

Characterization of Municipal Solid Waste and its Management Practice
and Comparative Analysis on Vermicomposting and Windrow Com-
posting system, The Case of Adama Town: Ethiopia



Yomi Degu Gurmessa

A Thesis Submitted to

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School of Civil & Architecture Engineering

Presented in Partial Fulfillment of the Requirement for the Degree of Master 's in
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Adama, Ethiopia

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Declaration

I hereby declare that this Master Thesis entitled “Characterization of Municipal Solid Waste and its Management Practice and Comparative Analysis on Vermicomposting and Windrow Composting system: Case of Adama Town: Ethiopia” is my original work. That is, it has not been submitted for the award of any academic degree, diploma, or certificate in any other university. All sources of materials that are used for this thesis have been duly acknowledged through citation. It is being submitted for the partial fulfillment of the award of the degree of Master of Science in Water Supply and Environmental Engineering at Adama Science and Technology University School of Civil & Architecture Engineering

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Abstract

Solid waste management is an important to provide hygienic, efficient, and economic solid waste storage, collection, transportation, and treatment or disposal of waste without polluting the atmosphere, soil, or water system. Furthermore, total municipal solid waste generated in developing country by 2012 is expected to be double by. The current Solid waste management system in Adama city is a very poor lack of coordination among stake-holders, insufficient communal containers, an inadequate number of vehicles deployed, and unavailability of a performance measurement system in the entire SWM chain. Therefore, characterization and quantifications of municipal solid waste play a pivotal role in formulating effective waste management policies for Adama city. This study aimed to assess the quantity, composition and generation rate of household solid waste of the study area applies vermicomposting and natural composting methods to manage a biodegradable solid waste, and assesses municipality solid waste management practices. Results of this study showed the total average domestic solid waste generation rate of sampled households of Adama town at three group of economic level Low-income, Mid. Income and high-income were 0.1689kg/cap/day, 0.21kg/cap/day, and 0.575kg/cap/day, respectively. The average household solid waste generation rate was found 0.3183kg/cap/ day. By taking the total population of the study area in to account, the annual household solid waste generation rate of the town was estimated to be 61561.542tons. A laboratory analysis was made for both vermicomposting and natural composting methods to compare the nutrient status; vermicomposting method has a greater amount of N, P, K, and OC contents. Vermicomposting has more nutrient quality of OC than of Conventional composting as soon as it harvested, but the convention composting has more efficiency in keeping its nutrient of OC for long period time. Natural composting has a greater C: N content. Therefore, the municipality of Adama city should adopt vermicomposting as MSW management system.

Keywords: Adama, Municipal Solid Waste, Waste Characterization, Vermicomposting

Acronyms

ASTU	Adama Science and Technology University
Av. fs	Average family size
AVK	Available Potassium
AVP	Available Phosphorus
C: N	Carbon Nitrogen Ratio
cap	Capita
CI	Commercial institute
CSA	Central statistical Agency
DI	Deionized
EPA	Environmental Protection Agency
GDP	Gross Domestic Product
GIS	Geographic Information System
HH	House hold
HHs	Households
HS-no.	House hold number
ISWM	Integrated Solid Waste Management
m.a.s.l	meters above sea level
MSW	Municipal solid waste
MSWM	Municipal Solid Waste Management
OC	Organic Carbon
PDSWGR	Per capita per day solid waste generation rate
PH	Per household
PLC	Public limited company
ppm	Part per million
Ppn.	Total population size
SES	Socioeconomic status
SPSS	Statistical Package for Social Studies
SS	Social service
SWM	Solid waste management
TN	Total Nitrogen

1. Introduction

1.1 Background of the study

Waste is an unavoidable byproduct of human activities. Economic development, urbanization, and improving living standards in cities, have led to an increase in the quantity and complexity of generated waste. Rapid growth of population and industrialization degrades the urban environment and places serious stress on natural resources, which undermines the quality of the immediate surroundings, and degradation of the environment in most cities of the developing world. Municipalities of developing countries are not able to handle properly the increasing quantities of waste, which results in uncollected waste on roads and in other public places (AMENU, March 2008).

From the days of primitive society, humans and animals have used the resources of the earth to support life and dispose of waste. In the early times, the disposal of wastes by human activities and other animals did not pose a significant problem because of the small population size and large amount of land available for the assimilation of waste. Problems with the disposal of waste can be traced from the time when humans first began to gather together in tribes, villages, and communities and the accumulation of waste became a consequence of life (Hofosha, 2018).

Waste is generated in any human settlement by day-to-day human activities which include: domestic, agricultural, commercial, institutional, construction and demolition, and industrial activities. Population growth, socio-economic status, family size, varying consumption patterns, feeding practices of individuals, and families, seasons of the year, urbanization and industrialization are some factors that influence the generation rate of waste. In all urban center huge quantities of wastes are generated by humans. The problems that related to wastes are intensified with gradual increase in waste generation and its poor management threatening public health and environmental pollution. Waste management is one of the major environmental and health burdens around the world today and this is more pronounced in developing countries including Ethiopia. Mode of solid waste management differs for developed and developing countries, for urban and rural areas, and for residential, industrial and commercial places (Hofosha, 2018).

Globally, solid waste management is one of the greatest environmental health challenges and continues to overwhelm local authorities and national governments as urban populations continue to rise and consumption patterns change (Rachael E Marshall 1, Khosrow Farahbakhsh, 2013).

The management of solid waste in Africa is often weak due to lack of appropriate planning, inadequate governance, poor technology, weak enforcement of existing legislation and the lack of economic incentives to promote environmentally sound development (Chalchisa, 2017) 125 million tons of municipal solid waste (MSW) were generated in Africa in 2012, which is expected to double by 2025. The growth in waste generation in Africa is expected to be so significant, that any decrease in waste generation in other regions globally will be overshadowed by Africa (experts and researchers from the African continent, 2018) In Ethiopia, the increase of solid waste generation is resulted from rapid urbanization and population booming. 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 (Chalchisa, 2017)

The current rate of solid waste generation is 0.252 kg /cap /day in the city of Addis Ababa ,Other cities also generate solid waste at a rate of 0.277 kg/d in Mekelle, 0.22 kg/d of Bahir Dar, 0.227kg in Debre Markos, and 0.267 in Adama town (Chalchisa, 2017).The daily SW generation rate of Sodo town for low-income, middle, and high-income HHs was 0.28kg/capita/day, 0.38kg/capita/day, and 0.76 kg/capita/day, respectively. This indicates that the waste generation rate of higher-income HHs was about 2.7 times higher than lower-income HHs (Endrias Goa and Solomon Sorsa, 2017). The total household waste generation rate of Adama town is 35.2tonnes in a day and on average, a household generates 0.77kg/HH/day (Wakjira L. A., 2018), and a per capita solid waste generation from low, middle, and high-income levels 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 (Wakjira L. A., 2018).

The composition of solid waste depends upon several factors, such as food habits, cultural traditions, and socio-economic and climatic conditions. The composition of solid waste varies not only from city to city but even within the same city itself and also seasonally (Iftekhara Enayetullah,, 2005). The composition of Solid Waste Generated Adama City is 35% food waste, Biodegradable waste 27%, Plastic waste 20%, Metals 6%, Textiles and shoes 6%, Glass and Bottles 4%, Others 2% (Kitila Alemayehu et al.,, 2021).

Solid waste collection and transport involves storage at the generation and pick-up points, pick-up by the crew, trucks driving around the neighborhood, and truck transport to a transfer station disposal point. The collection is difficult, complex, and costly. The collection of solid waste typically consumes 60-80 percent of the total solid waste budget of a community. Therefore, any improvement in the collection system can reduce overall costs significantly (Gaurav K. et al., 2014).

The municipality of Bahir Dar collects solid wastes through five waste-management companies, known as micro and small enterprises, along with one private limited company, called Dream Light PLC; however, according to the surveys made for this research, only 22% of the respondents were satisfied with the existing waste management services (Kassahun Tassie, Birara Endalew, 2018). This indicates the poor quality of the services, delivered by the abovementioned waste collectors. Similarly, the municipality has planned to regularly provide solid waste management services to the residents once a week through the MSEs and Dream Light PLC, while only 29% of the sample households received solid waste management services weekly. To add insult to injury, 25% of sample households never received any solid waste services. All these points indicate that there is a gap in monitoring and evaluation of waste management service provision, on one hand, and implementation of the plan, on the other. Among 350 households, 328 (93.7%) had solid waste storage receptacles, used to store solid wastes, while 22 (6.3%) did not have any. Also, 72% of them stocked up solid wastes in sacks, whereas 16.6%, 7.5%, 2%, and 1.9% of the respondents said that they used plastic containers, baskets, private pits, and metallic containers to store solid wastes in their houses, respectively. Results indicated that the majority of sample households (40%) of Bahir Dar disposed of their wastes illegally on roadsides and open fields, while 19.4% burned them, 8.9% buried them inside their compounds, and 5.1% threw them away in and around their compounds (Kassahun Tassie, Birara Endalew, 2018)

Solid waste management techniques such as incineration, pyrolysis, and gasification have high investment costs. Composting and vermicomposting of solid organic waste have been considered economically viable and sustainable waste management technologies. However, wastes often contain pollutants, such as heavy metals that are toxic to decomposer micro-organisms (Fatimah Alshehria, Fuad Ameenb, 2021). Vermicomposting is regarded as a clean, sustainable, and zero-waste approach to managing organic wastes but there are still some constraints in the

popularization of vermicomposting. Instead of increasing research in the field of vermicomposting, the practical application of vermicomposting needs more attention (Kavita Sharma PHD, V.K. Garg PHD, 2017). The various earthworm species such as red worms, tiger worms, and red wigglers are responsible for consuming organic waste such as flower waste, agricultural waste, animal waste, sewage sludge, etc. During the vermicomposting process, the digestive process of the earthworm is used as vermicompost. Under favorable temperatures $< 28^{\circ}\text{C}$, moisture content (60–80%), and suitable aerobic conditions the earthworms ingest organic waste such as vegetable waste, flower waste, kitchen waste, or industrial sludge and excrete a humus-like substance (Kunwar D.et al., 2022).

1.2. Statement of the problem

Solid waste management is an important element of environmental protection. Its purpose is to provide hygienic, efficient, and economic solid waste storage, collection, transportation, and treatment or disposal of waste without polluting the atmosphere, soil, or water system. The current Solid waste management system in Adama city is a very poor lack of coordination among stakeholders, insufficient communal containers, an inadequate number of vehicles deployed, and unavailability of a performance measurement system in the entire SWM chain. Private collectors did not serve the community properly, and regularly (Mengist Hailemariam, Assegid Ajeme, 2014). Besides, there was a lack of control by the city administration. SWM has now been a problem not only in the city but also in rural areas causing an impact on the environment and the inhabitants (Mengist Hailemariam, Assegid Ajeme, 2014). Therefore, there is a need for characterization and quantifications of municipal solid waste, because of it play an essential role in formulating effective waste management policies.

