



***Addis Ababa University
School of Graduate Studies
Environmental Science Program***



***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***

***By
Lemma Asfaw Wakjira***

*June 2007
Addis Ababa*

Acknowledgements

First and for most I would like to thank my research advisor Dr. Seyoum Leta, for his regular guidance, follow-up and advice throughout all phases of my thesis research activities.

I also express my deep appreciation to my office, Adama town Labor and social Affairs office and all its staff members who supported me financially and materially during the study.

Special acknowledgement goes to Ato Samson Tesfaye, Adoption Advocates International, country representative, who is always beside me, And Ato Dita Tuke, Forum on Street Children Ethiopia, Adama Branch Project Manager who assisted me financially to print the paper.

I am gratitude to Ethiopian Geological Survey, Central Laboratory, Hydrocarbon Division and its staff workers Ato Charu Gelan and W/ro Alemnesh Abate, who kindly supported me and handled proximate analysis of sample wastes within a short time.

I also extend my special thanks to my family particularly my wife Abebaye Regassa who encouraged me and physically participated in the sample identification and draft typing activities.

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Acronyms

AACG-SBPA	Addis Ababa City Government Sanitation, Beautification and parking development Agency
AMPRP	Adama Master Plan Revision Project
CSA	Central Statistics Authority
CV	Calorific Value (heat energy)
EEPCO	Ethiopian Electric Power Corporation
EPA	Environmental Protection Agency
HH	Household
HHW	Household Hazardous Waste
HICE	Household Income, Consumption and Expenditure Survey
Kg	Kilogram
MSW	Municipal Solid Waste
MSE	Micro and Small Enterprises
MSWM	Municipal solid Waste Management
USW	Urban Solid Waste
WB	World Bank

Abstract

Data on solid waste generation rates and waste composition are the basic information to plan and implement solid waste management systems. Adama town, like any developing country towns, has poor solid waste management. This is mainly because of lack of information on the generation rates of the waste. To fill the gap this survey has been conducted. The objective of the study was therefore to identify the compositions of household's waste and analyze its generation rate; and assess solid waste management systems of the town and suggest some waste management options.

The study was conducted on randomly selected 162 households, that are expected to represent all categories of income levels (low, middle and high income levels) and from all corners of the town. Daily waste from those households was separated into its components; weight and volume of each component were recorded. This has been conducted for 7 consecutive days to have better average per day domestic waste generation rate.

The study showed that waste generation rate has direct relationship with family's income level. This study finding showed that low, middle and high-income households generate 0.67kg/HH/day, 1.21kg/HH/day and 1.87kg/HH/day, respectively; and on average, a household generates 0.77kg/HH/day. Similarly a person from low, middle and high-income level generates 0.11kg/cap/day, 0.35 kg/cap/day and 0.57 kg/cap/day, respectively, and an average of 0.15kg/cap/day. Total household waste generation rate of Adama town is 35.2tones in a day. The average family size of participating households is 5.7 persons.

Regarding waste compositions, there are about 13 types of waste components that are identified from household wastes. Food waste has the largest proportion both in weight and volume (47.26% by weight). Ash accounts 45.38% by weight next to food wastes in household wastes. Putrescible wastes form 60.5% of the total waste, indicating that compost formation can be one of the options to manage the waste.

Particle sizes of wastes have been also assessed. More than 55% by weight of wastes has a particle size of 10 - 50mm. In addition, 37.7% is fine waste having particle size of less than

10mm. Laboratory analysis of this study indicated that food and yard wastes have high moisture contents, and most of the wastes have high calorific values; in both cases, one can conclude that material and energy recovery is feasible.

In general, from the study results, large proportion of the generated wastes is either compostable or recyclable or energy can be reclaimed from it. Therefore, the municipality has to reduce a waste that goes to disposal site through composting, recycling and energy recovery techniques.

1. INTRODUCTION

Increasing amount of solid waste is being generated as a result of rapid rate of urbanization and economic growth. This in turn presents greater difficulties for waste disposal. The problem is more acute in developing countries where the pace of urbanization is faster. Urbanization introduces society to a new, modern way of life, an improved level of awareness, new skills, a learning process, and so on. However, when the rate of urbanization gets out of control, it poses a big challenge to governance — optimizing forces become weakened, institutional capabilities become inadequate and ineffective, and, with these, the problems of urbanization are compounded (Achakeng, 2003).

Urbanization is not necessarily a new phenomenon on the continent of Africa, as shown by urban centers like Addis Ababa, Cairo, Kano, and Timbuktu (Onibokun and Kumuyi, 2003). What is noteworthy about contemporary urbanization in Africa is its fast pace. Although Africa is presently among the least-urbanized regions of the world, it is recording the highest rates of urbanization. For example, Africa and Asia recorded urban growth of 4.9% and 4.2%, respectively, between 1990 and 1992. However, urban growth in Europe and North America in this period was only 0.7% and 1.0%, respectively (United Nations, 1995). Furthermore, it has been observed that only two cities in Africa (Cairo and Lagos) attained populations of 1 million in 1950; by 1970, the number of cities in this category had increased to eight. By 1990, it had increased to 24 (Sha’Ato et al., 2006; Onibokun, et al., 2003).

According to UN-Habitat studies (2000) urbanization rate in developing countries is very rapid, especially in sub-Saharan African countries, with the growth rate of 5 % per year. On the other hand, the economic development of those countries is lower relative to the rate of urbanization. Hence, to cope up with the changes and fulfill the infrastructure demands of the residents is very difficult. The urban growth in cities of less developed countries strains the already over stretched capacity of city governments, to provide the necessary infrastructures and services.

The base of successful planning for a municipal solid waste management system is reliable information about the quantity and types of material being generated. The quantity and types of waste generated determines the decisions for appropriate equipment, material and personnel settings (Tchobanoglous et al., 1977). It is thus a prerequisite for collection program managers to have detailed information about the nature and quantity of solid waste generated in order to set appropriate management system.

Solid waste management (SWM) is one of the critical concerns facing the developing countries because of the social, economic and environmental implications once not properly managed. Studies show that only 30-50 % of the waste generated in developing countries is collected and managed properly (Dawit and Alebel, 2003). The rest is either burned or left to decompose in open space or dumped in unregulated landfills, which is environmental damaging.

In Ethiopia, alike developing countries, the increase of solid waste generation is resulted from rapid urbanization and population booming. According to Dawit and Alebel (2003) the amount of solid waste in Addis Ababa and other fast growing areas in the country has been increasing over time, largely attributed to rapid population growth rate. The same authors indicated that from the total solid waste released by the population in the City, about 50-60 % was collected and the rest was unattended. Recently the municipality has increased its coverage to about 85 % (AACG-SBPA- 2005).

Adama as being one of the fast growing towns of the country has increasing solid waste generation. The average per capita generation rate, according to estimation of Ministry of Health, a person generates 0.15kg/day solid waste (Ministry of Health, 1996). According to CSA population projection of 2006, Adama town has a population of 228,363 (CSA, Adama, 2006). Based on these data, 34.3 tones or 92.6m³ solid waste is being generated every day in the town.

1.2 Problem statement and justification

Adama as one of fast urbanizing town is far from satisfying the infrastructure demand of its inhabitant. Its solid waste management is poor. The section responsible for the waste management of the town is poorly equipped materially, financially, and in terms of human resources to provide the expected service appropriately (AMPRP- 2004).

One of the major issues that the development strategy should incorporate is the issue of urban environment, which mainly deals with the municipal waste management.

Practical aspects associated with solid waste management systems are financing, operations, equipment management, personnel, reporting, cost accounting and budgeting, contract administration, guide lines and public communications are basic for proper solid waste management (Tchobanoglous, *et al*, 1977). Adama has a population of more than 228,363 (CSA Adama, 2006) and experiencing rapid urbanization rate. Waste treatment, reduction from its source, recycling of wastes or energy recovery from the wastes are not well exercised, the main activity being done is collection and dumping of wastes at dumping site.

Currently the municipality is capable of collecting 43 % of the waste generated in the town (Adama MPRP-2004) the remaining 57 % is indiscriminately disposed off in drainage lines, open spaces, street sides, urges and or is informally burned. This spoils the beauty of the town and it affects the health of the inhabitants.

Poor environmental quality of cities can deprive citizens of a good quality of life as it affects their health and consequently, affect productivity and economic development adversely (Taddesse, 2004).

The amount, type and composition of the waste generated in Adama are not known. Its waste generation rate per capita per day is estimated based on the estimation set by Ministry of Health; a person produces 0.15 kg/day of waste in developing countries (Ministry of Health 1996). Another generation rate estimation taken by the municipality is based on the estimation forwarded by Cointreau, which is 0.4 kg-0.6 kg per capita for low in-come countries (Cointreau, 1982).

Any future system for collection and disposal of this refuse will have to be geared to the total amount and characteristics of the material produced (Hagerty, 1973). Hence, it is necessary to collect and generate baseline information with regard to the amount and compositions of solid wastes that are generated in the town.

The area (Adama town) is selected for this thesis research for the following reasons

- The town is among the fast growing towns in the country where solid waste management problem is crucial,
- No research was conducted so far regarding its solid waste generation rate and composition. This in turn creates big problem to manage the waste, and
- Adama has many resort and recreational areas where most prefer to pass their weekend breaks there. This also creates additional waste burden to the town's waste management.

1.3 Scope of the study

Municipal solid waste management encompasses all waste streams from various sources such as households, commercials, institutional etc. It also comprises of all activities including waste generation rate and composition identification, to waste collection, storage, transfer, waste processing, transportation, and disposal. The scope of this study focuses only on the generation rate and composition analyses of households waste.

General Objectives

- To enhance solid waste management of the town by generating information about household waste compositions and generation rate

Specific Objectives

- To assess and identify types and composition of household wastes
- To identify household waste generation rate of the town by assessing volume and weight of the wastes
- To recommend possible alternatives of waste management methods based on the characteristics of the wastes.

2. LITERATURE REVIEW

2.1 Municipal Solid Waste

Municipal solid waste is defined as, a material for which the primary generator or user abandoning the material within the urban area requires no compensation upon abandonment (Cointeau, 1982). This definition covers all urban solid wastes if it is generally perceived by society as being within the responsibility of the municipality to collect and dispose of.

Some authors also define municipal solid waste (MSW) as material which is useless or unwanted material discarded as a result of human or animal activity. Most commonly, it is solids, semisolids or liquids in containers thrown out of houses, commercial or industrial premises (ESI Africa, 2004). The major type and source of municipal solid waste are food, paper, plastic, glass, metals and various other households' items including street sweepings and general refuse from households, commercial, institutional establishments and non-hazardous solid wastes from industries (Tchobanoglous et al., 1977; Bilitewski et al., 1997).

