mm size**																

ANNEX 5: PLATES

Plate 8: One meter square wire mesh sorting tables.

Plate 9: Wood container with 11.9m^3, 4.1m^3, 139.9m^3 and 94.4m^3

Plate 10: Balance scale, tables, and data sheet

Plate 19: Plastic gloves for handling hand protective.

Plate 11: Accumulation of waste in side bridge of river

Plate 12: Accumulation of wastes in the riverbanks

Plate 13: Overflowing of wastes from communal containers

Plate 14: Trash bags prepared for disposal after sorting of wastes

Plate 15: Collected commercial solid waste for sorting

Plate 16: Volume and weight measurements

Plate 17: Preparing weighted wastes for sorting in the wire mesh table.

Plate 18: Sorting of Weighted wastes on wire mesh sorting table

Plate 20: Hand push cart for transport of waste.