THE ROAD MAP FOR SUSTAINABLE WASTE MANAGEMENT IN THE FEDERAL DEMOCRATIC REPUBLIC OF ETHIOPIA

by

ASEGID GETACHEW YIMENU

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ABSTRACT

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Asegid Getachew Yimenu

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Supervising Professor: Dr. Md Sahadat Hossain

Solid Waste Management (SWM) is a global issue from its social, environmental, and economic aspects. Poor SWM is one of the significant causes of resource degradation, environmental pollution, and public health problems. In this study, households' solid waste generation and characterization were determined for selected cities in Ethiopia. Quantitative and qualitative study methods were applied to collect primary and secondary data to assess the household's MSW generation rate and characterize the waste type's physical composition. The households' daily MSW generation rates in Bole and Kirkos sub-cities, Addis Ababa, were found to be 0.54 and 0.26 Kg/capita/day, respectively, and the average became 0.40 Kg/capita/day. The annual MSW generation from residential households was 67,000, 51,060, 56,095, 54,000, and 789,509 tons/day for Adama, Bahir Dar, Hawassa, Jimma, and Addis Ababa, respectively. The per capita daily MSW generation rate of residential households in the five cities was between 0.36 – 0.59 with an average of 0.46 Kg/day. The national daily MSW generation for urban residential homes was estimated as 0.37 Kg/capita/day. The primary composition of the MSW in Bole and Kirkos sub-cities of Addis Ababa was 65.9% of organic followed by 9.5% of plastics, 7.7% textiles, and 6.2% paper waste. Besides, 0.7% of the fraction was found to have hazardous waste materials, including old medicines, paints, chemicals, bulbs, spray cans, and batteries. It was found that there is a significant positive correlation between household MSW generation and their monthly income ($r = 0.525$, $p < 0.01$) and expense ($r = 0.409$, $p < 0.01$). The binary logistic regression analysis was conducted for selected explanatory variables, implied sorting at the source, households MSW disposal system and respondents' profession were determinant factors of household MSW generation ($p < 0.05$).

The global municipal solid waste generation is expected to project to 3.40 billion tons by 2050 and is estimated to be tripled in developing countries. Ethiopia's municipal solid waste generation rate was 6 million tons/year in 2015 and is predicted to rise to 10 million tons/year by 2030 and 18 million tons/year by 2050. In this regard, it is important to clearly understand the trend of household solid waste generation rate in large cities of Ethiopia to address major challenges of the MSW management system and its impact on the urban environment and to set an effective management system. Therefore, this chapter aims to analyze the trend of household solid waste generation and respective service provision, significant challenges in SWM service provision, and the impact of MSW mismanagement in the urban environment. Quantitative and qualitative methods were applied to collect all relevant data from the five cities, and trend analysis was done to determine the generation rate and service provision between 2016 and 2021. Households' MSW generation was also extrapolated between 2022 and 2050. Descriptive statistics were done using SPSS version 25 to present findings with graphs. The annual household's solid waste generation increased from 52.60 – 67.90 x 10^3 tons with an average annual incremental rate of 5% in Adama city. Similarly, from 32.90 – 51.06 x 10^3 tons with an average yearly incremental rate of 5% in Bahir Dar city, from 42.20 – 56.10 x 10^3 toons with an average annual incremental rate of 6% in Hawassa city, from 37.90 – 54.00 x 10^3 ton with an average incremental yearly rate of 7% in Jimma town and from 667.00 – 789.51 x 10^3 ton with an average annual cumulative rate of 3% in Addis Ababa city. The five cities' average solid waste generation rate increased by 5% annually. Based on the projected data, the household's solid waste generation rate will be quadrupled by 2050. The city's collection capacity increased from 45 – 65%, 48 – 65%, 52 – 68%, 42 – 65% and 71 – 84% between 2016 and 2022 in Adama, Bahir Dar, Hawassa, Jima and Addis Ababa cities, respectively.

None of the cities have sanitary landfill sites constructed according to the national standard for final solid waste disposal. Besides their quality, the existing disposal sites served between 20 – 60 years and are currently forced to perform beyond their capacity. Poor public awareness, weak solid waste management service mainly due to financial constraints; poor infrastructure, equipment, and material shortage; poor governance and policy gaps were found critical challenges of the management system. All the flaws of the management system had an impact on the environment – water, land, and air as well as on public health.

The solid waste management roadmap is therefore developed to support policy-and decision-makers for future implementation of sustainable MSWM at the national level.