Large volume of waste is generated from households. For example, in Addis Ababa household waste constitutes 76% of total solid waste generated (Tadesse, 2004; SBPDA, 2005); in Makurdi, Nigeria this waste stream contributes about 82% of the total waste (Sha'Ato et al., 2006). The major components of waste from this source are food preparation left over, ash from ovens (fuel wood) and floor sweeping (Cointeau, 1982). Such wastes are organic in nature thus easily decomposable and of high density.

2.2 Sources and components of solid waste

According to Tchobanoglous et al., (1977) solid waste streams should be characterized by their source, type of waste produced as well as by generation rates and composition. Accurate information is necessary in order to monitor and control existing waste management systems and make regulatory, financial and institutional decisions (AMPRP, 2004). Regarding its source Addis Ababa City Administration recognizes six major

source components (Tadesse, 2004). These are households, street, commercial institutions, industries, hotels and hospitals. According to the author, as is true in developing countries, large volume of waste is generated from households. Its share is about 76% of the generated wastes (SBPDA, 2005); And in Chongqing China, it contributes 59.2% of urban solid waste (Hui et al., 2006). The major components of waste from this source are food preparation leftover, ash from ovens (fuel wood) and floor sweepings. According to Tadesse, waste generated from hotels and commercial source in Addis Ababa is similar in type and composition to that of waste generated from households. Most of the waste components are food items and to some extent paper and plastics.

Various industrial plants generate wastes, which are mainly hazardous wastes during their raw material preparation, production or transportation processes. The waste generated from such sources is not only hazardous but also inorganic requiring special treatment before final disposal (Bilitewski et al., 1997). In this regard, Adama is next to Addis Ababa where concentrations of large and small scale manufacturing activities are found and produce significant amounts of industrial wastes (AMPRP, 2004). Substantial amount of waste like dust and fine materials of different sizes, debris, plastics and papers are generated from this source. In Addis Ababa about 10% of the generated solid wastes is from this source (Tadesse, 2004). In Adama the length of asphalted road is very small where street cleaning is under taken. Cleaning of the drainage lines is not frequently conducted, thus the lines are almost full with solid waste most of the time (AMPRP, 2004).

Health and education institutions produce both organic and inorganic wastes. Paper covers large component of waste generated from such institutions, which could easily be treated and mixed with other organic wastes generated in the town. Waste from health institutions (clinical waste) requires extra precaution when handling blades, syringes, wound dressing etc, which are biologically hazardous wastes (Tudor, 2006).

Plastics play an important role in almost every aspect of our lives. Plastics are used to manufacture everyday products such as beverage containers, household items, and furniture. The widespread use of this valuable material demands proper management of used plastics, as they have become a larger part of the municipal solid waste (MSW) stream in recent decades.

The United States generated about 11 million tons of plastics in the MSW stream as containers and packaging, over 6 million tons as non-durable goods, and more than 8 million tons as durable goods (EPA, 2005). The total amount of plastics in MSW—26.7 million tons—represented 11.3 percent of total MSW generation in 2003. The same source indicated that the amount of plastics generation in MSW has increased from less than 1 percent in 1960 to 11.3 percent in 2003.

Plastics are a rapidly growing segment of the MSW stream. The largest category of plastics are found in containers and packaging (e.g., soft drink bottles, lids, shampoo bottles), but they also are found in durable (e.g., appliances, furniture) and non-durable goods (e.g., diapers, trash bags, cups and utensils, medical devices) (Bilitewski et al., 1997; EPA, 2005). Plastics also are found in automobiles, but recycling of these materials is counted separately from the MSW recycling rate.

2.3 Properties of solid wastes

2.3.1 Physical properties

Different sources express physical property of municipal solid waste by its density, particle size, moisture content, etc. (Holmes, 1981; Tchobanoglous et al., 1977). According to these sources, density-specific weight (weight per unit volume) is managed by assessing total mass and volume of waste. Moisture content indicates water contents of the waste, which is percentage of the wet weight material to dry material. Moisture content of solid wastes is usually expressed as the mass of moisture per unit mass of wet or dry materials. The wet-mass moisture content is expressed as follows: Moisture content (%) = $((w-d) / w) \times 100$; where w = initial mass of sample as delivered and d = mass of sample after drying (Hui et al., 2006; Tchobanoglous, *et al* 1977; Yitayal, 2005).

It has major role in determining compaction, decomposition and incineration.

Other physical properties of municipal solid waste are particle size and porosity (permeability), which are important in managing material recovery and governing movements of liquid and gases in a landfill.

2.3.2 Chemical Properties

The most important chemical properties of solid wastes are proximate analysis (moisture loss at 105⁰c for 1hour, Volatile matter – additional loss on ignition at 950⁰c , ash-residue after burning, fixed carbon-remainder), ultimate analysis, percent of Carbon, Hydrogen, Oxygen , Nitrogen, Sulfur ,ash and heating value(energy value) (Hui et al., 2006; Yitayal, 2005). With regard to chemical composition of the waste, data for developing countries shows that organic substance (C, H, N) comprises about 40-50%, inorganic substance (P, K) 20-30%, moisture about 30-40% by weight, with less than 1000Kcal.of heat value (Abera , 1997).

2.4 Solid waste management

Municipal Solid Waste Management (MSWM) is the generation, separation, collection, transfer, transportation and disposal of waste in a way that takes into account public health, economics, conservation, aesthetics, and the environment, and is responsive to public demands (WWF, 2005).

According to the World Bank, overall goal of solid waste management should be to collect, treat and dispose of solid wastes generated by all population groups in an environmentally and socially satisfactory manner using the most economical means available.

In developing countries, it is common for municipalities to spend 20-50 percent of their available recurrent budget on solid waste management (Onibokun and Kumuyi, 2003). Yet, it is also common that 30-60 percent of all the urban solid waste in developing countries is uncollected and less than 50 percent of the population is served (WB, 2007). In some cases, as much as 80 percent of the collection and transport equipment is out of

service, in need of repair or maintenance. In most developing countries, open dumping with open burning is the norm.

Municipal solid waste management constitutes one of the most crucial health and environmental problems facing governments of African cities. This is because even though these cities are using 20-50 percent of their budget in solid waste management, only 20-80 percent of the waste is collected (Achankeng, 2003). The uncollected or illegally dumped wastes constitute a disaster for human health and the environmental degradation.

The key challenge for most African cities is collection and disposal of waste. Waste collection rates across Africa range from 20-80% (ESI Africa, 2004; Sha'Ato et al., 2006). For example, a survey carried out in Lagos, Nigeria, in the early 1990s, showed that waste was not collected from 31% of households. As a result, waste was often indiscriminately dumped in open plots of land and along streets or other public spaces. In Sudan, about 35% of the waste generated is collected, and only 12% of the households have access to regular disposal of waste (ESI Africa, 2004). In addition, the refuse collection service coverage in Ouagadougou (Burkina Faso) was estimated to be less than 25% in 1996.

Adama due to its seat for different governmental and non- governmental offices and transportation center to other towns, the economic activity is strong and serves large population that generates large volume of waste. On top of this due to its proximity to 'Sodore' resort area, the town attracts many tourists, whose waste generation capacity is substantial (Pace, 2004). 'Chat' chewing is widely practiced in the town, which produces large amount of waste thus increasing the amount of waste generated in the town. The use and discarding of plastic bags, commonly called 'festal' is observed everywhere in the town and the trend seems to be increasing. Not only is the 'festal' pollution unpleasant to look at but it also blocks natural and manmade drainage lines, decreases the rate of decomposition of organic wastes. Inadequate waste collection compounded with inappropriate final disposal system has increased the probability of 'festal' consumption by livestock, which has endangered their health and their produce. On top of this, it has adverse long-term effect on the environment.

2.4.1 Collection

The term collection includes not only the gathering or picking up of solid wastes from the various sources, but also the hauling of these wastes to the location where the contents of the collection vehicles are emptied (Tchobanoglous et al., 1993). Solid waste can be collected from door to door or by using communal containers. Collection in many developing countries is done by using communal containers in which containers are placed at a place where the residents of the area are required to bring their refuse and dump in. There are three basic types of collection equipments: Human powered, Animal powered, and Engine powered (Hagerty et al., 1977).

According to ENDA (1999), municipal waste collection in Addis Ababa is handled in three ways:

- door-to-door collection, for households located along accessible streets ;
- block collection, for clients (large hotels, enterprises and institutions) requesting the municipality to provide them with refuse containers (charged service);
- container system, which expects residents to carry and dump their waste in 8m³ refuse containers placed at supposedly accessible sites.

In practice, 85% of the waste is collected through the container system in Addis Ababa (ENDA, 1999).

2.4.2 Transfer

Waste collected from an area may be directly transported to the disposal site or it may be transferred to another type or size of equipment for hauling (Serra, 2005). In addition, transfer takes place from relatively small pieces of equipment to large pieces of equipment. For instance, refuse may be collected by pushcarts and brought to a neighborhood transfer depot, where the waste is then dumped to a tipping truck, and then the tipping truck brings the waste to an area wide transfer station, where it is dumped into a container which is finally transported by large trailer trucks (Dereje, 2001). The designing of transfer stations may be based on the economically viable radius of transport for each collection equipment.

2.4.3 Transformation

Solid wastes, depending on local condition, may be of value as a source of raw material for industry, fuel for the production of power, and material that can be used for the reclamation of land. To make the waste material convenient to the intended reclamation process, it should be converted or transformed physically, chemically or biological. Through transformation, size and volume of the waste is reduced, the process of material and energy reclamation is facilitated (Table 1).

Table 1: Waste Transformation

Process	Method	Principal conversion products
Physical		
Separation	Manual and/or mechanical	Individual components found in commingled 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 compost	Aerobic biological conversion	Compost
Anaerobic digestion	Anaerobic biological conversion	Methane, CO ₂ , trace gases, humus
Anaerobic composting	Anaerobic biological conversion	Methane, CO ₂ , digested (in land fills) waste

Extracted from Tchobanoglous et al., 1993

2.4.4 Material Recovery

Waste prevention is given the highest priority in integrated waste management (Tchobanoglous et al., 1993). This is a preventive action that seeks to reduce the amount of waste that individuals, businesses and other organizations generate. By not creating waste, fewer collection vehicles and a fewer number of refuse collectors would be needed (Medina, 1999; Zurbrugg, 2003); fewer and smaller waste handling facilities would be required, and it would extend the life of the landfills. Hence, society as a whole would be benefited from a successful implementation of a waste prevention program (Hui et al.,

2006). Source reduction can be a successful method of reducing waste generation. Practices such as grass cycling, backyard composting, two-sided copying of paper, and transport packaging reduction by industry have yielded substantial benefits through source reduction (EPA, 2002). Source reduction has many environmental benefits. It prevents emissions of many greenhouse gases, reduces pollutants, saves energy, conserves resources, and reduces the need for new landfills and combustors (Medina, 1999).