Illegal open dumping is hazardous and pollute both land and water bodies, it also can be concluded that proper management of the municipal solid waste should be practiced to minimize harmful effect on river which is also used for drinking and other domestic work by people living along the course of river (Dey, 2014). Adama city is a rapidly growing city, an increased population and infrastructures contribute a growth of municipal solid waste. Improper disposal of municipal solid waste in drainage lines and on open surface has impact on ground and surface water bodies by runoff and infiltration. In order to protect surface water and Ground water it's mandatory to assess the existing municipal waste management practice and find the gaps.

According to source from the Adama municipality the only mechanism solid waste managed is land fill, solid waste generation of the city is increasing due to urbanization and a growth of population number. Therefore, there is an increased demand of land for the disposal site, to settle down this demand it is necessary to adopt a vermicomposting for the biodegradable both at house hold level and municipal solid waste dumping site. According to (Ethiopian statistics service, 2022) an employment rate of Adama city is 27%. Therefore, Vermicomposting of Municipal solid waste will provide a job opportunity and decrease the unemployment rate beside of waste management system.

1.3 Research Questions

This study is designed to answer the following questions. Accordingly,

1. What is the per capita/day and total daily solid waste generation rate in Adama Town
2. What is the composition of the daily solid waste generated in Adama Town?
3. What is the management practice of municipal solid waste in the study Area?
4. What is the biodegradable potential of Municipal Solid Waste generated in Adama town by Vermicomposting Method?

1.4 Objectives

1.4.1 General objectives of the study

The general objective of this study is to characterize municipal solid waste and assessment of its management practice for the improvement of urban sanitation in Adama Town, Ethiopia.

1.4.2 Specific objectives of the study

1. To determine per capita/day and total daily solid waste generation rate in the study area
2. To characterize the composition of daily generated solid waste in the study area
3. To evaluate collection-to-disposal management practices, and customer satisfaction in the study Area
4. To apply earthworm species (vermicomposting) to manage biodegradable municipal solid waste

1.5. Significance of the study

This research has given some baseline information for solid waste characterizations, quantifications, management practices, and application of earthworms for accelerated decomposition. The study helps in designing a treatment plant since it shows a solid waste generation rate additionally it provides data on solid waste generation in relation to sectoral contribution. The Adama city administration will evaluate the existing customer care or service delivery satisfaction on the process of solid waste collection to the disposal stage. However, there are a little number of studies done on the study area but there is a gap in that studies have been done on a small portion of kebele and only explanatory research has been done in recent days also none of the studies conducted on using earthworm species as a decomposer to biodegradable waste. Since Adama city is a fast-growing population because city is the economic and political center of East Shewa Oromia, Ethiopia city needs to update the solid waste management system frequently.

1.6 Scopes of the study

This study spatially limited to Adama municipality particularly solid waste characterizations, quantifications, management practices, and applications, and adaptations of integrated solid waste management particularly the application of earthworms to accelerate the decomposition rate of biodegradable waste. The study Focused mainly on solid waste from households, public services centers, and commercial areas solid wastes. Furthermore, current management practices of the municipality, and applications of earthworms (vermicomposting) to accelerate the decomposition rate for better management of landfill sites. However, this study will not include quantifications and characterization of industrial solid waste in the municipality and characterization of compost quality for different applications. On the other hand, this study is limited to four consecutive months. This is due to the time given to the researcher by ASTU.

2. Literature review

2.1. Concept of solid waste

Waste is often found as a liquid or solid form (Abrhame, Assessment of Municipal Solid Waste Management Practices: A case Study of Bishoftu City Administration, 2017). Wastes are materials that are not prime products (that is products produced for the market) for which the initial user has no further use in terms of his/her purposes of production, transformation, or consumption, and of which he/she wants to dispose. Wastes may be generated during the extraction of raw materials, the processing of raw materials into intermediate and final products, the consumption of final products, and other human activities (GIRMA, 2020). Solid waste is defined as material that no longer has any value to its original owner, and which is discarded. The main constituents of solid waste, according to this author, in urban areas are organic waste (including kitchen waste and garden trimmings), paper, glass, metals, and plastics, Ash, dust, and street sweepings can also form a significant portion of the waste” (Abrhame, 2017)

2.2 Municipal solid waste

Municipal solid waste (MSW) is a term usually applied to a heterogeneous collection of wastes produced in urban areas, the nature of which varies from region to region. The characteristics and quantity of the solid waste generated in a region are not only a function of the living standard and lifestyle of the region's inhabitants but also of the abundance and type of the region's natural resources (Abrhame, Assessment of Municipal Solid Waste Management Practices: A case Study of Bishoftu City Administration, 2017). Some authors also define municipal solid waste (MSW) as material that is useless or unwanted material discarded as a result of human or animal activity (Wakjira L. A., 2018).

2.2.1 Source and Types of Municipal Solid Waste

Solid waste is classified based on its origin, risk potential, or characteristics. Based on origin, solid waste can be classified into food waste, rubbish, ashes and residues, agricultural waste, municipal service, industrial process waste, and demolition and construction waste. With regards to characteristics, it is also classified as biodegradable and non – biodegradable. In addition,

based on its risk potential, is again it can be categorized into hazardous and nonhazardous wastes (ALEMAYEHU, 2022).

Table 2.1 Source and type of municipal

Source	Typical waste generator	Types of solid wastes
Residential	single and multifamily dwellings	Food wastes, paper, cardboard, plastics, textiles, leather, yard wastes, wood, glass, metals, ashes, special wastes (e.g. bulky items,
Industrial	Light and heavy manufacturing, fabrication, construction sites, power and chemical plant	Housekeeping wastes, packaging, food wastes, construction and demolition materials, hazardous wastes, ashes, special wastes
Commercial	Stores, hotels, restaurants, markets, office buildings, etc.	Paper, cardboard, plastics, wood, food wastes, glass, metals, special wastes, hazardous wastes
Institutional	Schools, hospitals, prisons, government centers	Same as commercial
Construction and demolition	New construction sites, road repair, renovation sites, demolition of buildings	Wood, steel, concrete, dirt, etc.
Municipal services	Street cleaning, landscaping, parks, beaches, other recreational areas, water and wastewater treatment plants	Street sweepings, landscape and tree trimmings, general wastes from parks, beaches, and other recreational areas, sludge
Process	Heavy and light manufacturing, refineries, chemical plants, power plants, mineral extraction and processing	Industrial process wastes, scrap materials, off specification products, slag, tailings

Source (ALEMAYEHU, 2022)

2.3 Municipal solid waste generation rate

Waste generation refers to any or all activities of identification of materials as no longer being important and so are either thrown away or collected for disposal. Whereas Solid Waste generation rate refers to the “amount of waste disposed throughout a given period and therefore the quantification of it involves different methods: by measurement at the point of generation, through use of vehicle survey and by examination of records at the disposal facilities (Welfana, 2021)

2.3.1 Estimation of total and per capita municipal solid waste generation rate

Each country should adopt an appropriate way from the following to estimate total MSW generation according to a country’s capacity to collect data. Total MSW can be simply estimated by multiplying MSW generation per capita of selected areas by the country’s total population. This involves a collection of MSW per capita from as many areas and with as much variety as possible (at minimum, urban and rural). MSW generation for unreported areas can be estimated by multiplying reported MSW generation per capita and population and adding to the total amount of reported MSW generation from municipalities. MSW generation per capita is estimated by dividing the MSW generation of a certain area by that area’s population. When MSW collection substitutes for MSW generation, the total population associated with such MSW collection should be used instead of the total population of the demographic area, as this avoids underestimating MSW per capita. The population associated with the MSW collection service must be less than the demographic data in developing countries, where MSW collection service is lacking unless the demographic data is unreliable. Most central urban areas are covered by MSW collection services; while such coverage rates drop in suburban and rural areas. MSW generation per capita from households can be measured by sampling and weighing household waste and counting the number of occupants in households (Kosuke Kawai, Tomohiro Tasaki, 2013).

2.3.1.1 MSW Forecasting

MSWM requires accurate estimation of solid waste generation (Dyson and Chang, 2005). The amount of MSW in the future was calculated by multiplying the population in the future and the waste generation per capita

$$W(n) = \frac{[365 \times P(n) \times Pc(n)]}{1000} \dots \dots \dots \text{Equation 2.1}$$

Where $W(n)$ is the amount of waste in n year in the future (ton), $P(n)$ is the population in n year obtained from JDoS (2015), $P_c(n)$ is waste generation per capita in n year (kg/person/day) (Mahdi Ikhlayel et al., 2016).

The MSW generation is affected by several factors, such as population and population density, education or illiteracy, public awareness level, and GDP (Gross Domestic Product) per capita or income level. Such data were obtained from JDoS (2012) and statistically analyzed (Mahdi Ikhlayel et al., 2016).

$$W(n) = \alpha X_1 + \beta X_2 + \gamma X_3 + \delta X_4 \quad \dots \dots \dots \text{Equation 2.2}$$

Where α is a constant; α , β , γ , and δ are correlation coefficients; X_1 is population; X_2 is population density; X_3 is GDP per capita; X_4 is illiteracy rate.

2.4 Municipal solid waste management practices

Municipal Solid Waste Management (MSWM) is the generation, separation, collection, transfer, transport, and disposal of waste in a way that is responsive to public needs and takes into account environmental protection, sustainability, recycling, aesthetics, and the community. The ultimate objective of solid waste management is to collect, treat, and dispose of solid waste in an environmentally and socially acceptable manner. Solid waste management in Adama city began in the early 1960s. A wheelbarrow, locally called "kurikur", was used to transport the wastes to the Dejazmach Amdie neighborhood on the way to today's abattoir, which was the edge of the city by then. The work was done by the municipality in general and had no specific body to handle it [(Kitila Alemayehu et al., 2021). As practiced in many of the cities in Ethiopia, the Municipality of Adama has partly outsourced the waste management practice in the city to formally organized associations/partnerships to collect wastes from households, ditches, and streets and transport them to the transfer station. The pre-collected waste is then transferred into containers which are then collected by the municipality. Nevertheless, in the city, there are not enough containers and vehicles are very limited which are typically under maintenance or out of service for long periods (Kitila Alemayehu et al., 2021).

2.5 Integrated solid waste management

Integrated solid waste management refers to the strategic approach to sustainable management of solid wastes covering all sources and all aspects, covering generation, segregation, transfer, sorting, treatment, recovery, and disposal in an integrated manner, with an emphasis on maximizing resource use efficiency (MEMON, 2011). The EPA (2002) explains: the integrated solid waste management (ISWM) approach is a comprehensive and holistic management system that combines waste prevention and waste stream from the point of generation to final disposal; it manages the waste effectively to protect human health and the environment. ISWM also examines the current waste management system needs and then helps to select the most appropriate waste management method for a certain city or country (Mahdi Ikhlayel et al., 2016)

2.6 Domestic Solid waste generation and current management practices of the municipality

In this section, Domestic Solid waste generation and current management practices of study area is reviewed. Source of domestic solid waste generation are from households, public services centers, and commercial areas. Current management practices of study area are discussed below from secondary data.