Keywords*: Solid waste generation rate, solid waste characterization, trend analysis, solid waste collection service, sanitary landfill, challenges of municipal solid waste management, environmental impact*

TABLE OF CONTENTS

LIST OF ACRONYMS

AASWMA	Addis Ababa Solid Waste Management Agency
BD	Bulk Density
CBOs	Community-Based Organizations
CE	Circular Economy
CSA	Central Statistical Agency
EC	European Commission
EPR	Extended Product Responsibility
ETB	Ethiopian Birr
GHGs	Green House Gases
GTP	Growth and Transformation Plan
ISWM	Integrated Solid Waste Management
MSEs	Micro- and Small-Scale Enterprises
MSWM	Municipal Solid Waste Management
NGOs	Nongovernmental Organizations
MSW	Municipal Solid Waste
SWM	Solid Waste Management
SWOT	Strength, Weakness, Opportunity, and Threat
USA	United States of America

LIST OF FIGURES

LIST OF TABLES

CHAPTER 1

INTRODUCTION

1.1 BACKGROUND

Humans generate waste in their day-to-day activities. Residential areas are one of the major sources of municipal solid waste (MSW). The global change in the production and consumption patterns of products and services as well as the emerging consumer society leads to an ever-increasing generation of MSW with more complex composition and characteristics (Sharma and Jain, 2020). The rate of MSW generation is rapidly increasing in urban areas. In the current consumer society; population growth, urbanization and economic growth are the main driving forces for an increased in MSW generation (Kaza et al., 2018, Powell et al., 2018, Sharma and Jain, 2020).

Currently, municipal solid waste management (MSWM) is a universal issue affecting every single person in the world. It is a global environmental and public health concern. The global municipal solid waste generation was 2.01 billion tons in 2016 and annual global production is expected to project to 3.40 billion tons in 2050. Though high-income countries account for 16% of the world's population, they generate about 34% of the world's MSW. Besides the quantity, the complexity and nature of municipal solid waste generated in high-income countries is rapidly changed due to technological advancements in the production system and product types as well as due to prosperity and life style of the society (Kaza et al., 2018, Powell et al., 2018, Sharma and Jain, 2020).

The urban population in developing countries are growing rapidly and two-third of the population expected to live in urban areas by 2025. At the same time, waste generation was generally found to increase at a faster rate for incremental income changes at lower income levels than at high income levels. The total quantity of waste generated in low-income countries is expected to increase by more than three times by 2050. It is estimated that MSW generation in lower income countries in Africa will double every 15 – 20 years (Kaza and Yao, 2018, Kaza et al., 2018). Regardless of high MSW generation and increasing projection of the generation rate; around 50% of urban waste in developing countries remains uncollected. Besides, the circumstances are even more complex in Africa where less than half of the solid waste generated is collected, and where 95 % of it is either haphazardly disposed at different dumping sites on the fringes of urban centers and/or empty lots scattered throughout cities (Gautam and Agrawal, 2021).

Ethiopia is one of the fastest growing countries in sub-Saharan region and the second populated country in Africa next to Nigeria. The country is one of the least urbanized (only 20%) countries in Africa. However, it is estimated that urbanization will double in the coming two decades. The annual solid waste generation rate of the country is expected to project from 6.5 million tons in 2015 to 10 million tons in 2030 and 18 million tons in 2050 (Hirpe and Yeom, 2021, Teshome, 2021).

In Ethiopia – besides the rapid population growth and urbanization – the economic growth and the associated improvement in monthly income, change in lifestyle due to modernization introduced with the impact of globalization and the change in consumption behavior of the society is expected to drive an increase in the municipal solid waste generation in the cities of Ethiopia. Regarding SWM; it is reported that 43% of the country's solid waste goes to open dumps and around 30 % of the solid waste in Addis Ababa is uncollected. Major cities of Ethiopia, including Addis Ababa and regional capital cities are challenged from improper solid waste management (Gelan, 2021, Hirpe and Yeom, 2021, Teshome, 2021). Ethiopia is one of the most populated country next to Nigeria in Africa with a total population of 120 million. (Figure 1.1)

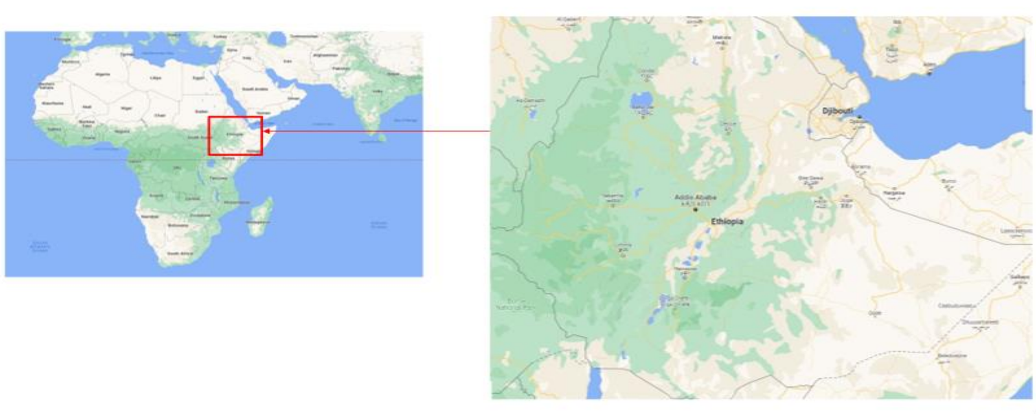

Figure 1.1: Background of the study

1.2 PROBLEM STATEMENT

SWM is one of the most persistent and critical issues across the globe, especially in cities. Due to rapid growth in the world population, planned and unplanned urbanization, economic growth and technological advancement as well as unlimited behavior of the consumer society, there is an enormous increase in the MSW generated all over the world. The type and complexity of the generated waste has also been changed in the last decades and expected to become more challenging for improved management system (Sharma and Jain, 2020).