2.4.4.1 Reuse

Once the waste prevention program has been implemented, the next priority in an integrated waste management approach is promoting the reuse of products and materials. Reuse consists in the recovery of items to be used again, perhaps after some cleaning and refurbishing (Tchobanoglous et al., 1993). Reusing materials and products saves energy and water, reduces pollution, and lessens society's consumption of natural resources compared to the use of single-use products and materials (Hui et al., 2006).

Reuse of materials and products is regarded as more socially desirable than recycling the same materials. Cardboard boxes that are used for shipping products, for example, can be folded and sent back to the manufacturer to be reused for shipping the same or other products. Cardboard boxes can also be recycled at paper mills, but in order to recycle the boxes water and energy are required. Paper recycling also generates sludge in the process, which need to be disposed of (Holmes, 1981; Zurbrugg, 2002).

Beverage bottles –soda or beer bottles– can be disposable, returnable (reusable) or recyclable. Reusable bottles have the lowest environmental impact of the three, while disposable bottles require the most energy, water and generate the largest amount of waste and pollution (Zurbrugg, 2002). Products, such as office furniture and appliances, can also be reused. Therefore, reuse of products and materials can prevent pollution, reduce waste, and improve industrial and economic competitiveness (Hui et al., 2006).

2.4.4.2 Recycle

After the reuse of materials and products, recycling comes next in the Integrated Waste Management hierarchy (Medina, 1999). Recycling is the recovery of materials for melting them, repulping them and reincorporating them as raw materials (Onibokun and Kumuyi, 2003). It is technically feasible to recycle a large amount of materials, such as plastics, wood, metals, glass, textiles, paper, cardboard, rubber, ceramics, and leather (Holmes, 1981; Yen, 1975). Besides technical feasibility and know how, demand determines the types and amounts of materials that are recycled in a particular region. Furthermore, areas with a diversified economy and industrial base usually demand more different types of raw materials that can be recycled. In many African countries, artisans also constitute a significant source of demand for waste materials (Onibokun and Kumuyi, 2003; Kofoworola, 2006). African artisans and micro-entrepreneurs manufacture consumer products from waste materials, such as sandals, lamps, pots and pans.

Recycling can render social, economic, and environmental benefits. It provides an income to the scavengers who recover recyclable materials (Kofoworola, 2006). Recycling saves energy, water, and generates less pollution than obtaining virgin raw materials, which translates into lower operating costs (Bilitewski et al., 1997; Hui et al., 2006). Recycling also reduces the amount of wastes that need to be collected, transported and disposed of, and extends the life of disposal facilities, which saves money to the municipalities (Kofoworola, 2006). Recycling can result in a more competitive economy and a cleaner environment, and can contribute to a more sustainable development.

Recycling can be conducted in a number of ways. In the developed world, municipalities have created recycling programs, which usually involve separation of recyclable materials at the source of generation. In this type of programs, individuals and businesses separate their recyclable materials in a different container and before they are mixed with the rest of their garbage. The materials commonly separated at the source include metals, glass, paper and plastics (Onibokun and Kumuyi, 2003). The cleaner and the more homogeneous a material is, the higher the price industry is willing to pay for it.

Therefore, source separation is preferable to salvaging materials from mixed wastes. In the developing world, municipalities usually lack recycling programs (Kofoworola, 2006). That does not mean, however, that recycling does not exist. Informal recycling is common throughout Africa, Asia and Latin America (Medina, 1999). Scavengers carry out the bulk of recycling of municipal wastes. According to the author, scavengers salvage recyclable materials on the streets, before collection crews arrive, at communal refuse dumpsters, at illegal open dumps, as well as at municipal open dumps and landfills.

In Adama town reuse of inorganic materials like plastic, metal etc. at source of waste generation, like other areas in the country is a common exercise due to poverty (Dereje, 2001). Though the action is unintentional, its impact is worth mentioning. Recycling is not commonly practiced in the country; the case is not different for the town, Adama (Pace, 2004). Some localities (Particularly Kebele 06, located at the center of the town) are famous for their tire recycling to make traditional shoe (berebaso) and other products, generating income to substantial number of the inhabitants. These activities are located within residential area creating unpleasant site to the viewers and polluting the air while burning.

2.4.4.3 Compost

Composting municipal solid waste involves managing conditions to accelerate the biological decomposition of some of its organic components. The result is an organically rich product with potential benefits for agricultural soils. The conditions for efficient biological decomposition of organic waste depend on optimum temperatures (130–150° F), moisture (46–56%), oxygen (15–21%), pH (6.0–7.5) levels, and carbon to nitrogen (25:1–30:1) ratios of the feedstock (Mamo *et al.*, 2002; Vesilind and Rimer, 1981). If conditions deviate from these optimum levels, the composting process is slowed and chemically unstable compost may be produced. When microorganisms degrade the organic materials under optimum oxygen levels, the process is called aerobic composting. In contrast, a different group of microorganisms can degrade the organic material under limited oxygen levels, where the process is called anaerobic composting (Bilitewski et

al., 1997). Aerobic composting is usually preferred over anaerobic composting because it is faster in biological oxidation and does not generate as many foul odors (i.e., ammonia, sulfur compounds, and organic acids).

Municipal solid waste is mixed waste from residential, commercial, institutional, and industrial sources. Municipal solid waste has a compostable potential of 60–90% (Holmes, 1981). For example, in Guadalajara- Mexico compostable waste is about 63.4% of the total solid wastes (Perez et al., 2001), where as in Guangzhou- China it constitutes 64.4% (Chung and Poon, 2001). Its typical composition includes paper, glass, wood, plastics, reusable goods, soils, chemicals, food waste, plant debris, metals, textiles, and rock, with the organic materials making up 50–70% of all municipal solid waste (Mamo et al., 2002). Ideally, the compost feedstock should only contain compostable materials such as food scraps, paper, cardboard, yard waste, and wood. Non-compostable waste (glass, metals, and plastics) contaminates the municipal solid waste to varying degrees. In general, the fewer noncompostable materials in the feedstock, the better the finished compost will be for agricultural use (Holmes, 1981; Tchobanoglous et al., 1977).

Carbon to nitrogen (C: N) ratio

Carbon and nitrogen are essential to microorganisms that break down organic material. In the process of breaking down the organic material, microorganisms use the carbon as an energy source and the nitrogen as the building block for protein synthesis. A nutritional requirement for microorganisms is that the C:N ratio of organic matter must be at a level for optimum decomposition efficiency. The limiting C:N ratio for most microbial organisms ranges from 25:1 to 30:1 (i.e., 25–30 parts carbon to 1 part nitrogen). When the C:N ratio of the compost exceeds 30:1, the organisms become deficient in nitrogen and the process of decomposition is slowed (Mamo *et al.*, 2002).

2.4.4.4 Energy recovery

Mixed waste streams are by definition heterogeneous and assumptions regarding the average composition of MSW must recognize variability in calorific value arising from waste pre-treatment and the processing of waste solids into gaseous fuels. The calorific

value (CV) of MSW is influenced by the extraction of recyclable and/or low CV materials. Studies by the UK Government have showed that the CV of MSW can range from between 9-11 GJ/tonne with respect to various recycling scenarios (EPA-UK, 2003). The second major consideration in evaluating the energy potential of a MSW waste stream is whether it is utilized as a solid fuel or converted to a gaseous fuel through active or passive processes. Direct comparisons can be made between different energy conversion processes, but it is important to note the additional steps required to calculate usable energy when the solid waste feedstock has been converted to a methane-rich gas feedstock.

The production of biogas by anaerobic digestion can be designed around several biodegradable feedstocks. The technology is not suited for unsorted MSW. A direct comparison between anaerobic digestion and other MSW management options is therefore of limited value as MSW will need significant treatment before it could be considered an acceptable feedstock input for this technology (Tchobanoglous, *et al*, 1977). It is also important to recognize that anaerobic digestion technology is not optimized around the production of energy. In fact, a significant amount of the calorific value of the input waste stream is not converted to gas but rather remains in other outputs from the system such as compost.

2.4.5 Disposal

Final disposal of wastes at sanitary landfills is given the lowest priority in an Integrated Waste Management approach (Tamronglak, 2005; Tchobanoglous *et al.*, 1993). A sanitary landfill is a facility designed specifically for the final disposal of wastes, that minimizes the risks to human health and the environment associated with solid wastes. Sanitary landfills commonly include one, two or three different liners at the bottom and sides of the disposal area, in order to prevent leachate from polluting nearby surface waters or aquifers (Medina, 1999). Liners also prevent the underground movement of methane. Waste arriving at landfills is compacted and then covered with a layer of earth, usually every day. This prevents animals from having access to the organic matter to feed. Sanitary landfills may also include other pollution control measures, such as

collection and treatment of leachate, and venting or flaring of methane. It is possible to produce electricity by burning the methane that landfills generate.

Disposing of all municipal wastes collected at landfills is not desirable from a social, economic and environmental point of view. Sanitary landfills require significant investments and they often present political obstacles for their construction, due to local opposition. Residents who live near a proposed landfill may oppose its construction.

Land disposal of waste has been practiced for century; because it is the cheapest solution method for waste management, and it was generally believed that leachate from landfill is completely attenuated by soil and ground water (Kirov, 1972). Thus, disposal of waste on all landforms was an acceptable practice, which United States of America has change waste disposal method from open dump to landfill since 1940 (Tamronglak, 2005). However, with increasing concern for the environment in the late 1950 landfills came under scrutiny due to the study reported that leachate do contaminate ground water. As a result, waste was divided into two categories, hazardous and non-hazardous, and two separate design concepts evolved, natural attenuate and containment type of landfill.

Natural attenuate landfill is designed for non-hazardous waste only, and leachate is supposed to filtrate by soil. However the study showed that soil cannot attenuate all the contaminants leached, no matter how thick the underlying layer is. So, this type of landfill is totally banned in some places and countries.

The design concept of containment landfill consisted of constructing a low permeability liner to restrict leachate from percolating through the base of landfill and a pipe system to collect generated leachate. Containment landfill was mandated for disposal of hazardous waste and commonly practiced for all waste in many countries, including Bangkok landfill sites (Medina, 1999; Tamronglak, 2005). However, landfill is still the main approach for Integrated Solid Waste Management as the final disposal; since this method is the cheapest and simple to operate. Proper management of landfill site is of a major

concern because landfill might cause environmental impacts, such as, bad odor in the neighborhood, leachate leakage, and ground water contamination (Jones et al., 2006).

Solid waste disposal site of Adama town as was visited by solid waste disposal site selection study team; it was observed that the solid waste brought by trucks from the town is indiscriminately disposed in open field without taking any sanitary measures to safe guard the local environment. Big birds and wondering animals were observed, which are indication of environmental nuisance. Uncontrolled on-site incineration was also observed at the site (AMPRP, 2004).