2.6.1 Household solid waste generation

The waste generation rate survey of households' of Adama town is summarized as that Households are categorized into three groups depending on the monthly per capita income of their family members. Per capita income level and solid waste generation rates have a direct relationship. Households that have better life standards use more consumption materials than low-income households do, through which they generate higher waste (Wakjira L. A., 2018).

2.6.2 Current management practices of the municipality

Currently, all activities in the waste management chain, are conducted on the daily basis, including waste collection, waste transfer, transportation, recycling, composting, and disposal of waste.

Table 2.2 Label of income group

Descriptions	Low income	Middle income	High income
Monthly income (per capita)	<300 birr	300-600 birr	> 600 birrs
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

Source: (Wakjira L. A., 2018)

2.6.2.1 Onsite Solid Waste Handling, Storage, and Processing

On-site handling refers to the activities associated with the handling of solid wastes until placed in the containers and used for storage before collection. Handling may also be required, depending on the type of collection service, to transfer the loaded containers to the collection point and return the empty containers to the point where they are stored between collections. In Adama, about 67% of the respondents in this study are less likely to store/segregate solid wastes properly. It is therefore difficult for wastes to be handled by recyclers, decomposers, and other interested individuals for environmental protection (Kitila Alemayehu et al., 2021).

2.6.2.2 Solid Waste Disposal Practices and Management on Disposal Site

There are three main approaches for waste disposal and handling including sanitary landfills, and incinerators. However, the majority of domestic cities use open dumping sites, creating various negative impacts on the environment including on human beings. The final waste disposal site of Adama city is found in the southwest direction, 9.8 km away from the center of the city on the road to Finfinnee/Addis Ababa locally known as ‘Jogo Goaded’. However, the recommended distance for the selection of a waste disposal site is not less than 2 km from a suitable main road

and residential areas, but the current location is only 200 meters away from the main road and residential houses. Each day more than 210 tons of solid wastes are expected to be disposed of by the municipality. However, concerning the expected waste generation capacity per day 65% of solid waste in the city is properly disposed. Due to the lack of waste disposal capacity, 35% of solid waste is not disposed. Out of the 402 respondents in the study area, 138 (34%) of them have practiced dumping in municipal containers around their dwelling when both official and unofficial collectors did not empty containers in time (Kitila Alemayehu et al., 2021).

2.7 Impacts of solid waste on the urban drainage system

In most cities characterized by a developing economy, there is a great need for suitable drainage systems to help manage surface water runoff. Neighborhoods keep popping up without proper planning, and this implies, designing drainage and sewage or waste disposal systems. Drainage systems are designed to make sure that wastewater and sewage are transported neatly to disposal points, thereby keeping the environment well-drained and free of waste. In Abiergué drainage basin is situated in Yaoundé which is the administrative and political capital of Cameroon. About 60% of the households in the watershed practice unauthorized dumping. Poor waste management is of particular concern to developing countries. These wastes are found to impact seriously the ability of storm drains to evacuate rainwater and this study has revealed how much (10%) poor solid domestic waste management and other poor land use practices impact the drainage system.

2.8 Vermicomposting

Vermicomposting is derived from the Latin term 'vermis', meaning worms. It is fundamentally the consumption of organic material by earthworms, which enhances the rate of decomposition and forms a nutrient-rich and microbial-active end product, called vermicompost or worm castings (Li, September 2007).

2.8.1 Benefits of vermicompost

A. Nutrient content of vermicompost

The plant nutrient contents in vermicompost depend on the source of the raw materials and the earthworm species used for composting. A fine vermicompost is rich in macronutrients like nitrogen (N), phosphorus (P) and potash (K), and other secondary and micronutrients as well. Nutrients in vermicompost are present in readily available form and are released within a month of

application (Loitongbam et al., 2018). Nutrient content (N, P & K) is higher in vermicompost than rural composts (Loitongbam et al., 2018).

Table 2.3. NPK content of vermicompost and Rural compost

Element	Vermicompost	Rural compost
N (%)	1.68	0.50 - 1.0
P (%)	1.06	0.40 – 0.80
K (%)	1.57	0.18 – 1.2

Source: (Loitongbam et al., 2018)

B. Application of vermicompost for different crops

Mode of vermicompost application depends upon the type of crop grown in the field/nursery. It is applied in the tree basin for fruit crops. It should be added in the pot mixture for potted ornamental plants and for raising seedlings. Vermicompost should be used as a component of integrated nutrient management system for better crop production (Loitongbam et al., 2018).

C. Soil health improvement and crop productivity enhancement

Vermicompost is simply the excreta of earthworms rich in plant nutrients, plant growth hormones and humus. It is used as an important source of organic matter to the soil as well as soil amendment for sustainable agricultural production. Its application may result in soil health improvement and crop productivity enhancement because of the following reasons: Vermicompost is rich in beneficial micro flora such as N-fixers, P-solubilizers, cellulose decomposing microflora, etc. which can improve soil environment. Vermicompost contains earthworm cocoons and increases the population and activity of earthworm in the soil. It prevents nutrient losses and increases the use efficiency of chemical fertilizers. Vermicompost is free from pathogens, toxic elements, weed seeds, etc, (Loitongbam et al., 2018).

Vermicompost minimizes the incidence of pests and diseases, it enhances the decomposition of organic matter in the soil. It contains valuable vitamins, enzymes and hormones like auxins, gibberellins, etc. Superiority of vermicompost over other synthetic growth media is more pronounced in plant nurseries: It can be used as rooting medium and for establishment of saplings in nurseries. Provides excellent effect on overall plant growth, encourages the growth of new shoots/leaves and improves the quality and shelf-life of the produce (Loitongbam et al., 2018).

It improves taste, lusture and maintains the quality of the produce. Immobilized enzymes such as protease, lipase, amylase, cellulase and chitinase present in vermicompost keep on their function of biodegradation of agricultural residues in the soil so that further microbial attack It speeded up. It does not have foul Odor unlike manures and decaying organic wastes (Loitongbam et al.,, 2018).

Vermiculture is environment friendly since earthworms feed on anything that is biodegradable, vermicomposting then partially aids in the garbage disposal problems. No imported inputs required, worms are now locally available and the feeding materials are abundant in the locality as market wastes, grasses, used papers and farm wastes. It is also highly profitable, both the worms and castings are saleable (Danilo Rogayan Jr., 2019.).

2.8.2 Vermicomposting systems

Generally, there are three main vermicomposting systems on an industrial or commercial level, namely windrows, single-batch reactors and continuous flow systems (li, September 2007). Vermiculture and vermicomposting are two similar but different processes. The former is the breeding of earthworms to continually increase the number of worms in order to obtain a sustainable harvest, whereas the latter is the process by which worms are used to convert organic materials (usually wastes) into a humus-like material known as vermicompost, to process the material as quickly and efficiently as possible. Studies about the methods of earthworm cultures under artificial conditions have been conducted since the early 1970s in many regions and countries of the world (li, September 2007).

2.8.2.1 Types of Vermicomposting Systems

No matter how large or small, vermicomposting piles are contained in three basic types of systems: bins, beds and windrows (Hamilton, 2018).

Worm Bins: are completely above ground, and they come in all shapes and sizes. Being above ground makes it easy to remove worms and vermicompost from bins. The downside of bins is they can change temperature rapidly (Hamilton, 2018).

Worm beds: are long troughs dug or placed into the soil, because soil temperature stays fairly constant, beds solve the problem of worms getting too hot or too cold. Beds put worms in their

natural habitat – the earth. The problem with worm beds is digging is required to remove worms or compost (Hamilton, 2018).

Worm Windrows: are a compromise, Windrows are long mounds sitting on top of the ground. Being fairly large, windrows resist sudden temperature changes. And because they are above ground, windrows allow easy access for worm and compost removal. The main disadvantage of windrows is their size, not likely to set a worm windrow up in the kitchen (Hamilton, 2018).

2.8.2.2 Basic Environmental Requirements of Composting Worms

Water was added to the fully-fermented municipal solid waste to maintain the moisture content between 70% and 80%, and the pH value was adjusted between 6.0 and 8.0 by diluted acid or alkali. Then the waste was placed into nine numbered flowerpots. One hundred young earthworms were weighed and then placed in the waste in each of the nine flowerpots. The nine flowerpots were divided into 3 groups. Each group was maintained in a container with temperature controlled at 15°C, 20°C and 25°C. During the experiment, a layer of substrate (about 1cm) was added at 20:00 daily. All the experiments were conducted under dark conditions indoors and water was sprinkled every 7 days to maintain the desired moisture contents. The worms were weighed weekly. When the round-belt appeared on every group and worms began to lay eggs, the experiment was terminated (Hou Jicong et al., 2005.).

Maximum growth of red wiggler occurs in the temperature range 65 F to 85 F (19 C to 29 C). Composting worms can resist temperatures greater than 85 F for short periods of time, but die if exposed to high temperatures for very long. They are more tolerant of temperatures below 65 F (Hamilton, 2018).

Water is an absolute necessity for worm survival. The optimum moisture content for growth is 70 percent to 85 percent. This is a little wetter than microbial composting piles, which generally range from 50 percent to 60 percent moisture. Red wigglers can survive in completely saturated bins for short periods, but will escape when oxygen starts to run out (Hamilton, 2018).

One of the most difficult technical obstacles to solve in the production of vermicompost is drying the end product. It is necessary to reduce the initial water content of 75-80 % to about 50-55 %. Less than 45 % moisture means that the casts may become dusty and gray, which diminishes the microbial activity and changes its attractive black color. It does not recover its texture after rewetting. Generally, acceptable moisture contents range from 30 to 50 % (Aivars et al., 2017).

2.8.1 Characteristics of Vermicompost

Composting is done by earthworms in vermicomposting. There are some special species preferred for commercial production. The most important species are *Eisenia fetida*, *Eisenia Andrei*, *Dendrobaena Veneta*, *Lumbricus rubellus*, *Perionyx excavatus* and *Eudrilus eugeniae*. *Eisenia fetida* is the most preferred worm species. One of the most important reasons for this is the higher reproductive potential. Worms in this species consume food faster than other worm species. This allows faster fertilizer production. Adaptation ability is much higher than other species. Vermicompost products obtained with this worm species have higher organic matter content.