The final disposal site is found on the southwest direction, 8 km. away from the town (on the road to Addis Ababa). The town uses the lowest type of disposal system that is controlled dumping. All types of solid wastes generated in the town are dumped indiscriminately at the final disposal site, except fencing and guarding. Solid and liquid final waste disposal site are found within the same compound. The site was selected, as an alternative to the previous one, by the 1995 master plan (AMPRP, 2004). The total area coverage is 14,000m² with 1 m depth (about 4, 200m³ total volume) (Pace, 2004). No compaction activity is carried out other than naturally; the final disposal site will not accommodate the amount of waste generated in the future.

The site is accessibly by trucks, which is an advantage. The other advantage of the site is that, the slope is appropriate; there is available material for covering the solid waste. On the other hand, the site is visible from the main road to Addis; it is situated on the general flow direction of Awash River. The existing site to continue operating sustain ably needs to be upgraded to sanitary landfill (Pace, 2004).

2.4.6 Waste incineration

In an Integrated Waste Management approach, incineration occupies the next to last priority, after waste prevention, reuse, recycling and composting have been undertaken (Tchobanoglous et al., 1993). Incineration is the burning of wastes under controlled

conditions, usually carried out in an enclosed structure. Incineration may include energy recovery.

Wastes generated in developing countries, however, usually do not allow energy recovery, due to their high moisture and high content of organic matter (Akankeng, 2003; Hui et al., 2006). Experience with incineration in developing countries has been mostly negative. Incinerators built in Africa, Asia and Latin America did not function as promised. In Lagos, Nigeria, incinerators were built at a cost of U.S. \$ 10 million (EPA, 2002). The moisture content of wastes was so high that fuel had to be added to maintain combustion, which increased costs significantly. The incinerators never operated normally, one was abandoned and the other turned into a community center. Similar experiences have been observed in India, Mexico, the Philippines, Indonesia, and Turkey. Therefore, incineration of MSW is likely to fail in many Third World cities.

Burning MSW can generate energy while reducing the amount of waste by up to 90 percent in volume and 75 percent in weight (EPA, 2002; Hui et al., 2006).

3. MATERIALS AND METHODS

3.1 Description of the study area

Adama town is located in the Ethiopia rift valley, which makes it a seismically active area. It is located at about 100km southeast of Addis Ababa on the high way to Harar. It is enclosed between 8°33' 00" -8°36' 00" north latitude and 39°17' 57" -39°21' 15" east longitude. Adama town has a total area of 9,616,399.5m² (Dereje, 2001). The average altitude of the town is 1620 m.a.s.l it has a relatively flat topography. Adama town lies in sub humid tropical zone with an average annual temperature of 21°C (Daniel, 2000 cited in Dereje, 2001). The town has a population of about 228,363 in 2006 (CSA, 2006).

Established in 1917, Adama is relatively old town by Ethiopian standards (Addis & Ass. 2004). Regarding population it is the largest town in Oromia region and one of the largest in the country. Adama has been serving as the center for different levels of administrations at varying times. In 1946, it became the seat of the then Yarer and Kereyu Awraja and later in 1988 it became the seat for the East Shoa Administrative Region. From 1992-2003 and, since 2006 Adama has been the seat of East Shoa Zone Administration and Adama Woreda Administration. At present, it is serving as second seat of Oromia National Regional State, and as center for industry, trade and culture. Now the town is being administered by Mayor and has a status of Zone Administration and answerable directly to the Oromia National Regional State. The town had 20 kebeles, but recently after restructuring some kebeles merged and now the town has 14 administrative kebeles. Two kebeles (kebele 10 and 11) were considered in this study.

3.2 Sample size determination

In any sample survey, sample size determination is an important step. To determine sample size of households those to participate in the study, a sampling technique (formula), which was developed by Cochran to determine sample size (n) with the desired degree of precision for general population, was used. In this case population variable (P) is house units variable, and is given as:

Where

$$n = \frac{NZ^2PQ}{d^2(N-1)+Z^2PQ}$$

n= Sample size of housing units

P= Housing unit variable (residential houses)

Q= Non-residential houses (offices, schools, etc.) = 1-P

N= Total number of housing units

Z= Standardized normal variable and its value that corresponds to 95 % confidence interval equals 1.96

d = Allowable error (0.05)

According to data obtained from Housing Development Section of the town (2006), there are about 40,000 housing units (N): out of these more than 90 % (P) are of residential and the rest 10 % (Q) is for commercial activities and offices.

$$\text{Hence } n = \frac{NZ^2PQ}{d^2(N-1)+z^2PQ} = \frac{40,000(1.96)^2 \times (0.9)(0.1)}{(0.05)^2(40,000-1)+(1.96)^2(0.9)(0.1)} = 138$$

Therefore, n=138 is the minimum sample size of housing units for reliable results. To be safe in cases of non-cooperativeness of households, unforeseen problems during collection and other cases the sample size was increased to 180 households. However, due to incomplete participation, incomplete socio-economic data and different reasons some 18 households were excluded from final analysis. Therefore, results of 162 households' solid wastes were analyzed; which is sufficiently enough according to the sample size calculated above.

3.3 Identification of households

To identify participatory households, all households were stratified in to three income level groups, low, middle and high-income groups. This was done in discussion with kebele officials and personal observations, since there was lack of data on income level of the households. Moreover, some information collected from different surveys of Addis Ababa and at country level by the central statistics authority and other researchers, were taken into consideration.

Based on their life standards, housing and other facilities, households were categorized in to low-income groups (the poor group), middle and high in-come groups. Households which were categorized under low income (the poor) were those who leave in slum areas and congested living rooms. Illegal settlements and resettlement area (Dembela) and other place that the kebele administrations have categorized as the poor are included in this group. In this process, effort was made to represent all corners of the town.

After grouping (stratification) households, 166 households (92%) from low-income group, 9 households (5%) from middle income and 5 households (3%) from high-income groups were randomly selected.

After the house numbers of the housing units of each kebeles were selected, the participating houses were identified using their respective house numbers after intensive survey. To select the participating households, the number of households in the compound (housing units) was first established and if the housing unit has more than one household each households were given a unique number starting from one and the participating households were selected randomly. Otherwise, the housing unit itself was taken as a participating household.

If the selected housing units were not serving as a home or just demolished for purpose of condominium or households were non-cooperative; the next housing number was selected. Households in the housing unit were informed about the study that it is for scientific purpose and for the benefits of the community (as it is the basis for their solid waste management that affects their sanitation and healthy conditions).

3.4 Socio-economic data collection

Questionnaires were designed carefully to obtain all the necessary information such as sex of householder, family size, family's income, types of their energy sources, household waste handling, etc. from participating households.

3.5 Collection and sorting of wastes

Actual collection and sorting of wastes from the participating households has been conducted for seven consecutive days. In order to have an average result of the whole days of the week, in cases of differences in waste generation between days. Each household was given a plastic bag labeled with its house number. Next day during collection another bag with the same label was given for the next day collection, and this process continued for seven days. The collection was done by four horse- pulled carts. One cart is assigned to a maximum of 45 households. Every morning these carts bring data to two strategically selected working sites. At the sites there were six enumerators (three at each site) who sorted and recorded all the necessary data.

3.5.1 Sorting by waste type

First wastes have been sorted into different types of components on a blue plastic sheet stretched on the floor, in a sorting hall (Plates 1 and 2).



Plates 1 and 2: Sorting and measuring wastes

After sorting the wastes in to its components, its volume was measured with appropriate sized wood buckets. The weight of wastes was measured with weighting scale. Major waste components are: food wastes , paper , textile, plastic , cardboards, yard wastes , wood, leather, rubber, miscellaneous organics, metals, glass, ash and dust/ sweepings.

3.5.2 Sorting by particle size

After recording the total weight and volume of waste components, each component of waste was sorted by its particle size with wire meshes of sizes 50 mm and 10 mm. First, wastes were placed on the 50 mm wire mesh, and then weight and volume above and below the mesh wastes were taken. Wastes that passed through the 50mm mesh, again placed on the next mesh sized of 10 mm.

3.5.3 Measuring weight and Volume of the waste

Weight and volume of all the wastes, above and below the meshes were measured accordingly. This process continued for all waste components for seven days. After recording weight and volume of waste with respect to its particle size, it was dropped in to big trash bags through which it was finally transferred to near by waste container.

3.6 Proximate analyses

For proximate (moisture content, volatile content, calorific value, ash content after combustion) analyses, six waste components were collected from different households on the last day of the survey. These waste components are: food wastes, yard wastes, textile, paper, cardboards, and wood. The other waste components were excluded due to lack of capacity of the laboratory, to conduct the analysis. Sample size of 100 gms of each paper, card board, textile and wood, and 50 gms for food and yard wastes each were taken for analyses to Geological Survey of Ethiopia, Central Geological Laboratory, Hydrocarbon Division.

For moisture content analyses, samples of food and yard were first weighted and put in an oven of 105^o c for 24 hrs. Then weights after heating were also recorded. For other waste

stream components, the length of time was 1hr, because the wastes were dry. For volatile combustible matter, additional loss of weight on ignition at 950^oc in a covered crucible was determined after six minutes of ignition. Ash content was determined after burning solid wastes for 3 hrs at 750^oc. The energy content (calorific value) of organic components of solid wastes was determined using bomb calorimeter (adiabatic calorimeter).

3.7 Data analysis

SPSS (Statistical Package for Social Science) was used for the analysis of data obtained from solid wastes and questionnaire. The average waste generated by the different households was calculated for low, medium and high-income levels. Results were compared whether the average waste generation rate was the same for each socio-economic level or not. The relationship between the number of persons in a household and the waste generation rate was described with correlation. Moreover, the household waste components were analyzed and compared based on socio-economic levels. The percentage composition of fractions by household income is presented using tables and graphs.

3.8 Materials

Materials for the survey were obtained partly from local materials. Some of these were wood buckets for volume measurement, which were designed at home and made from wood and plywood by woodworker. Those buckets were designed to measure 0.1 L; 0.25L 0.5 L and 1 L. Two kinds of wire meshes were also used, to separated waste according to its size. The first one, 50 mm is to separate coarse wastes out of the bulk. A mesh with 1 m length and 1 m width and a sieve size of 25 mm was bought. To enable to sort a particle size of 50 mm, the size was increased to 50 mm by pulling one wire from a row and one wire from a column throughout its width, as shown in Plates 3 and 4.



Plate 3: Beam balance and Wood buckets



Plate4: Wire mesh and Horse-drawn cart

3.9 Limitations

The major limitation in this study is lack of relevant socioeconomic data on population of the town. For example, housing units in Adama were estimated to be about 25,000, 32,000 and 45,000 by different sources.

Regarding socio economic status of the population, no survey has been conducted. According to CSA 2001 the expenditure (indirect estimation of income) of Adama town households is about 2,000-12,599 birr per annual for 77.7% of households, which is around 170-1050 birr per month per household. Another data found from a local NGO, VISION community development (Addis & Asso., 2004) households, living in low income kebeles have monthly income below 300 birr per month. Therefore, finding households categorized into income levels as low, middle and high-income level is difficult.

The other problem is due to restructuring of kebeles, reorganizing (merging) two or more kebeles under one kebele administration or dividing a kebele into two administrations made some house numbers to be duplicated in a kebele and others are scattered un-sequentially. Even there were some house numbers missing. All these together with

distributions of randomly selected households, made the identification of sample households difficult.

Willingness of selected households to give reliable information and participate in the survey is also another difficulty. Despite the explanation given to them about the usefulness of the study, some households suspected that they might be asked financial contribution based on their income and the waste they generated. Specially information on income level of the family is difficult to find, or needed asking several questions and long discussion.

In some kebeles (kebele 11) language barrier appeared with few householders who were displaced from neighboring countries. The family sizes of those households might not be the one they told us, because mostly they live in groups and have large and varying family sizes, most of the time two or more families chew 'Chat' together and such waste might have contribution in increasing per household's yard wastes.

Considering variations between days in waste composition and generation rate, a week round (seven days) sampling was conducted. However, due to lack of resources and time seasonal variation was not considered.

In general, since no such kind of study has been conducted so far in the town, lack of references, baseline data on solid waste generation rates and composition were also the major problems.

4. RESULTS AND DISCUSSIONS

4.1 Waste generation rate

The waste generation rate survey of households' of Adama town is summarized in Table 2. Results of 162 households were analyzed. This sample size is comparable with that of similar studies conducted at different areas of developing countries. For example, 196 HHs in Arada Sub-City Addis Ababa (Yitayal, 2005); 100HHs in Makurdi – Nigeria (Sha’Ato et al., 2006) and 300 HHs in Guadalajara – Mexico (Perez et al., 2001).

Households are categorized into three groups depending on their monthly per capita income of their family members. Per capita income level and solid waste generation rates have a direct relationship (Wells, 1996). Households that have a better life standard use more consumption materials than low-income households do, through which they generate higher wastes.

Table 2: Household solid waste generation rate of Adama town

Descriptions	Low income	Middle income	High income
Monthly income (per capita)	<300 birr	300-600 birr	> 600 birr
Number of households	139 (85.8%)	16(9.9%)	7(4.3%)
Average family size	6.07	3.44	3.29
Kg/HH/day	0.67	1.21	1.87
L/HH/day	2.28	3.50	3.47
Kg/cap/day	0.11	0.35	0.57
L/cap/day	0.38	1.02	1.06
Density (Kg/m ³)	294	346	539

As shown in Table 2 a household generates 0.67 kg/day for low-income families, whereas middle income and high-income households generate 1.21 kg/day and 1.87 kg/day respectively. Similarly, per capita generation rate of a person is 0.11 kg/day, 0.35 kg/day and 0.57 kg/day for low, middle and high income, respectively.

Regarding the volume of waste, in low-income families, a household generates 2.28 L/day whereas middle and high-income persons generate 3.50 L/day and 3.47 L/day, respectively. This indicates that generation rate has direct relationship with in-come level. Similar trends were observed in Arada Sub-City Addis Ababa (Yitayal, 2005), and Makurdi-Nigeria (Sha’Ato et al., 2006).

As shown in the Table 2 per capita generation rate of low in-come families is three times less than that of middle and high-income families. This indicates that there is great income difference between these groups, especially between low income and middle in-come groups.

4.1.1 Per capita generation rate

To calculate overall average per capita generation rate, contributions of households in different income groups is taken in to account. Because as it was discussed earlier, the mean household generation rate of one income group is different from the other groups. Hence, the average per capita generation rate should include their percentage contribution in order to minimize errors. Therefore, products of per capita generation rate and its household percentage of each income group were added together to yield 0.15 kg/cap/day and standard deviation, SD of 0.09 (Table 3).

Table 3: Overall average generation rates

Generation rates/day	Weight (kg)	SD	Volume (L)	Density (kg/m ³)
Per Household	0.77	0.50	2.46	326
Per capita	0.15	0.09	0.47	326

4.1.2 Total generation rate

The total domestic solid waste generation rate can be calculated from the average per capita generation rate of the studied households, and it is 0.77 kg/HH/day with standard deviation SD of 0.50. Calculating total generation rate of households enables us to

estimate the total solid waste that can be generated in a day or in a year, which in turn enables us to plan accordingly for better municipal solid waste management (Table 4).

Table 4 shows household solid waste generation rates of an individual and total population in a day, week, month and a year.

Table 4: household waste generation rates in a year

Generation rate	Day		Week		Month		Year	
	Wt.	Vol.	Wt.	Vol.	Wt.	Vol.	Wt.	Vol.
Per Capita	0.00015 t	0.00047 m ³	0.00108 t	0.00331 m ³	0.00462t	0.0142 m ³	0.0563t	0.1728 m ³
Total	35.2 t	108m ³	246.2 t	756m ³	1056 t	3,240m ³	12,856.8 t	39,447m ³

4.1.3 Comparison with other areas

Comparing with other areas that have similar socio-economic status with Adama town enables us to estimate the magnitude of solid waste problem of the town. In Arada Sub-City of Addis Ababa, 17,885 tones of domestic solid wastes are being generated in a year (Yitayal, 2005). Adama town generates 12,856.8 tones household solid waste as indicated in Table 4. This is less than that of Arada, because Arada Sub-City has larger population size than Adama.

The daily generation rate of domestic solid waste in Adama town varies from 0.11- 0.57 kg/cap/day (Table 2) or on an average 0.15 kg/cap/day (Table 3). In Arada Sub-City, it varies from 0.075 kg/cap/day to 0.163 kg/cap/day (Yitayal, 2005). Similar survey conducted in Guadalajara-Mexico indicates that household solid waste generation rate of a person varies from 0.356 to 0.659 kg /cap/day, an average of 0.508 kg/cap/day (Perez et al., 2001), and in Makurdi-Nigeria it is about 0.54 kg/cap/day (Sha’ Ato et al., 2006).

Table 5, below shows per capita solid waste generation rates of some African and Asian developing countries. The generation rates of the countries indicated in the Table 5 are of

mixed (total) solid wastes, but the above calculated generation rate of Adama is only household solid wastes. From different survey results of Addis Ababa, household waste constitutes the largest proportion of municipal solid wastes (76%). If other waste streams were included, this value (per capital generation rate in Adama) would increase to about 0.203 kg/cap/day. However, still it is less than the results indicated in the Table 5. Perhaps this is because of socio-economic differences between Adama and these countries.

Table 5: Waste generation rates of some African countries

Country	City	Per capita SW generation, kg/day
Benin	Porto Novo	0.5
Burkina Faso	Ouagadougou	0.7
Burundi	Bujumbura	1.4
Egypt	Cairo	0.5
Uganda	Kampala	0.6

Source: extracted from Achankeng, 2003

4.2 Solid waste composition

Table 6 indicates the major compositions of domestic solid wastes from the studied households. As can be seen from the Table food wastes constitute 37.8 % of the total household wastes by weight. Food waste is being generated from 152 (93.8 %) of the surveyed households. Studies also showed that large portion of solid wastes of developing countries is food wastes (Tchobanoglous et al., 1993). For example, food waste accounts 59.17 % by weight of the total wastes in Arada Sub-city, Addis Ababa (Yitayal, 2005), 36% in Makurdi-Nigeria, (Sha’Ato et al., 2006), 40.7% in Guadalajara, Mexico (Perez et al., 2001).

Next to food wastes, ash accounts for (36.2 %) in Adama town, which is very large compared to that of Arada sub-city, (10.13 %) by weight (Yitayal, 2005); in Makurdi it

forms about 21-41% of household wastes (Sha’Ato et al., 2006). This might be due to all fine wastes including fire residue, dust/soil and floor sweepings were included in the ash component during the survey. In Guangzhou-China all wastes having particle size of <15 mm are categorized under fine wastes (ashes, sand & unrecognizable) (Chung and Poon, 2001).

Table 6: Domestic Solid Waste Composition

No	Waste category	Wt. (kg)	Standard Deviation (SD)	Variance	Vol. (L)	% By wt	% By vol.
1	Food	47.26	0.239	0.057	135.87	37.8	34.2
2	Paper	2.23	0.027	0.001	24.81	1.8	6.2
3	Textile	1.34	0.031	0.001	7.01	1.1	1.8
4	Plastic	2.68	0.028	0.001	23.22	2.1	5.8
5	Cardboard	1.32	0.027	0.001	8.91	1.1	2.2
6	Yard	15.13	0.124	0.015	77.72	12.1	19.5
7	Wood	0.47	0.038	0.001	1.53	0.4	0.4
8	Leather	0.13	0.012	0.001	0.55	0.1	0.1
9	Rubber	0.77	0.108	0.012	2.39	0.6	0.6
10	Mis.Org.	7.79	0.171	0.029	24.81	6.2	6.2
11	Metal	0.31	0.012	0.000	0.30	0.2	0.1
12	Glass	0.54	0.054	0.003	1.27	0.4	0.3
13	Ash/dust	45.38	0.494	0.244	80.76	36.2	20.3
	Total	125.21			397.73	100	100

Dust is a major problem of the town. A study conducted by Adama town Master Plan Revision Project showed that the major sources of dust are flooding and soil transportation from near by catchments, poor quality of road network, quarrying activities under taken in the town, establishments like woodwork, shops, coffee and Soya bean processing plants produce dust in their production processes (AMPRP-Env.2004). This is

aggravated by high wind of the area. The major factor, which causes the proportion of ash to be high, is the life style of the population. As mentioned earlier more than 73 % of the households use traditional kitchens whose energy sources are mainly, fire wood, charcoal, yard and paper wastes. This generates high amounts of ash. It is fourth in frequency that 112 households (69.1 %) contributed the waste (ash).

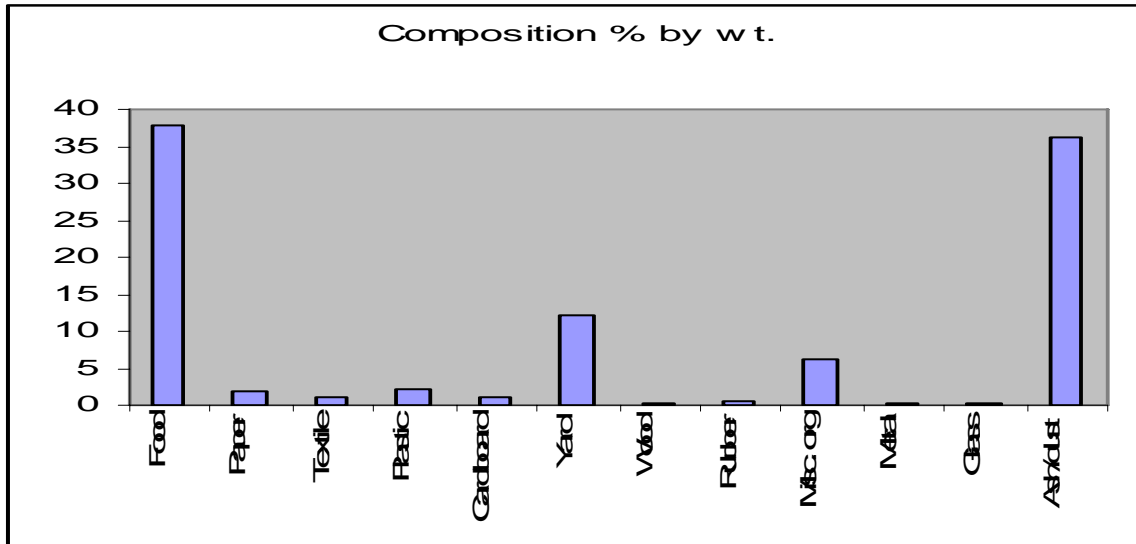


Figure 1: Solid waste composition percent by weight

Yard waste ranking third accounted for 12.1 % by weight and 19.5% by volume. Nearly three-fourth of the households, 121 (74.7%) contributed these wastes. Because of the windy and relatively high temperature of the town, most people plant trees and garden in their compounds to break wind and have tree shadows during high sunshine time (noon). Litters of these trees and garden in addition to grasses during coffee ceremony and ‘chat’ wastes significantly increase the proportion of yard wastes.