2.8.2 Comparison of Natural compost and Vermicompost

The pH values of the composting and vermicomposting kitchen waste was 7.4 and 7.23 respectively. Composting had higher pH value than vermicomposting. The lower value of pH observed during vermicomposting could be due to production of CO₂ and carbonic acid during decomposition by earth worms. It could be also attributed to high mineralization of nitrogen during vermicomposting (Kenasa Degefa et al., 2022). The organic carbon recorded during composting and vermicomposting were 3.71% and 8.5% respectively. The analysis result indicates that higher value of Organic Carbon was recorded in vermicomposting than composting method. The possible reason could be because of a longer thermophilic phase during composting that enhances the loss of carbon as CO₂ (Kenasa Degefa et al., 2022). The recorded Available Phosphorus during composting and vermicomposting were 12.35 (ppm) and 20.15(ppm) respectively. The study shows that vermicomposting had higher Olsen extracted available phosphorus content when compared to composting. This variability could be because of the effect of earth worm activity which converts insoluble phosphorus in to soluble forms (Kenasa Degefa et al., 2022). The result of Total Nitrogen observed during composting and vermicomposting were 0.60% and 1.70% respectively. Like Organic Carbon, the study found out that higher value of total nitrogen was observed during vermicomposting than conventional composting (Kenasa Degefa et al., 2022). The recorded values Carbon Nitrogen ratios of composting and vermicomposting were 20.58% and 11.56% respectively. Contrary to organic carbon and total nitrogen, higher value of C: N ratio was observed during composting when compared to vermicomposting. The lower value of C: N ratio during vermicomposting could be due to higher degradation of organic material and the loss of carbon through mineralization and respiration by earthworms (Kenasa Degefa et al., 2022)

3. Materials and Methods

3.1 Description of the study area

Adama city 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. The average altitude of the town is 1620 m.a.s.l it has a relatively flat topography. Based on the 2007 Census conducted by the Central Statistical Agency of Ethiopia (CSA), this city has a total population of 220,212. Adama city lies in sub humid tropical zone with an average annual temperature of 21°C (Wakjira L. A., 2018). Based on the 2007 Census conducted by the Central Statistical Agency the population projection made for 2022 by Adama city administration is projected to be 529,883.

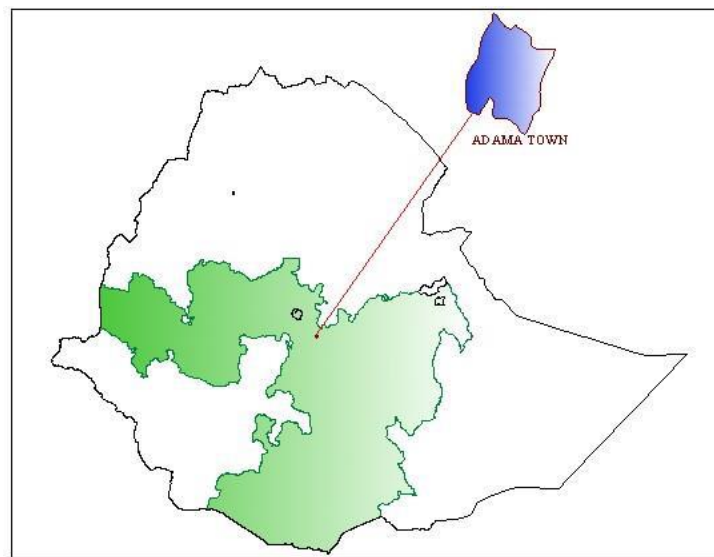


Figure 3.1 Map of study area

There are four climatic seasons, Gena/Kiremt, (rainy period) Bona/Bega, (dry period) Belg (small rains) and Meher (a spell between the long and small rains). The daily temperature varies between 5.5°C during November/December and 35°C during March to May. The mean annual ambient temperature is between 19°C and 22°C. Maximum temperatures usually occur in March to May. The mean monthly maximum exceeds 30°C. Minimum temperatures are at their lowest in November. The mean annual rainfall for the years 1995-1998 is 822.5mm. The wettest months

are July and August. The average amount of rainfall in July is 230 mm and in August 200 mm (Wakjira D. , 2021).

3.2 Research methodology

3.2.1 Research Design and General Approach

This study is an explanatory and experimental type of study because it is more appropriate to describe the existing characteristic and quantity of municipal solid waste and its management practice in the case of Adama city by direct observation and through grasping residents and official responses, opinions, and perceptions about households, characterizations and quantifications of municipal solid waste and its management practice in the study area. A vermicompost laboratory research is done with the use earth worm to produce a compost material from house hold biodegradable waste at a controlled biotic and abiotic condition.

Mixed research approaches (quantitative and qualitative approaches) are used to address the issue under study. The quantitative approach is the numerical variables of waste generation rate and compost generation rate in the use vermicompost from biodegradable waste. The qualitative approach is the information that has collected from respondents through questionnaires and interviews.

3.2.2 Data Sources and collections

Data collection is done through primary and secondary data sources. The primary data is collected from household respondents, field observation, and key informants. The study additionally conducted primary data sources from sample households solid waste, using a structured questionnaire by applying face-to-face interviews to reduce the non-response rate and incompleteness of data. The related published and unpublished materials, books, journals, several research papers, governmental publications, websites, and reports from environmental protection and healthy stations are from which the secondary data for this study was collected. Sample from households, Questionnaires, interviews and observation was used in this study to obtain an important information about characteristic and quantity of house solid waste and its management practice.

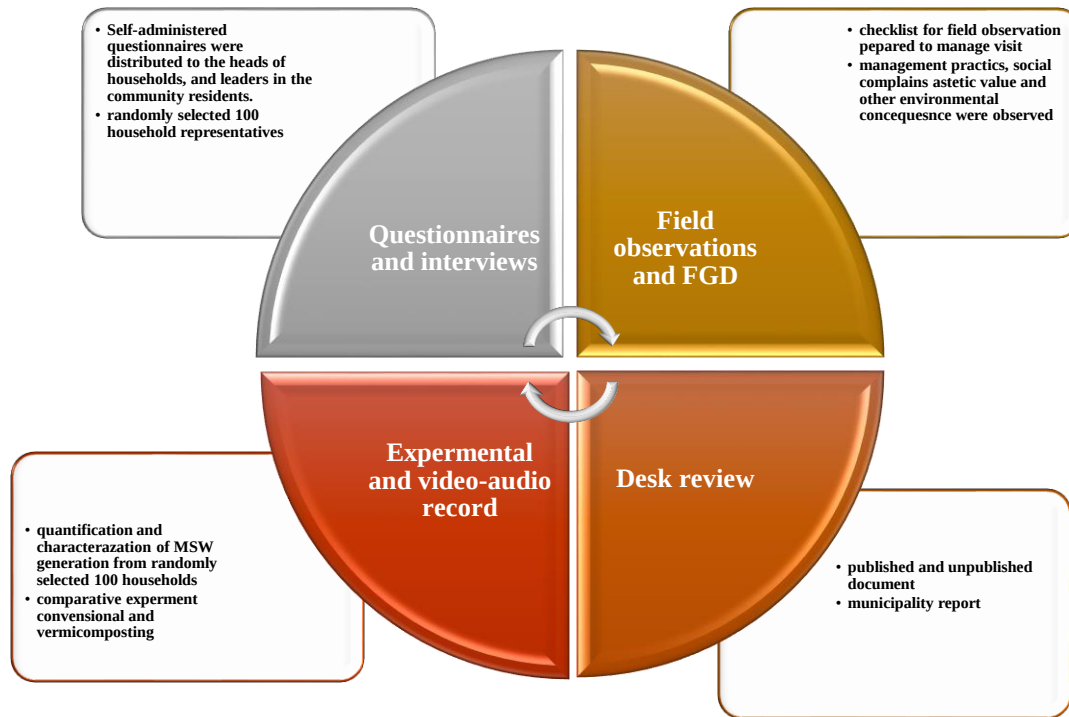


Figure 3.2 Data collection techniques

3.2.2.1 Questionnaires survey

Questionnaires are prepared for this study. Self-administered questionnaires were distributed to the heads of households, and leaders in the community residents. Also, interviews were held in case if there are issues which are not covered in the questionnaires. To get relevant information from randomly selected representatives of households, questionnaires were developed.

3.2.2.2 Field Observation

In addition to strengthening and realizing the information which is obtained from the sampled households, questionnaires, and from selected key informants using semi-structured interviews, the researcher also conducted field observation using a checklist.

3.2.2.3 Materials and Instruments

During the study time, the following listed materials was used Audio and video cameras (for recording and capturing pictures of the working process), mouth and nose masks (to protect against bad smell and inhalation of any fumes), hand protective plastic gloves (to protect hand from direct contact with dirt). Plastic sheets (to ensure no loss of waste during sorting), and plastic bags

(to collect sold wastes from sampled households, public services centers, and commercial institutes). Spring balance (for weight measurement of collected sample wastes) and trash bag (for handling materials needed to research work), shovels for waste sorting, and lorries to transfer wastes from the sample area to the waste collection site.

3.2.2.4 Sample size determination

A Simple random sampling method is applied in sampling method. The selected households were randomly in each kebele. A community based cross-sectional study was conducted on 100 households to assess the quantity, composition, and generation rate of household solid wastes produced by the randomly selected households. The selection of households was in a systematic approach that reduces the frequency of the same data due life style and living habit. The sample size of households was calculated based on total population 529,883 from Adama city administration and family size was calculated by CSA at 2007 is 3.66.

HS-no.= house hold number in the city

Ppn. = Total population size in the city

Av. fs = Average family size in the city

$$HS - no = \frac{Ppn}{Av\ fs} \dots\dots\dots \text{Equation 3.1}$$

$$HS-no=529,883/3.66 =144,777$$

Now we find the estimated number of house hold in Adama city is 144,777 which is too large to collect data from all the house hold we should have to take representative number of house hold from the total possible samples.

According to Glenn D. Israel sample size determination using published tables to calculate a sample size. Table can provide a useful guide for determining the sample size, you may need to calculate the necessary sample size for a different combination of levels of precision, confidence, and variability (Israel, 2003).

Table 3.1 Sample size determination using published tables

Population size	Sample Size (n) for Precision (e) of:			
	$\pm 3\%$	$\pm 5\%$	$\pm 7\%$	$\pm 10\%$
500	a	222	145	83
600	a	240	152	86
700	a	255	158	88
800	a	267	163	89
900	a	277	166	90
1,000	a	286	169	91
2,000	714	333	185	95
3,000	811	353	191	97
4,000	870	364	194	98
5,000	909	370	196	98
6,000	938	375	197	98
7,000	959	378	198	99
8,000	976	381	99	99
9,000	989	383	200	99
10,000	1,000	385	200	99
15,000	1,034	390	201	99
20,000	1,053	392	204	100
25,000	1,064	394	204	100
50,000	1,087	397	204	100
100,000	1,099	398	100	100
>100,000	1,111	400	204	100
a = Assumption of normal population is poor (Yamane,1967). The entire population should be sampled.				

Source: (Israel, 2003)

As it is shown in the above table of in the last row for population size of 100,000 and above it is recommended to select 100 sample size with precision of $\pm 10\%$. Since our house hold size is 144,777, the sample size for this study is 100 households with precision of $\pm 10\%$. Sampled house hold selected 6 HH from each 18 kebeles randomly

3.2.2.5 Households solid waste Data Collection Methods

Data regarding quantity, composition and generation rate of household solid wastes were collected from April 29 - June 7/2023 by administering structured questionnaires to sampled house premises called sample points, by door-to-door waste collection from the sample point (source) and by field survey observation. Data on waste composition and generation were collected per 7 days from each sampled household for consecutive 4 weeks. Each sampled household was requested to prepare a plastic bag to store the solid wastes generated per day. On the first day of data collection the existing solid waste was removed with cooperation of small enterprise working in Adama city. In the next day solid waste were stored in empty plastic bags for seven days, the measurement of solid waste was done after 7 days, 7 days were selected to have a measurable amount of waste. Every week the collected waste was stored on a plastic sheet at each household by trained waste sample collectors using human power. Finally, the collected solid wastes were sorted out physically in to their categories, weighed and recorded.

3.3 Estimation of solid waste Generation rate

Method for Estimation of solid waste generation per household, per day (PHPDSWGR) and per capita per day solid waste generation rate (PCPDSWGR) of the sampled households will be done by using Microsoft Excel 2019.

$$\text{PHPDSWGR} = \frac{\text{Total solid waste generated in four weeks}}{4\text{weeks} \times \text{Total no. of sampledhouse hold}} \dots \dots \text{Equation 3.2}$$

$$\text{PCPDSWGR} = \frac{\text{Total solid waste generated in four weeks}}{4\text{weeks} \times \text{Total family size of 100 sampled house hold}} \dots \dots \text{Equation 3.3}$$

3.4 Vermicompost's laboratory process

3.4.1 Waste Materials

The waste materials Used were bio-degradable solid waste from household waste that we collected during our data collection period. The wastes were Injera, Grass, Potato layer, and onion layer. These wastes were stored separately in a laboratory room for 15 days for a pre-decomposition process with water wash in case the sample had a harmful property to the warms.

All the wastes were weighed separately. The biodegradable waste feed was used as table below with the same amount for both natural composting and vermicomposting to examine decomposition rate, harvesting, and application time for compost and nutrient variations between conventional and vermicomposting.

Table 3.2. Worm feed and windrow composting

No.	Waste	Weight (kg)
1	Injera	24.34
2	Pilled potato	5.365
3	Grass	8.575
4	Pilled onion	5.7
5	Warm and warm feed	5
6	Total	48.98
1	Water	12liter

Each amount of feed was supplied for both Worm composting and windrow composting because the nutrient (NPK) result depends on the material content.

3.4.2 Source of Earthworm

The earthworms were obtained from a commercial source in Adama city the species used was Epigenic (red wigglers). This one is the most commonly used and best for municipal organic waste because it lives on the surface, tends to move horizontally through the soil, does not create burrows, and feeds on surface litter. All of those characteristics are important because the worms need to eat food that is near the surface (Hamilton, 2018).

3.4.3 Physical and chemical analyses

3.4.3.1 Moisture content, Analysis of pH and electrical conductivity

The moisture content of waste materials and vermicomposting were calculated using the formula as Described by Suthar (2007):

$$\text{Moisture content} = \frac{(\text{wet weight} - \text{Dry Weight})}{\text{Wet weight}} \times 100\% \dots \dots \dots \text{Equation 3.4}$$

The dry weight of vermicomposting and waste was determined by placing a sample in an oven for 16hrs at 80°C using Genlab Mino/50/F/DIG Laboratory Oven.



Figure 3.3. Moisture content lab. test

The pH and electrical conductivity of wastes and vermicomposting were measured in a dish using 180g of compost sample and 50 ml of deionized (DI) water. Both PH and electrical conductivity were measured using one sample.



Figure 3.4. Analysis of ph and electrical conductivity

3.6.4.3 Nutrient status of Natural composted and vermicompost

Composting and vermicomposting were processed that generate Natural compost and vermicomposting by biodegrading organic wastes by microorganisms and earthworms, respectively. The study was conducted and sample data were collected in ASTU at the Water Resource and Environmental Engineering Department Building in a laboratory room given for this thesis. The composted and vermicompost organic wastes were prepared and analyzed at the Melkassa Agricultural Research Center using laboratory procedures.

3.6.4.4 Compost collection

Production of compost from Municipal solid waste results was collected after 65 days with a total amount of 8.73kg of compost material with different material content and different material sizes.

3.6.4.5 Compost screening

A) 4.75mm grain size of 2.15kg of compost material was collected using a screening sieve of 4.75mm sieve.

B) 2.6mm grain size 1.93kg of compost material was collected using a screening sieve of 2.6mm sieve.

C) The third type of grain size of compost material is fine material which can pass through the sieve screen size of 2.6mm screener which is the largest amount weighed 4.65kg.

The separation of compost using based on grain size was made by manual separation method the compost material was collected in a sieve shown below and Shake until a separated size of material is gained.



Figure 3.5. Screening sieve

3.5.4.5 Warm wash and counting

A warm wash was done to separate compost material and biodegradable waste which is not processed by the worm. Additionally to count the reproduction rate or newly born worms during 65 days of composting process, in the beginning of the laboratory process the worm number was 140 at June 9 2023 during the final day of warm harvesting the number was found 182 on August 14 2023. It has found that there are 42 additional worms in worm bed, it's expected that there will be more worms because of a newly born worms are not accessible to collect and counting.



Figure 3.6. Warm wash and counting

3.6 Ethical consideration

An official letter will be written to the Adama municipality office, and other administrative and concerned bodies to communicate about the research and to gather required data.

4. Results and Discussions

4.1 Socioeconomic status (SES) of sampled households

4.1.1 Economic status of head of sampled households

Individuals with different income levels participate in society differently. Income is important to feed the family properly, for clothing and schooling, to be diagnosed when sick, and for having access to credit.

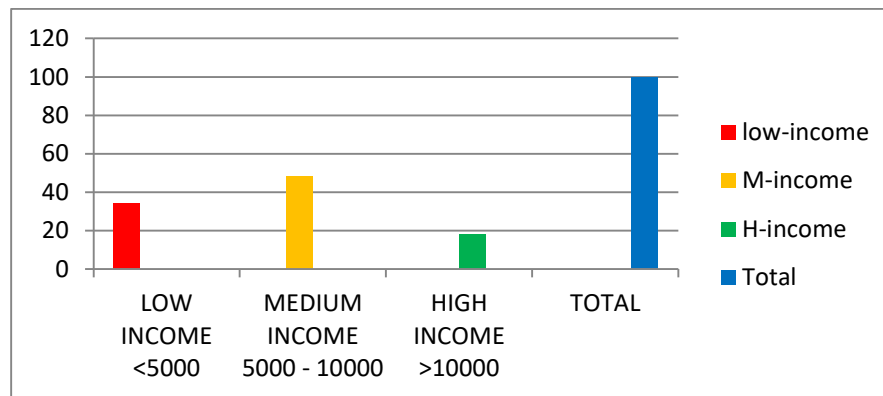


Figure 4.1. Graphical representation of income group

In the study area, the head of sampled households were labeled in to three economic levels based on their monthly income they earn. As shown above in the table of Economic status of head of sampled households 18, 48 and 34 of sampled households were assigned as high-, middle- and low-income levels respectively. Classification of economic level has done based on Adama city administration standards ranges of income level.

4.1.2 Educational status of head of sampled households

Education plays a major role in skill sets for acquiring jobs. It is also one of the factors that stratify people with high socio-economic status from low socio-economic status.

Table 4.1. Educational status of head of sampled households

Educational levels	Frequency	Percentage
Adult education	23	23
1 – 8	12	12
9 – 10	20	20
Diploma	16	16
Degree	18	18
Masters	11	11
Total	100	100

4.2 Generation rate of domestic solid waste in the study area

4.2.1 Total solid waste generation rate per day per household and Per capita

The total generation rate per household per day is equal to the total weight of sampled solid waste in seven days divided by the total sampled households conducted. The total domestic solid waste generation rate survey of households in the study area is estimated depending on the data collected from the sampled households. Results of quantitative data obtained from sampled residential houses through direct measurement of domestic solid waste generated were analyzed using tables, averages, ratios, and percentages as the major summarizing tools. The average household solid waste generated by the sampled households was calculated with respect to socio-economic level and a comparative analysis of average waste generation rate has been done.

Table 4.2. Solid waste generation rate per day per household and Per capita

Level	Low	Mid.	high	Total Average
Total SW/HH	198.8397	349.2503	578.1	1,334.79
No. of HH	34	48	29	100
Kg (HH) day	0.835	1.039	2.848	1.861
Kg (Cap) day	0.169	0.210	0.576	0.318

As data analysis from the above Table indicates the study area's sampled households generate an average of 1.861kg of domestic solid waste per /HH/ day and the total average domestic solid waste generation rate of the total average daily per capita solid waste generation rate is 0.3183kg/cap/ day. As previous studies made in some towns of Ethiopia shows, this study also demonstrates a direct relationship between income levels and the daily per capita solid waste generation rate. high-income groups generate more solid waste per person per day than low-income do. The average quantity of domestic solid waste generated generally by the study area's sampled households was 0.3183kg/cap/ day. When compared to a similar study conducted in Shambu town, this figure shows a significant variation. For example, Shambu Town's average daily per capita solid waste generation rate, according to (Hofosha, 2018) was 0.148 Kg/Cap/day

and the average daily per capita solid waste generation rate of Jimma town according to (Mekonnen, 2012) was 0.140kg/cap/day which is 2.1 times lesser than with our study area.

However, there is no significant difference in the figures when this study is compared to studies conducted in Addis Ababa sub-cities, Debre Berhan, and Bahir Dar towns. Addis Ababa's average daily per capita solid waste generation rate, according to (Kitila, September, 2017) was 0.229 Kg/Cap/day. The average daily per capita residual solid waste generation rate of Debre Berhan town according to (Asmamaw Abera et al., January 7, 2017) was 0.253Kg/capita/day. When compared to the living standard of the residents of the study area, relatively same solid waste generation rate of these towns is attributable to their high economic level and technological advancement.

Domestic solid waste generation rates vary depending on socioeconomic strata, family size, technological advancement, individual feeding habits, family consumption patterns, seasons of the year, and so on. According to the data analysis from Table the daily per capita residual solid waste generation rate of sampled households increases from low-income groups to high income groups ranging from 0.169kg /cap/ day to 0.576kg /cap/ day. This study also shows that, in relation to individual income, as family size increases, so does the rate of solid waste generate. Individual technological advancement also has an impact on the amount and type of domestic solid waste generated. Individuals' waste generation rates change as their lifestyles change. According to the data from the municipality office, the current total population of the town is estimated to be 529,883 by applying this figure, the study area's annual domestic solid waste generation rate is estimated to be 61561.542ton. The annual domestic solid waste generation rate of the study area has great variation in figure when compared with similar studies made in Shambu town. The annual solid waste generation rate of Shambu town according to (Hofosha, 2018) was estimated to be 4296.05 tons. which is approximately 12 times that of domestic waste generated in this study area. This difference in figure is estimated due to differences in population size, economic variation, and living standards between the two study areas.

4.3 Composition of household solid waste in the study area

In determining the composition of waste to be disposed of, representative waste samples were taken and sorted into their categories. Household solid waste composition categories of the study

area include organic waste, plastics, paper, metals, glass, and other miscellaneous wastes. Household solid waste categories, total weight, and their percentage in the study area are indicated below.