From Table 6 the least solid wastes in terms of weight are leather and metal wastes constituting only 0.1% and 0.2% in weight, respectively. This is because metal can be reused repeatedly and it can be recycled or remolded to other durable useful materials. More over, plastic, wood and other local materials are replacing most metal furniture’s by now. Next to metal waste, wood and glass wastes are also the least ones constituting

0.4% each by weight. Wood waste has high demand for energy production (fuel) in households who use traditional kitchens. Glass waste was less because it can be reused for many times, besides glass cups and other utensils are being replaced by plastic one.

Next to food waste, plastic waste is the second in that it was contributed from 122 (75.3%) of the households. Although its magnitude was less, plastic waste is a common problem of more than three-fourth of the households. Plastic wastes constitute 2.1 % by weight and 5.8 % by volume of the total waste generated. Due to its non-decomposability and easily movable by wind plastic wastes are found everywhere. Particularly the final disposal site and its surroundings are being polluted by 'festal' (Plate 5).



Plate5: plastic wastes disseminated around disposal site

High proportion of the households waste (60.5 %) is easily decomposable. These wastes (food, yard wastes, miscellaneous organics, wood, paper and cardboards) are easily decomposable. Similar surveys indicate that in Guadalajara putrescible wastes form 63.4% of total household wastes (Perez et al., 2991), and in Guangzhou it constitutes 64.4% (Chung and Poon, 2001).

4.3 Particle size

Identifying particle size of waste helps to assess its feasibility and the way how to handling material and energy recovery (Bilitewski et al., 1997; Vesilind and Rimer,

1981). Table 7 and Figure 2 show summary of particle size distribution of household wastes. Wastes are divided in to three particle size categories. These are coarse wastes which are larger than 50 mm of size, wastes which have particle sizes between 10 mm and 50 mm and fine wastes which have a particles size of less than 10 mm. From Table 7 paper, textile, plastic, cardboard and wood have particle size greater than 50mm, where as ash/dust has no particle size greater than 50mm. It has 99.96% by weight or 98.2% by

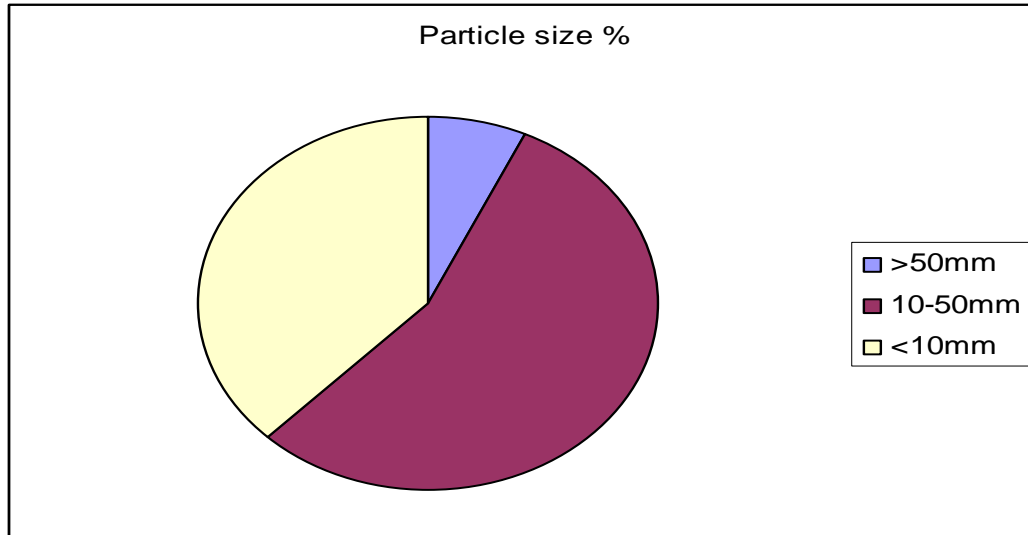


Figure2: Particle sizes of waste percent by weight

volume less than 10 mm of particle size (fine waste). Food, yard waste and miscellaneous organics have their large proportions in the particle size of 10-50 mm, and less percentages in the particle size of greater than 50mm and less than 10mm.

Household waste on average, has the least proportion (6.9% by weight) in the particle size of greater than 50 mm (coarse waste), but its largest portion (55.4%) is found in the particle sizes of 10-50 mm. The rest 37.7% by weight is in the category of fine waste of less than 10 mm particle size, this is largely attributed to ash / dust generated from households. From the result, it can be observed that large proportion of household wastes is found in particle size of 10-50 mm.

Table 7: Particle Sizes of Domestic Wastes

Waste type	Particle size					
	> 50 mm		10-50 mm		<10 mm	
	% by wt.	% by vol.	% by wt.	% by vol.	% by wt.	% by vol.
Food	6.0	6.9	87.5	88.8	6.5	4.3
Paper	100	100	-	-	-	-
Textile	100	100	-	-	-	-
Plastic	100	100	-	-	-	-
Cardboard	100	100	-	-	-	-
Yard	13.7	28.3	77.1	62.4	9.2	9.3
Wood	100	100	-	-	-	-
Misc. org.	0.4	4.1	80.3	69.9	19.3	26.0
Metals	63.6	66.7	36.4	33.3	-	-
Glass	42.2	60.9	54.8	39.1	-	-
Ash/ dust	-	-	0.04	1.8	99.96	98.2

4.4 Moisture and calorific value

As indicated in Table 8, moisture contents, volatile matter, fixed carbon calorific value (heat energy) and ash (residue) of six selected wastes are analyzed. Results showed that moisture contents of food and yard wastes are very high, 67.03 % and 55% by weight, respectively. In Guangzhou, moisture content of wastes is 47.4% by wt. (Chung and Poon, 2001), and in Chongqing-China, it is 64.1% (Hui et al., 2006). This agrees with that of Cointreau's estimation of moisture content for developing countries, 40-80% by wt. (Cointreau, 1982). High moisture content inhibits waste incineration and creates difficulty during waste handling. As indicated in Table 8, all the analyzed wastes have high calorific values (high heat energy contents). Textile wastes and wood have the highest heat energy 4831.89 cal/g and 4564.63 cal/g, respectively. This high calorific value indicated the feasibility of energy recovery from these wastes. Regarding its residues after combustion, very small part of the waste goes to ash. Food waste generates 14.19% of its weight where as wood generated only 1.68 % by weight. This shows that

incinerating wastes highly reduces the volume of a waste which is to be finally disposed. This in turn saves disposal areas and costs of land filling processes.

Table 8: Proximate analysis of domestic wastes of Adama

Waste component	Moisture %	Volatile Matter %	Fixed carbon %	Calorific value cal/gm	Ash %
Food	67.03	62.44	13.26	3600.58	14.19
Yard	55.00	62.98	17.91	3805.27	8.94
Wood	7.92	70.77	19.64	4564.63	1.68
Clothes	1.29	87.26	8.29	4831.89	3.16
Paper	4.85	71.05	11.82	3390.35	12.29
Cardboard	4.94	69.81	12.51	3635.27	12.76

4.5 Socio economic conditions

Incomes of house holds

The income level of the participating households (162) is illustrated in Table 9, households were categorized into three groups depending on their family income. Thus, households who earn less than 300 Birr per month are low income, those who have monthly income between 300 and 600 Birr (middle income) and households that earn greater than 600 Birr (high income group). Accordingly, 29 households (17.9 %) are low income, and 78 (48.1 %) of the families are middle-income group. The remaining 55 households (34%) were those who have monthly income of greater than 600 Birr.

Data from VISION sample survey indicates more than 75% of households in selected kebeles are low-income groups (Addis &Asso, 2004). Further more, according to CSA, 2001, report on the 1999/2000 household income, consumption and expenditure survey, only 16% of the households in Adama were categorized under high expenditure group (high in come group). The rest, about 84% households were either middle or low-income groups. From different socioeconomic surveys conducted in Addis Ababa 91.5% of the

population is low-income, 5.6% middle and 2.9% are high-income groups. Their monthly income is <300, 300-600 and >600Birr, respectively (Yitayal, 2005).

Table 9: Income level of families in the study area

Monthly income in Birr	Frequency	Percent
<300	29	17.9
300-600	78	48.1
>600	55	34.0
Total	162	100.0

According to the Central Statistics Authority (2001) survey, low, middle and high expenditure households in Adama town are 6.3%, 77.7 % and 16 %, respectively. Domestic expenditure of households is indirect indication of household's income level. When monthly income of a household is distributed to its respective family members, the majority of households come under low-income level. This is because most households support large family sizes with limited income. As indicated in Table 11, 139 households (85.8%) came under low-income, where middle and high-income groups accounted for 9.9 % and 4.3 %, respectively. From survey of Arada Sub-City, the ratio of in-come level of households was 83.2%, 11.2% and 5.6%, in that order (Yitayal, 2005).

Table 10: Per capita income and average family size of households

Status of households	Low income	Middle income	High income
Monthly income per capita	< 300 Birr	300-600 Birr	>600 Birr
Households	139 (85.8%)	16 (9.9%)	7 (4.3%)
Average family size	6.07	3.44	3.29

Economic status of households is one of the major factors which has direct impact on domestic solid waste generation rate. The Gross National Product (GNP) is strongly

associated with the increasing volume of solid waste, but population is weakly associated with the generation of solid waste (Wells, 1996).