We have categorized solid wastes into four groups Bio-degradable Solid Waste, Recyclable Re-usable Solid Waste, other unidentified Solid Waste, and Hazardous Solid Waste. Bio-degradable solid waste consists food wastes and textile rubber & and leather. Recyclable re-usable solid waste consists paper, carton & packaging wastes, glass ceramic, plastics and metals wastes. Hazardous solid waste consists medical wastes, industrial chemicals, and e-waste. Others unidentified consists sand, dirt, ash, and fine particles of waste.

Table 4.3. Composition in item of household solid waste in the study area

Composition of HH solid waste	SW generated Daily/capita in kg	Percentage %
Food wastes	0.2514	78.986
others unidentified	0.0591	18.565
Plastics	0.0003	0.081
Industrial chemical	0.0036	1.13
Paper, carton & Packaging wastes	0.0023	0.736
Glass & Ceramic	0.0000	0.0021
Medical wastes	0.0006	0.196
Textile, Rubber, and leather	0.0006	0.184
E-wastes	0.0004	0.11
Total Solid composition (Capita/day)	0.3183	100

Household solid waste categories, total weight, and their percentage in the study area are indicated in table below

Table 4.4. Composition of HH SW generated Daily/capita in kg

Composition of HH solid waste	SW generated Daily/capita in kg	Percentage %
Bio-degradable Solid Waste	0.252	79.17
Recyclable Re-usable Solid Waste	0.003	0.82
others unidentified Solid Waste	0.059	18.57
Hazardous Solid waste	0.005	1.45
Total Solid composition/Week/HH	0.318	100

Household solid waste composition categories of the study area includes: Bio-degradable Solid waste, Recyclable Re-usable Solid Waste, others unidentified Solid Waste, and Hazardous Solid waste. In this respect, the percentage composition of sampled residential solid waste components generated by households was determined in relation to stratified socioeconomic strata.

As previous studies made in some towns of Ethiopia depicts; this study also illustrates that composition by mass of bio-degradable Solid waste coming from kitchens and gardens (yard wastes) primarily, comprises the largest amount of residual waste generated per household, followed by others unidentified solid waste Sand, dirt, ash, and fine particles of waste, hazardous solid waste - medical wastes, industrial chemicals, and e-waste comprises the third level, the las amount is recyclable re-usable solid waste - paper, carton & packaging wastes, glass ceramic, plastics and metals wastes this category of waste become negligible because plastic bottles, cartoon paper and metals are sold for local market before the waste is collected in temporary waste storage.

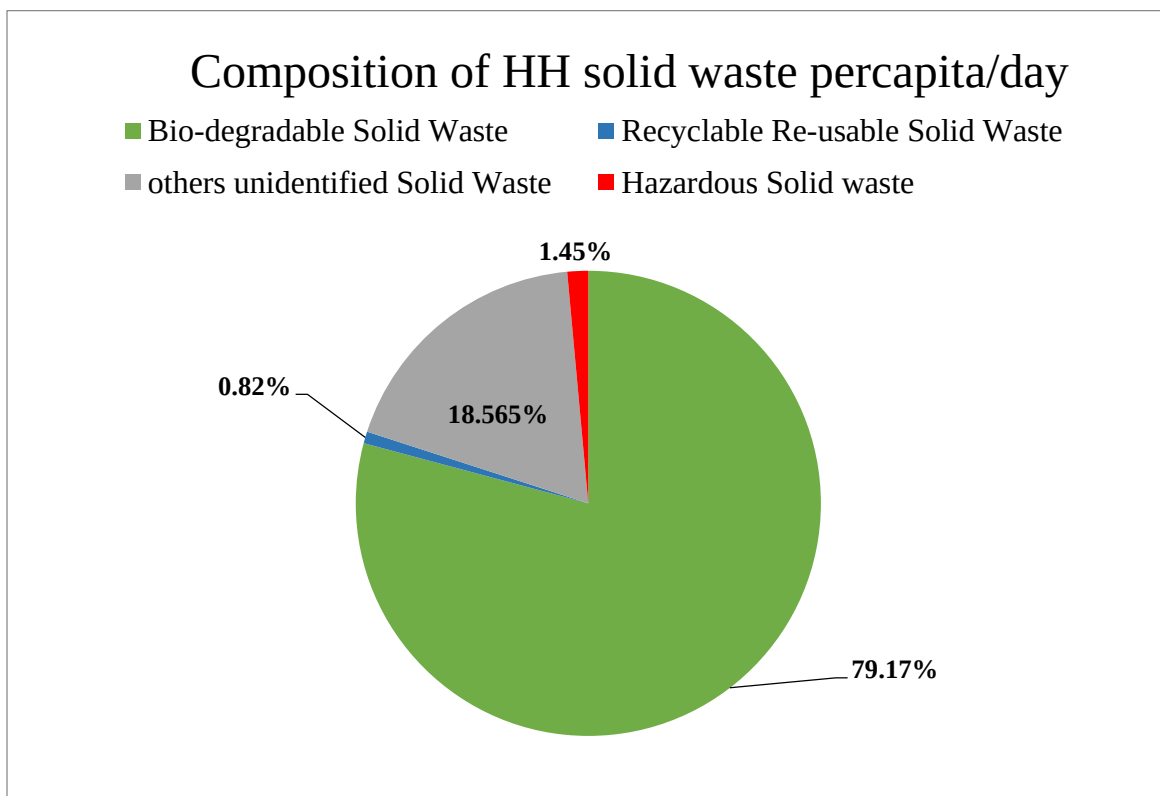


Figure 4.2. Chart representation of Composition of HH SW generated Daily by percent

In this study area, the majority of the composition of solid waste is biodegradable waste which comprises 79.17% of the total composition of the waste, followed by disposable waste which comprises 18.565%, hazardous solid waste 1.45%, and the total volume of the waste and the recyclable waste appear in negligible amount 0.82%. In this study, it is shown that the majority of the composition of solid waste is biodegradable waste which comprises 79.17% of the total composition of the waste. This is a huge opportunity to adopt a waste composting method rather than direct dumping. From components of solid waste composition; biodegradable wastes comprise about 79.17% of the total percentage of domestic solid waste generated. So, the appropriate solid waste management strategy in the study area is composting which is not completely practiced.

Data analysis from above represents that Bio-degradable Solid Waste contributed the largest component 79.17% of the total composition of solid waste generated. This is followed by others unidentified Solid Waste which comprised of 18.565 percent of waste composition. The ash and dirt proportions in unidentified Solid waste of the study area are high. Hazardous Solid Waste comprises the third order that makes up 1.45 percent of the composition of the waste stream. The last amount of waste during the survey is Recyclable Re-usable Solid Waste 0.82 percent. From the survey data analysis and visual observation on the composition of solid waste generated at the house hold level of the study area, biodegradable waste comprises 79.17 of the total components of the waste, followed by disposable waste unidentified Solid Waste that comprises 18.565 % of the total volume of the waste and the recyclable waste appear in negligible amount, 0.82 %. 1.45% percent of Hazardous Solid waste need another additional treatment before disposal.

4.4 A municipal solid waste management practice in the study area

4.4.1 General Observation of Solid Waste Management in Adama Town

This research was conducted in Adama City, Oromia regional state, Ethiopia to determine the domestic solid waste generation rates and characterize their composition in order to contribute to decision support in planning and development of municipal solid waste management systems.

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

period the sampled households were assessed for socioeconomic status, solid waste handling practices, domestic solid waste generation rate, options used to reduce the generation rate of solid wastes, and composition of household solid waste generated. 100 households were sampled during the data collection time.

4.4.2 Domestic Solid Waste Handling and Disposal Practices

In the study area, solid waste handling practice at the household level was mainly the responsibility of the mothers and daughters when compared with other family members. In total, there is no sorting of solid wastes into their categories in the sampled community members. Out of the total 100 households, 100 % of the sampled households have temporary storage materials which include: sacks, plastic bags, baskets, and cartons. There is no household without temporary storage.

Table 4.5. Solid waste handling practices of sampled households

Availability of storage material	Frequency	Percent
Available	100	100
Not available	0	0
Total	100	100

The survey analysis and visual observation of the study area show that the absence of accessibility of household solid waste collection and transfer services, absence of communal dumping containers, and inappropriate and insufficient placement of landfills, discourage the inhabitants to dispose of domestic solid wastes along the road side and water drainage systems.

4.4.4 Small and Micro enterprises

According to source from Adama city administration there are Small and Micro enterprises (SME) in three different categories which are Street sweeping, Drainage cleaning, and Door to door collection. Human resource, machinery use, and payment type are discussed in table below.

Table 4.6. A description of small and micro enterprises

No.	Enterprise Types	No. of enterprise	Human power	payment	Machinery use/enterprise	
					vehicle	Hand
1	Street sweeping	61	610	m ²		61
2	Drainage cleaning	22	220	m		22
3	Door to door collection	54	1080	HH	14	40
4	Total no. of enterprise	137	1910	-	14	123

As shown in the above table the city administration has created a temporary and regular job opportunities for 1910 persons. From all categories enterprise street sweeping and Drainage cleaning enterprises have a payment agreement with city administration. Street enterprise collects their payment accordance to the area they have clean the street, and the drainage enterprise collect their payment per a meter of a drainage line they have cleaned. Unlike these two Door to door solid waste collecting enterprise the payment agreement is done on the deal between HH members and the enterprise. The city Administration has no clue how much money is paid per HH for the Door-to-door solid waste collecting enterprises.

4.4.5 Source of solid waste in study area

According to source from Adama city administration there are four different solid waste sources, which are house hold, street, public enterprise, and industrial. The composition these sources are listed in the table below.

Table 4.7. Adama city solid waste source composition

No.	Types	Composition (%)	Source detail
1	HH	75	from household
2	street	10	Main roads, road accesses, and drainage lines medical centers, Governmental sectors, restaurants, and
3	p-services	13	commercial centers
4	Industrial	2	Industrial and Manufacturing sectors
5	Total	100	

According to the city administration has no waste source composition analysis methodology rather data is recorded (collected) at transfer site from truck drivers and waste collecting enterprise. This is not a trusted and reliable data because the data should have to be collected at the main source. Also, sometimes Industrial and Manufacturing wastes are disposed direct to the dumping site because of delay service from solid waste collecting enterprise which would be challenging to have the accurate amount from the source.

From these source HH constitutes first amount of which is 75%, and followed by p-services solid waste 13%, street waste takes the third amount 10% and Industrial solid waste has the last contribution 2%. Municipal Solid Waste (MSW) comes from residential, commercial, institutional, and industrial sources. 45% of MSW comes from the residential sources, which includes kitchen scraps, yard waste, paper and cardboards, glass bottles, plastic containers and sando bags, foils, soiled tissues and diapers, and special wastes such as containers of household cleaning agents, batteries and waste electrical and electronic equipment (WEEE) (NICCDIES, 2023). Commercial sources are second at 21% which include commercial establishments. Institutional sources which account for 12.1% of total MSW include government offices, education and medical institutions. Finally, the remaining 4.1% come from industrial and manufacturing sector (NICCDIES, 2023). The city administration has no efficient system to measure the source of waste stream, source are identified at transfer station from truck drivers and waste collecting enterprise.