Family Size

Table 11: Family size of participating households

Number of persons	Households	Percent
1.00	2	1.2
2.00	10	6.2
3.00	16	9.9
4.00	28	17.3
5.00	34	21.0
6.00	16	9.9
7.00	18	11.1
8.00	17	10.5
9.00	7	4.3
10.00	8	4.9
11.00	4	2.5
12.00	1	.6
13.00	1	.6
Total	162	100.0

Table 11 shows family sizes of the participating households. Families, with five members accounted for 21 % (34), and family size of four accounted for 17.3 % (28) ranking second. Households of family size of one and the largest family size thirteen have least proportions, 1.2 % and 0.6 %, respectively. The average family size is about 5.69, which is slightly higher than that of over all family size of urban population of Ethiopia 4.6 (CSA, 2001).

Sources of energy of most households are wood, charcoal, kerosene, cow dung, paper, yard trimmings, etc. Electric power for most families is, if they have access to the

services only for light purpose. This is due to lack of capacity to afford the installation costs and service charges. Significant number of housing units is not legally registered (illegal houses), that they cannot get direct service from EEPCO. Hence, householders build their kitchen in such a way that it could serve them with the helps of the above mentioned energy sources. Some even have no kitchen at all. They cook their daily meal on open area at their home sides or in side their living rooms. Table 12 and 13 show kitchen condition and energy sources of surveyed households.

Table 12: Type of kitchen

Kitchen	Households	Percent
No kitchen	18	11.1
Traditional	119	73.5
Modern	25	15.4
Total	162	100.0

Table 13: Sources of energy

Sources	Households	Percent
Electricity, kerosene, charcoal	26	16.0
Electricity, charcoal, wood, paper, cow dung	135	83.3
Wood, dung, yard trimmings	1	0.6
Total	162	100

From Table12, only 25 households (15.4 %) have modern kitchen; About 119 households (73.5%) have traditional kitchens, which use wood and other materials as sources of energy, which generate large amounts of ash. The remaining 18 households (11.1%) have no kitchen, they use their living rooms or open spaces. This also consumes wood, dung and the like and consequently contributes to ash generation.

Regarding sources of energy, 135 households (84 %) use charcoal. Wood, dung, paper and kerosene in addition to electricity for their source of energy. Only 26 households (16 %) use electricity, kerosene and charcoal. No family depends solely on electric power as its source of energy. Therefore, ash is common solid waste in the majority of households.

Toilet facility

Table 14 and 15 indicate facility and type of toilets. From Table 14, 14 households (8.6%) have no latrine. Some households 15 (9.3%) have shared latrines, where as 11 households (6.8) use public latrines that found nearby their residences. About 122 (75.3 %) of the households have their own private latrines. Regarding the types of toilets among the existing toilets about 85.2 % are dry pit latrines, only 6.2% of the households surveyed use water flushed latrines.

Table 14: Toilet facilities of participating households

Toilet	Households	Percent
No toilet	14	8.6
Public toilet	11	6.8
Common toilet (shared)	15	9.3
Private toilet	122	75.3
Total	162	100.0

Table 15: Type of toilet

Toilet	Households	Percent
Dry pit	138	85.2
Water flushed	10	6.2
No response	14	8.6
Total	162	100.0

One of the major problems that need attention is toilet facility. More than 22 types of infection diseases of developing countries are due to improper management of solid wastes (Yami, 1999). It spoils the aesthetic value of the environment. From this survey few cases were observed that human excreta put in plastic bags in the solid wastes that to be analyzed. In fact, it is not significant compared to the total solid wastes (< 0.07% in weight) but in terms of human health and aesthetic aspects it is the worst. From previous survey it was indicated that this problem (human excreta) was prevailing, due to lack of adequate latrines for a number of households, especially those in the congested areas, dispose their night soils in to the streets in plastic bags during night times which further increases the amount of waste collected as solid (Dereje, 2001).

4.6 Waste handling

Onsite waste handling refers to the activities related to the handling of solid wastes until they are placed in the containers used for their storage before collection. Depending on the type of collection service, handling may be required to move the loaded containers to the collection point and to return the empty containers to the point where they are stored between collections. The persons responsible for onsite handling and the auxiliary equipment and facilities that normally are used at the sources where wastes are generated are households or the one who generates the wastes.

Solid waste storage

Table 16: Solid waste storage of households

Storage type	Households	Percent
Trash bag	113	69.8
plastic bag	35	21.6
others	13	8.0
Not responded	1	.6
Total	162	100.0

As shown in Table 16 most households 113 (69.8%) use PP bag (trash bag) for their temporary waste storages. This is because it is longer lasting than plastic bags. Its size also has contribution to its preference and for most families it accommodates a week round wastes. Moreover, it is convenient to handle when wastes are transported by carts from houses to containers. Some households especially who dispose or transfer their wastes to containers themselves use plastic bags. This accounted for 21.6 % (35). The rest 13 households (8%) use other materials such as baskets, metal buckets, plastic containers and open areas at their home sides, as their temporary waste storage.

Waste reuse

Table 17: Conditions of Waste reuse

Reuse	Households	Percent
No	65	40.1
Yes	97	59.9
Total	162	100.0

Householders were amazed when they were asked that whether they reuse or sell their solid wastes; rather than replying to our question they in turn asked us how waste could be reused or sold. For few of them, it even seemed insulting and up-set. However, after discussing what we wanted to say and convincing, most of them responded positively. Tables17 & 18 show families that reused wastes and types of wastes that being reused. From Table 18, 97 households (59.9%) reused some kinds of wastes (food, wearing and utensils).

Table18: Types of solid wastes reused

Wastes	Households	Percent
Food wastes (home compost)	13	8.1
Paper, wood, plastics (for fuel)	32	19.8
Cans and bottles (reuse)	52	32.1
Not responded	65	40.1
Total	162	100.0

Among respondents, 13 households (8 %) compost or reuse food and vegetable wastes for soil enrichment for their gardens and horticultures. Cans, bottles and other packaging materials are being reused by 52 households (32.1 %) and 32 households (19.8%) reuse paper, wood, plastic and yard trimmings as fuel (fire wood).



Plate 6: old tires recycling in Adama

Plate 6 indicates when household materials are being made of old tires.

There is the possibility of recycling plastic materials, particularly plastic bags. However, it has limited short-term economic return because it is costly to recycle plastic bags than to produce a new one. One thing that should be considered is that the use of plastic bags in every day life of individuals should be minimized and substituted with environmental friendly items requiring immediate broader policy intervention. Otherwise, the long-term negative consequence on the environment is likely to be costly. Final disposal site and its surrounding areas are even now, being polluted by this waste (Plates 7 and 8).



8

Plate 7 and 8: Problems of plastic wastes at the disposal site in Adama town

Changed or sold wastes

Table 19: Changed or sold wastes

Waste items	Households	Percent
Cloths	106	65.4
Shoes	16	9.9
Plastic and glass bottles	14	8.6
No response	26	16.1
Total	162	100.0

Similarly, households that sold wastes or exchanged wastes for plastic and other utensils are shown in Table 19. From Table 19 most of the households 106 (65.4%) changed their cloth wastes for plastic and other utensils to “**Lewach**” or sold their wastes to “**Koralew**”. The remaining households 16(9.9%) and 14 households (8.6%) have exchanged or sold their worn out shoes and plastic and glass bottles, respectively. Only 26 households (16%) responded that they never sell or exchange for other materials.

Solid waste combustion (burning)

In the ideal incineration process, hydrocarbon compounds of the combustible refuse combine chemically with oxygen of the air to form carbon dioxide and water, and leave the minerals and the metals as solid residue. This chemical reaction releases high energy, which can sterilize the residue, destroy odorous compounds in the refuse, and convert the water in to vapor which together with the carbon dioxide, becomes an acceptable and invisible part of the atmosphere (Baum and Parker, 1974). If the constituents are not intimately mixed in the proper proportions, and if they are not sustained at the proper temperature for the proper length of time, the reaction will be incomplete and undesirable products and effects may result. An uncontrolled rubbish fire which causes smoke, air borne particulate matter, odors and putrescible residue is an example of incomplete combustion.

According to this study, some households burn (incinerate) their combustible wastes to rid of uncollected wastes. Some times, they do so to reduce the volume of the wastes that would cause them to pay high charges for pre-collections.

Table 20: Solid waste mass burning (incineration) condition of households

Waste burning	Households	Percent
No	22	13.6
Yes	140	86.4
Total	162	100.0

As shown in Table 20, 118 households (72.8 %) burn part or all of their combustible wastes on open air as shown on plate 9. Some 44 households (27.2%) never combust any of their wastes at all.



Plate 9: Household waste burning

4.7 Waste collection

Regarding solid waste collection, households have three options. The first option is that households take their solid wastes and dispose it in to a container nearest to their home. The second option is having contract agreement with micro and small enterprise associations (pre-collectors) to take their wastes to the container. The third option is that the municipality has assigned two trucks and households can collect their wastes in to these trucks. All the three options are available at centers and main roads; the peripheries dispose their wastes at ditches and riverbanks.

From Table21, it can be seen that most households prefer the first option. This is because it has no collection cost or less cost that most households especially low income families prefer. Some middle and most high-income households prefer the second option (pre-collectors), and this accounted for 52 (32.1 %).

From the surveyed households door-to-door collection (municipality) covers only 11 (6.8 %) of the participated families.

Table 21: Waste pre-collection from households

Pre-collectors	Households	Percent
Households themselves	99	61.1
Micro and small enterprise (MSE)	52	32.1
Town administration (municipality)	11	6.8
Total	162	100.0

Solid waste collection in Adama town is being conducted in three ways:

1. Door – to- Door collection: - Two trucks of capacities 7m³ and 5m³ (manual loading) type are assigned to collect street sweepings and wastes from households. Due to limited capacity this method of collection can not touch all corners of the town, it mainly focuses on at center kebeles and congested areas. To cover large areas the municipality uses shift round. The trucks collect wastes and transport to the disposal site, in doing so a truck is expected to cover four trips a day. However, due to technical and other constraints these two trucks cover less than eight trips a day. Plate 10 shows when a truck collecting street sweeper and plate11 when a multi-loader picking a container from a storage site.



Plate 10: door- to- door waste collection, 2007

2. The second and third types are container systems; there are 24 containers of capacity 7m^3 and 8m^3 distributed at different areas. Some of these containers (17) are cited at different kebeles to serve households and any residents. The other 7 are distributed to public firms like hospital, university, bus station etc. To collect and dispose wastes from these containers two multi – loader trucks of capacity 7m^3 and 8m^3 are assigned. A truck is intended to cover 8 trips in a day, again due to technical and others it covers less than this.



Plate 11: Block and container collection system, 2007

Waste transportation from the town to the disposal site is done by these 4 trucks, which have maximum capacity of 168 m^3 a day. Waste collection from firms and households to containers (pre- collection) is partly done by 8 legally registered micro and small enterprises (MSE). These micros have different material capacity and manpower. Most of them have wheelbarrows (hand pushed carts) some of them have horse drawn carts. They are serving more than 2000 households and organizations. They have more than 150 youth workers.

Responsible body for the solid waste management of the town is a section organized under the municipality called ‘Health and Environmental Sanitation Section’ the section has limited manpower and lacking relevant professionals.