4.4.6 Solid waste handling practice at transfer sites and Dumping site

According to a source from Adama city administration, there are 37 solid waste collecting transfer sites, all of the transfer sites are open landfills and have no facilities, which is the main cause of the odor, reproduction of insects, and source of communicable disease. Transfer stations generally require electricity to operate equipment, such as balers and compactors, lighting, water for facility cleaning, restrooms and drinking, and sanitary sewer systems for wastewater disposal (Green Group Studio, 2014). Additionally waste management is done only by land fill and no other waste management system is employed by the city administration. A more sustainable waste management approach prioritizes practices such as reduced production, waste classifications, reuse, recycling, and energy recovery over the common practices of landfilling, open dumps, and open incineration (Ismaila Rimi Abubakar 1,* , Khandoker M. Maniruzzaman 2, 2022)



Figure 4.3. Picture of waste containers

The city administration has 37 solid waste transfer station, nevertheless none of them has facilities in waste segregating, electrical power source to operate equipment, water for facility cleaning, restrooms and drinking, and sanitary sewer systems for wastewater disposal. Due to lack of facility transfer stations can be source of transmitted disease, water borne disease can be transmitted due to improper sanitation system.



Figure 4.4. Picture of waste at land fill site

4.4.7 Customer satisfactions on service delivery

The straightforward functioning, payment, building of client loyalty, and client retention all depend heavily on the quality of service provided to customers or clients. The survey results indicate that 58% of door-to-door solid waste collection customers have get service once a week as agreed by both parties, i.e. waste collecting enterprises and customers. 29% of customers get the service of waste collection from the enterprises within 10-30 days and the rest 13% don't have sustainable service in summer (Kiremt) month they don't get the service almost more than 2-3 months. According to the survey collected the respondents especially before and after holidays they don't get service up to 10-15 days. 58% customers respond that are strongly satisfied by the collection process. The rest of 29% are dissatisfied and shows interest to have a meeting with stake holders to solve the sustainability of the service. The 13% percent of respondent are not likely to continue any service and would like to dispose the waste by their own mechanism like Burning and dispose by labor power, which makes them highly dissatisfied on the current service delivery.

Table 4.8. Service delivery routine and satisfaction level

List no.	Frequency of respondent	Service delivery days	Satisfaction level
1	58	1/7days	Highly satisfied
2	28	1/ (10-15) days	Dissatisfied
3	19	variable	Highly dissatisfied

The service delivery in door-to-door waste collection system needs control and follow up by the city administration. The customer satisfaction level varies from household to household because due to service delivery. 58% of sampled residents are highly satisfied because the get every 7 days, however the rest 29% and 13% are dissatisfied and highly dissatisfied with the existing service and management practice. According to (Donkor, 2018) 55.8% of door-to-door solid waste collection customers have their refuse bins serviced (lifted) once a week and strongly satisfied with the lifting frequency, whiles 36.8% and 3.3% are serviced once every two weeks and once a month respectively. 4.3% are serviced twice a week which are not satisfied with the repetition of the service.

4.4.8 Community participation for enhanced MSW service

One of the significant factors, which is been emphasized today, is the role of community in waste management. Several success stories of community participation across developed and developing countries have strengthened the view of government and local bodies that they cannot work in isolation and require active participation of all the stakeholders to manage waste (Kalra, 2019). In this study it is estimated that the community potential in wealth collection, If we can collect 1birr/person/ day for solid waste management service we could have a huge amount of capital monthly and annually.

Table 4.9. Community participation for wealth collection

No.	Current Population size of in the city	Daily contribution (Birr)	Daily collection (Birr)	Monthly collection (Birr)	Yearly collection (Birr)
1	529,883	1birr	529,883birr	15,896,490birr	193,407,295birr

As it is seen to from the above table with on birr contribution from each person at city level with current population size, we could have collected 193,407,295birr capital annually. According to Adama city administration source the current annual budget for municipal solid waste management is 40,000,000birr. Therefore, the 1birr/person/day provision will generate 483.5% greater amount of money than the current city annual budget.

4.5 Physical and chemical analyses of a vermicompost

4.5.1 Temperature Measurement

A wet sample of material was examined for temperature result using dish plate as shown on an image below with a digital machine the result was taken by professional personnel using micro-processor model-1601. The result shows 16.6°C.

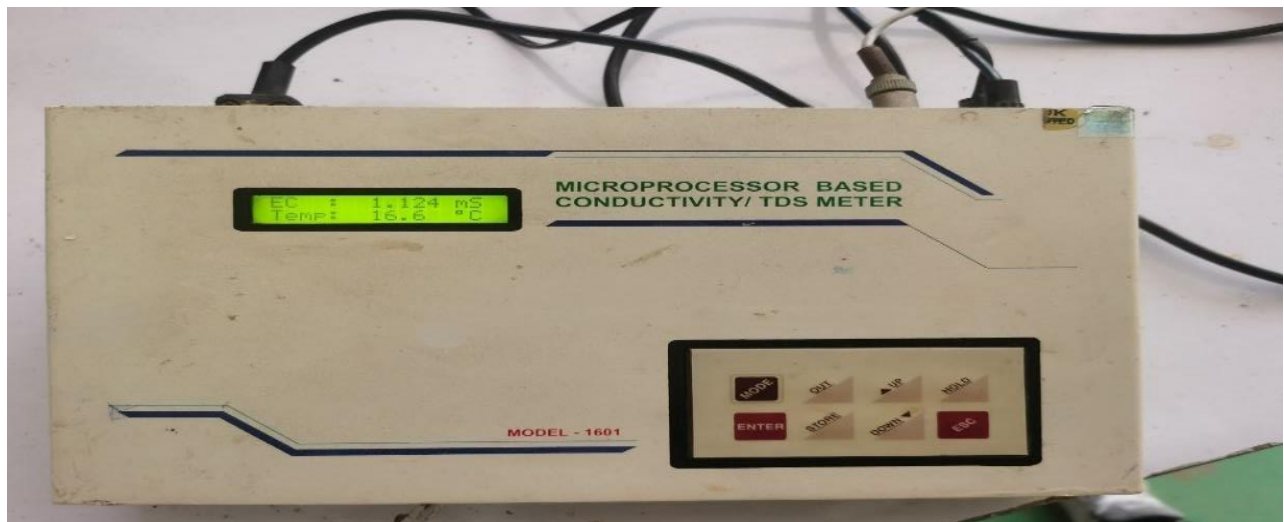


Figure 4.5. photo taken while Temperature Measurement

4.5.2 Moisture content

A 180g of compost sample were sent to laboratory to examine the moisture content of sample, A sample was placed in an oven for 16hrs at a temperature of 80°C. After 16hrs the weight of a sample was determined again the result found was 80g which means the moisture content is 50%.

4.5.3 PH and electrical conductivity

PH and Electrical conductivity of vermicomposting has been from one sample 180g of sample was used to determine electrical conductivity and PH, 50 ml of deionized (DI) water also used during the test. The PH of compost is 5.5 which show there is slight Acidic content, electrical conductivity of the sample is 1.124mS.

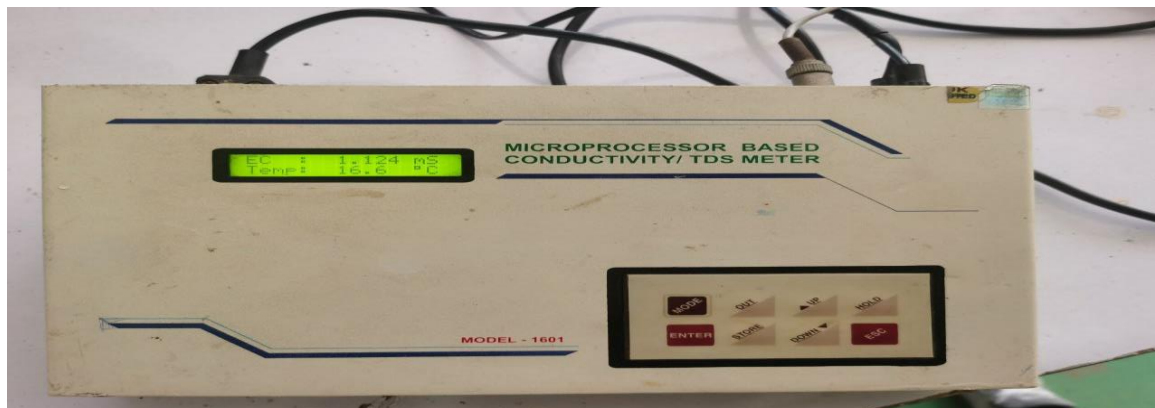


Figure 4.6. Moisture content, PH and electrical conductivity test result

4.5.4 Worm feed routine

The first kitchen waste was sorted with layer in pre-prepared bath sink Injera, pilled potato, grass, and pilled onion of a total with a total weight of 8.63kg on June/9/2023 for 14 days for pre sedimentation sprinkling of 8liters water to maintain moisture content of the waste. After 14 days waste completely loss smell and develops a uniform look On June/24/2023 the second round of feeding was done with injera, Pilled potato, Grass and leaves, and Warm and warm feed with the total weight of 15.25kg during this feeding warm and warm feed was stored directly in the pre sedimented waste while the rest of waste was stored at broadside array to give the second-round feed waste pre sedimentation period at this stage the moisture content was enough wet. After 15 days the moisture turns to lose and starts to have grey color after detecting moisture content physically a 3.5 liters water where July/9/2023 sprinkled to provide the moisture content. After wards of July/9/2023 waste starts to develop brown color and attractive view which shows

the composting result starts also worms start to move inside waste from first round sorted to the secondly sorted waste. At July/20/2023 for the third round additionally 3liters of water were sprinkled and results more moisture to the compost, at same day dry mater of garden waste 3kg to ensure the moisture level not be beyond the optimum level. For 8 days no any other food was given to the worms, with in these 8 days worms food consumption was increased comparing to the previous rounds which shows the newly borne worms start to consume foods. On July/28/2023 for the final round sorted food was feed for the worms feed was contain onion and injera, grass, and onion with the total weight of 22.1kg during this round mass food was high comparatively from all three round because of it has observed there was an increment in worms' number. On August 14/2023 compost harvesting was done.

4.5.5 Change in volume waste to compost and Odor emission

From the beginning of worm bedding to the final warm washing and collecting a total volume of biodegradable municipal solid waste which feed to the worm was 0.4m³ On the final day of compost screening which means after 50 days a volume was reduced to 0.1 m³ which shows 75% of a volume was lost. The same volume of biodegradable waste is adopted for Natural composting; however the change in volume was lesser than the vermicomposting method. From total amount of 0.4m³ of solid waste only 0.14m³ of is lost by the biodegradation process.

Table 4.10. Change in volume waste to compost

Type	vermicomposting (volume)	Natural compost (volume)
Day-1	0.4m ³	0.4m ³
Day-50	0.1m ³	0.26m ³

During the laboratory process it was observed that natural compost has bad odor than of the vermicompost. A total weight of 48.98kg of biodegradable waste were supplied for both types composting, however the result was overviewed on two conditions which are Change in volume waste to compost and compost nutrient quality. Change in volume from the total amount of raw biodegradable waste to compost material in meter cube which was 0.4m³ but after composting processed is finalized the reduction in volume were observed that 35% of volume reduction in the natural(conventional) composting which is 0.14m³ amount only is reduced the rest of 0.26m³

is still left, in vermicomposting method 75% of volume reduced which is 0.3m³ only 0.1m³ of solid is left. According to the result shows that vermicompost has more potential to reduce waste volume, this is because the earth worms in vermicomposting method consume (feed) the biodegradable waste. Therefore, vermicomposting can be adopted to reduce a waste midden observed at dumping sites and vermicomposting can easeful the burden of city municipality that is related to huge waste dumping sites area and save the land for another service or production.

4.6 Nutrient status of Natural compost and vermicomposting

4.6.1 Organic Carbon

In a vermicomposting process several physical, chemical and biological reactions take place due to the existence of earth worms, thereby resulting changes in organic carbon matter in certain period of time is resulted.

Table 4.11. Organic carbon content in vermicomposting and natural compost

Method	Time of days				Avg. OC %
	0	30	60	90	
Vermicomposting	26.57	21.86	16.94	9.85	18.8
Natural compost	16.7	16.2	15.4	14.10	15.6

However, Organic carbon content of vermicompost is greater than the natural compost method but, its fast releasing or reduction of organic carbon nutrient as time after separation of compost and worm is increased. Reduction organic carbon is also observed in the natural compost but the rate of release is way better than of the vermicompost method. As shown in research done before the organic carbon content in vermicompost, It was found the organic carbon content in vermicomposting 31,36,22.6,15.1 percent (%) at 0,30,60, and 90 days respectively ,some parts of OC converted into worms biomass through the assimilation process, which consequently reduces the carbon budget of waste substrate in the compost (ANAND et al.,, 2017).

The Avg. OC nutrient content result in this study was 15.6% and 18.8% for natural (conventional) composting and vermicomposting respectively, which shows Vermicomposting has more Avg. OC nutrient content than the natural (conventional) composting. During the laboratory it was ob-

served that the organic carbon content decreases from 16.7% to 14.10% and 26.57% to 9.85% in natural (conventional) composting and vermicomposting respectively from day 0 to day 90. A study conducted by (Chhotu D. Jadia and M. H. Fulekar, 2008) shows that over the course of the composting and vermicomposting trial, the concentration of organic carbon declined from 36.27 to 13.50%. As shown above application of compost early after compost harvesting to the farming process can give the optimum amount of organic carbon to the soil.

4.6.2 Total Nitrogen

The result of Total Nitrogen observed during composting and vermicomposting were 1.93% and 2.25% respectively. Like Organic Carbon, the study found out that higher value of total nitrogen was observed during vermicomposting than conventional composting. According to (Kenasa Degefa, Misganu Tullu and Nigatu Samuel, 2022) this could be probably due to the coupled effect of earth warm activity as well as a shorter thermophilic phase making the plant availability of most the nutrients higher in vermicomposting than that of composting process.

The result of Total Nitrogen as listed in the table during composting and vermicomposting were 1.93% and 2.25% respectively, which means vermicomposting has greater content of nitrogen. According to (Kenasa Degefa et al., 2022) The increased nitrogen content in the vermicomposting is due to accumulation of mucus, nitrogenous excretory substances, growth stimulating hormones and enzyme secreted by the earth worms. The study conducted by (Tolera Abera, Tolcha Tufa, Adane Adugna, Tesfaye Midega, Hirpa Legesse and Buzayehu Tola, 2020) also shows that higher Total Nitrogen was produced from vermicompost made of various worms.

4.6.3 Carbon Nitrogen (C/N) ratio

A laboratory result indicates Carbon Nitrogen ratios of Natural compost and vermicomposting were 12.37% and 11.9% respectively. Contrary to organic carbon and total nitrogen, higher value of C: N ratio was observed during Natural composting than vermicomposting. The lower value of C: N ratio during vermicomposting could be due to higher degradation of organic material and the loss of carbon through mineralization and respiration by earthworms (Swati Pattnaik, M. Vikram Reddy, 2010).

As shown in the table below Carbon Nitrogen ratios of Natural compost and vermicomposting were 12.37% and 11.9% respectively. Contrary to organic carbon and total nitrogen, higher value

of C: N ratio was observed during Natural composting than vermicomposting. According to (Kenasa Degefa et al., 2022) the recorded values Carbon Nitrogen ratios of natural (conventional) composting and vermicomposting were 20.58% and 11.56% respectively, the lower value of C: N ratio during vermicomposting could be due to higher degradation of organic material and the loss of carbon through mineralization and respiration by earthworms.

4.6.4 Available Phosphorus

The Available Phosphorus during Natural compost and vermicomposting were 209.62 (ppm) and 215.59 (ppm) respectively. The study shows that vermicomposting had higher available phosphorus content when compared to Natural compost. (Kenasa Degefa et al., 2022) States that home and market compost had the lower available phosphorus content than vermicomposting.

The Available Phosphorus during Natural compost and vermicomposting were 209.62 (ppm) and 215.59 (ppm) respectively. The result shows that vermicomposting has more phosphorus content than natural (conventional) composting. (Rajiv K. Sinha^{1*}, Dalsukh Valani¹, Krunal Chauhan¹ and Sunita Agarwal², 2010) Study compared the benefits of vermicomposting with the conventional composting and concluded that vermicompost provided extra phosphorus (1.55-2.25 percent). High value of available phosphorus obtained was also due to high phosphate solubilizing bacteria, and actinomycetes in the vermicomposting (Govindapillai et al., 2018).

4.6.5 Available Potassium

The Available Potassium during Natural compost and vermicomposting were 313.25 (ppm) and 355.47 (ppm) respectively. The study shows that vermicomposting had higher available Potassium content when compared to Natural compost. (M. S. Islam et al., 2016) study proved that vermicompost application showed higher amount of potassium compared with conventional compost or combination of vermicompost and conventional compost, Potassium simulates early growth, increases protein production and vital for persistence and longevity.

Table 4.12. Analysis results of nutrient status of composting and vermicomposting

No.	Different nutrient status	Unit	Composting methods	
			Natural Composting	Vermicomposting
1	OC	%	15.6	18.8
2	TN	%	1.93	2.25
3	C: N	%	12.37	11.9
4	AVP	ppm	209.62	215.59
5	AVK	ppm	313.25	355.47

Note: AVP= Available Phosphorus, AVK=Available Potassium C: N= Carbon Nitrogen Ratio, OC= Organic Carbon, TN= Total Nitrogen, ppm= part per million

4.7 Environmental Advantage of Vermicomposting and Conventional Composting

In Natural compost and vermicomposting process it is observed the Natural compost has odor and bad stinky smell all the composting process, which is unlikely not observed in vermicomposting process. Due to this factor vermicomposting is more friendly with the environment and relief the specific site selection criteria and can be adoptable in social service areas.

One common concern with Natural compost is the potential for unpleasant odors. However, vermicomposting is virtually odorless when done correctly. The worms' activity helps break down the organic waste efficiently; minimizing the release of foul odors associated with traditional composting methods (Why Vermicompost is Better than Compost, 2023).

5. Conclusion and recommendation

5.1 Conclusion

From the study conducted, the total average domestic solid waste generation rate of sampled households of Adama town at three group of economic level Low-income, Mid. Income and high-income were 0.1689kg/cap/day, 0.21kg/cap/day, and 0.575kg/cap/day respectively. The total average daily per capita solid waste generation rate is 0.3183kg/cap/ day. Economic status has direct impact on the per capita/day and total daily solid waste generation rate in Adama Town, the more economic capacity is associated with more the per capita/day and total daily solid waste in the study area. For the total population of the study area, the daily, weekly monthly and yearly generation rate of domestic solid waste is estimated to be 168.662, 1180.632, 5059.853, and 61561.542 tons respectively. The study shows that, socio economic strata, family size and technological advancement affect the quantities of solid waste generated.

In this study, it is shown that the composition of household solid waste was biodegradable waste which comprises 79.17%, unidentified Solid Waste 18.565%, hazardous solid waste 1.45%, and recyclable waste appear in negligible amount 0.82%. Biodegradable waste comprises the greater value of household solid waste than total amount the other types of solid waste

The customer satisfaction on the existing municipal solid waste management system was labeled at three different degree, 58%, 29%, and 13% with highly satisfied, dissatisfied, and highly dissatisfied respectively. More than 58% of Adama city residents are satisfied with the current municipal management system, the rest 42% are dissatisfied. The city Administration has no role in providing tariff for door-to-door waste collecting enterprises, which is door opening for theft. MSW transfer sites has no facility, didn't meet the standards required for msw transfer sites, transfer sites are source of pollution. City administration has created a temporary and regular job opportunities for 1910 persons on solid waste collection

Vermicomposting has more nutrient quality of OC than of Conventional composting as soon as it harvested, but the convention composting has more efficiency in keeping its nutrient of OC for long period time. Higher value of total nitrogen was observed during vermicomposting than conventional composting. Higher value of C: N ratio was observed during Conventional than vermicomposting. The study shows that vermicomposting had higher available phosphorus content

when compared to Conventional composting. The study shows that vermicomposting had higher available Potassium content when compared to Conventional composting.

Vermicomposting has more nutrient quality than of Conventional composting, vermicomposting decrease OC nutrient as time after harvesting increase, and vermicomposting has no bad odor unlike the convention composting, it can be used in house hold.

To have a complete illustration on the solid waste management of the study area similar studies should have to be conducted to update and modify the data and information regarding the existing management practice and future plans.

5.2 Recommendation

The following points are recommended for the improvement of the services and for the efficient solid waste management:

- Awareness for reduction of per/capita solid waste generation should be given, since the total solid waste generation is mainly dependent on per/capita generation.
- A vermicomposting should adopt at municipal level because of 79.17% the composition of msw of Adama city is biodegradable, vermicompost minimize landfill size, and creates job opportunity.
- Investing in composting and recycling facilities: Composting and recycling are two high-priority areas for innovation and investment. Both initiatives reduce the amount of waste going to landfill and maximize the economic benefits from the waste value chain that the city controls
- Solid waste management requires a coordinated and collective effort. Regular campaign, education and training programs should have to be given at the grass root level to create public awareness and to enhance the potential of the administrating bodies service delivery
- Establishing a waste governance structure: A regular solid waste management strategy is a clear indicator of the effectiveness of a municipal administration.
- Adopt effective Integrated solid waste management practice at city level

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