Road access to containers

Due to its fast growth in economic activities and constructions, Adama has better inner and main roads. Recent construction activities of all type roads made all kebeles to have

access to main roads and other services. From Table 22, most of the households, 146 (90.1%) have access to communal solid waste containers. Only 15 HHs (9.3 %) indicated that they do not have access to nearby container.

Table 22: Accessibility to containers

Accessible	Households	Percent
Yes	146	90.1
No	15	9.3
No response	1	.6
Total	162	100.0

Distance from containers

Regarding distances that a container apart from their houses, most of the households are far away from the containers (Table 23). Only 35 households (21.6 %) are within the radius of 100 meters, 43 (26.5 %) are found in between 100-200 meters. The rest 53 (32.7 %) of the households have to move more than 500 meters to reach the container. Even there are families 11 (6.8 %) who do not know where the container is cited.

Table 23: Distances of containers from households

Distance	Households	Percent
< 100 meters	35	21.6
100_ 200 meters	43	26.5
201_500 meters	20	12.4
> 500 meters	53	32.7
No response	11	6.8
Total	162	100.0

According to some surveys, estimation a household should get a container within 200 meters of his vicinity (Yami, 1999), and one container provides services to a maximum of 2000 people. Based on this estimation only 78 (48.1 %) of the households are found within the service area of the container. From personal observation, some households are far away (more than 2km) from any nearby container. Some kebeles do not have containers at all.

5. CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

The study showed that the household solid waste generation rate of Adama town is 0.15 kg/cap/day or an average of 0.77 kg/HH/day. For the total population 35.2 tones, domestic solid waste is generated from the town in a day. This does not include other municipal solid waste streams. To have a complete picture on generation rate similar studies should be conducted on the other waste streams.

Wastes generated from different sources are indiscriminately collected and disposed off. Uncollected wastes are being illegally disposed at ditches and riverbanks. Plastic wastes now days are becoming a challenge for any country particularly developing countries, where mitigation methods are not well exercised. In Adama plastic wastes too are polluting the environment by blocking drainages attached or stitched to fences, trees and buildings creating material damages and aesthetic loss. Especially around waste disposal site, wide area is being covered by this waste.

Recently the municipality improved its capacity of waste collection and transportation activities; still some parts of the town are unattended. Waste minimization techniques such as recycling, composting, energy recovery practices are limited. Some individuals recycle old tires to different useful materials, like shoes, containers and others. Few families use their food and yard wastes to soil enrichment for their gardens.

Waste collection system of the municipality is weak. Particularly door –to- door collection is inefficient. The trucks assigned to this purpose are old ones. The coverage is also very limited. Regarding the container system, trucks are relatively efficient (one new and one old multi loaders). But sometimes containers are transported to disposal site half filled to remove bad smell and avoid flies breeding at the storage site. This reduces the efficiency of the trucks.

Moreover, the peripheries are not given due attention. Due to lack of containers nearby their home or no door –to-door waste collection services, they dispose of wastes at open areas, ditches or riverbanks. The study also showed that household waste particularly food and yard wastes contain high amounts of moisture. If it is made to air-dried its weight and volume will be reduced to less than half of its initial weight.

From the survey result large proportion of the waste (more than 60%) is decomposable organic matter, which could help to reduce disposable waste by compost formation. In addition to this, household wastes have high heat energy (calorific value) and less amount of ash generation. This again indicates that energy can be recovered from wastes under proper control of emission to avoid air pollution.

5.2 Recommendations

As mentioned earlier, waste collection system of the municipality is weak. To improve this municipality has to:

- ✱ Capacitate ‘Health and Environmental Sanitation Section’, the responsible body to manage municipal wastes of the town, with relevant manpower and equipment both qualitatively and quantitatively. Most of the vehicles assigned to waste collection and disposal are old ones, which could not cover the planned target. Especially door-to-door collection trucks need regular servicing and are not convenient to collect and dispose wastes.
- ✱ Increase waste storage sites (containers). In Adama some households travel more than 2km to find a container. Therefore the municipality should increase number of containers and distribute at a distances reasonable from households or firms, boarder kebeles should be given proper attention.
- ✱ Incite and motivate workers. Waste management particularly for workers who have direct contact with the waste, it has a health risk and socially given low status. Hence, the municipality has to equip these workers with proper personal protective devices and arrange some kinds of incentives to increase their efficiency and responsiveness.

* Increase public awareness. Waste disposed of illegally at any open spaces are not only because of lack of nearby containers or lack of municipal waste collection services but also due to lack of awareness of the consequences of mismanaged municipal wastes. Since solid wastes are generated by the entire population by all segments of society, any solution to the problem of solid wastes must arise from and be supported by that same population. Hence, the municipality has to raise their awareness and encourage their participation in solid waste management activities.

From this study results large proportion of the generated wastes is either compostable or recyclable or energy can be reclaimed from it. Therefore, the municipality has to reduce a waste that goes to disposal site through:

* Composting wastes. From the study, 60.5% of the wastes are easily decomposable organic matter, indicating large potential for compost formation. But only limited households use food wastes for their garden growing. Hence, by mobilizing the community and NGOs in the town it is possible to generate huge amount of compost, which enriches the soil for urban agriculture and creates job opportunity for many youth job seekers.

* Waste reuse and recycling. Some items can be reused again and again for the same purpose, or after worn out can be collected and processed again to produce new product (recycled). In Adama these activities specially recycling is not exercised. The only reuse/ recycled being practiced in Adama is cutting and reshaping of old tires for different useful items. In the same way other waste materials like plastic wastes can be recycled and the municipality has to explore means of waste recycling.

* Energy recovery. From laboratory analysis, some wastes such as wood, textile, yard wastes and food wastes have high heat energy. Hence, those wastes can generate energy as a fuel if properly sorted, controlled and air-dried.

Energy can be extracted from the waste by direct using as firewood after drying it. Bio-gas formation is another way of energy recovery that the municipality might consider as an option of waste management.

As can be observed from laboratory results these wastes generate less amounts of ash on combustion. This increases the lifetime of disposal site and save resources.

Currently prevailing challenges of any developing country is the problem of plastic wastes. Adama is also facing this challenge. Particularly waste disposal site and its surrounding is being covered by this waste.

The municipality has to take measures to minimize the effects of this problem, through:

- ◆ Allocate budget to collect and dispose (bury) in a separated area or recycle the already disseminated plastic wastes from the disposal site.
- ◆ Arranging special plastic waste collection method and recycling mechanisms or separate and controllable disposal method, for the future
- ◆ Encouraging local solid waste (Plastic waste) reuse and recycling practices and innovations.

In general, if the town administration improves its effort on municipal waste management system and gives equal attention to all corners of the town, it is not far future to see the vision of the administration 'Green and Clean Adama'.

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Annexe 1: Questionnaire for socioeconomic data collection

1. Householder's name _____ house no. _____
sex _____ age _____ education _____, family size male _____,
female _____ total _____ family's income _____.
2. Ownership of the house: private _____, kebele _____ . Agency _____ ,
individual's _____ , other _____ , No. of rooms
_____ .
3. Kitchen facility No _____ , traditional _____ , modern _____
private _____ , shared _____ .
4. Source of energy: A. Electricity _____
B. Charcoal, Kerosene _____
C. Charcoal, wood, paper, dung _____
D. Wood, dung, yard trimmings _____
5. Tap water facility No _____ , Yes _____
Private _____ , shared _____ , public _____
6. Toilet facility No _____ , Yes _____
Private _____ , shared _____ , public _____
Dry pit _____ , water flushed _____
7. Do you have contractual agreement with 'micros' (MSE) who collect and
transport wastes to containers? Yes _____ , No _____ . If yes, how much
do you pay them monthly? _____
8. Is the existing waste management of the municipality satisfactory? Yes _____
, No _____ .
If no. what measures should be taken to improve?

9. Whom do you expect to cover the expenses of the improvement? Public
_____, government _____ , NGO _____ , others _____ .
10. Do you have temporary solid waste storage in your home? Yes _____ No _____
If yes what kind of storage? _____

11. Do you reuse household wastes? Yes _____ No _____
 If yes what kinds of wastes? _____
12. Do you use household wastes for fuel? Yes _____ No _____
 If yes, which wastes? _____
13. Do you use wastes as soil fertilizer? Yes _____ No _____
 If yes, which type of wastes? _____
14. Did you sell household wastes? Yes _____ No _____
 If yes, what types of wastes? _____
 To whom did you sell or changed?

15. Do you burn solid wastes? Yes _____ No _____
 What kinds of wastes do you burn? _____
 Have you arranged a place for waste burning? Yes _____ No _____
16. Is there accessible road to the nearest container? Yes _____ No _____
17. How far is the container from your home? _____
18. What means do you use to transport wastes?
 A. By hands (ourselves) _____
 B. Hand pushed carts (kurkur) _____
 C. Horse drawn carts _____
 D. Others, specify _____
19. Is there any body who monitors that waste is properly collected and transported to the disposal site? Yes _____ No _____
 If yes, who? _____
20. What actions do they take on persons who improperly dispose wastes?

21. What types of wastes are common in:
 Rainy season? _____
 Dry season? _____

Annex 2: Data sheet for composition (weight and volume record)

Category	Day																			
			1		2		3		4		5		6		7		8		Av.	
			W	V	W	V	W	V	W	V	W	V	W	V	W	V	W	V	W	V
Food waste	Total																			
	50 mm	Ab																		
		Be																		
	10mm	Ab																		
Be																				
Paper	Total																			
	50mm	Ab																		
		Be																		
Textiles	Total																			
	50mm	Ab																		
		Be																		
	10mm	Ab																		
Be																				
Plastics	Total																			
	50mm	Ab																		
		Be																		
	10mm	Ab																		
Be																				
Cardboard	Total																			
	50mm	Ab																		
		Be																		
	10mm	Ab																		
Be																				
Yard waste	Total																			
	50mm	Ab																		
		Be																		
	10mm	Ab																		
Be																				
Wood	Total																			
	50mm	Ab																		
10mm		Ab																		
		Be																		
		Ab																		
		Be																		

Not: - Ab= Above
 Be= Below
 W=Weight
 V= Volume

Category	Day																			
			1		2		3		4		5		6		7		8		Av.	
			W	V	W	V	W	V	W	V	W	V	W	V	W	V	W	V	W	V
Leather	Total																			
	50 mm	Ab																		
		Be																		
	10mm	Ab																		
Be																				
Rubber	Total																			
	50mm	Ab																		
		Be																		
	10mm	Ab																		
Be																				
Misc. organic	Total																			
	50mm	Ab																		
		Be																		
Metals	Total																			
	50mm	Ab																		
		Be																		
	10mm	Ab																		
		Be																		
Glasses	Total																			
	50mm	Ab																		
10mm		Ab																		
	Ash dirty	Total																		
50mm		Ab																		
	10mm	Ab																		
		Be																		
		Ab																		
		Be																		