On the other hand, the process and practice of proper solid waste management is not equally advanced with the increase in the generation rate as well as the type and complexity of the solid waste generated (Khan et al., 2021, Powell et al., 2018).The problem of SWM is more severe in developing countries and mismanagement is a big challenge to environmental protection agencies and the public health sector in African countries and is all the same in the case of Ethiopia (Hirpe and Yeom, 2021, Nigatu et al., 2011).

In Ethiopia, solid waste management is a persistent and very serious problem. The overall solid waste handling and management practices (from collection to disposal) are poor. In all cities and urban dwellings, wasting wastes in the streets, dumping in sewerage systems and water bodies (streams, rivers, lakes) and burning are common practices. Lack of infrastructures (road, waste collection vehicles, transfer and waste processing cites and technologies, landfill sites), inadequate institutional capacities and negligence of municipalities', poor implementation of policies and lack of legal frameworks, weak political commitment, weak cooperation between stakeholders, and lack of public awareness and poor engagement of the community in the management process are among the main factors contributing to the existing solid waste management problems (Hirpe and Yeom, 2021, Teshome, 2021).

Currently, cities and urban centers are progressively facing environmental, public health, climate, and social challenges associated with the contest of physical and economic development. It is very important to promote sustainable urban environmental management resilient enough to maintain the well-being of inhabitants (Powell et al., 2018, Sharma and Jain, 2020). Besides, the sustainable development goals (SDGs) cannot be met unless waste management is addressed as a priority. Economic models that treat resources as infinite will fail to address SDG 12 (ensure sustainable consumption and production pattern) and will promote consumption patterns that favor disposal (more waste) (Tripathi et al., 2022). Combining capacities, policy and strategies, implementation skills, and local knowledge is essential to identify shared solutions and to achieve well accepted and sustainable results given the seriousness of the challenges that cities in developing countries are experiencing currently. Finding effective responses to these challenges will be critical for attaining the smart, sustainable and comprehensive society foreseen in the sustainable development goals; more importantly SDG 11 (make cities and human settlements inclusive, safe, resilient and sustainable). According to SDG 15, life on land can only be healthy when the terrestrial resource is sustainably used, including waste is properly managed (UN, 2015).

Therefore, this study is designed to address the main gaps and challenges of SWM in the cities of Ethiopia and develop a road map for sustainable SWM that will be used by decision makers and relevant stakeholders for proper implementation.

1.3 RESEARCH OBJECTIVE

The main objective of the research was to assess the existing SWM in Ethiopia and develop a road map for sustainable SWM that can be used by decision-makers.

Specific and at same time interdependent tasks were addressed in order to answer the main objective of the research. Specific tasks addressed in this research include:

1. Determination of per capita solid waste generation rate and composition of solid waste generated in the cities at the household level,
2. Trend analysis on solid waste dumping and the impact of mismanagement of solid waste on urban environments,
3. Estimation of number of jobs that could be created from the SWM sector in the cities after the road map is developed,
4. Conclusion on major challenges of MSWM practices in the cities, and
5. Propose a road map on SWM for decision-makers.

1.4 DISSERTATION ORGANIZATION

The research work is organized into 8 Chapters. The first Chapter, Chapter 1, is an introduction that provides background of the research, statement of the problem and the main objective and specific tasks of the study. Chapter 2 presents a detailed review of related literatures, global to national and local practices of SWM, different approaches of SWM including ISWM and current models that integrate SWM with the concept of circular economy. Besides, policies and strategies of SWM were also reviewed in this chapter. Chapter 3 – 7 specifically present findings of each of the specific tasks designed to address the main objective of the research. Chapter 3 focuses on solid waste generation and determination of composition of solid wastes generated at the household level in the selected cities. Chapter 4 addresses the trend analysis for solid waste management practices and associated impacts from ill management of solid waste. Chapter 5 investigate the possible job creation options of the SWM system while Chapter 6 present major challenges of the MSWM practices in Ethiopia. Chapter 7 presents the SWM road map produced for decision makers. The last Chapter, Chapter 8, provides the summary and major conclusions drawn out of the overall research.

CHAPTER 2

REVIEW OF RELATED LITERATURE

2.1 INTRODUCTION

Waste generation is inevitable. Humans generate waste in their day-to-day activity. The amount, type, nature and complexity of the generated waste greatly varied based on income, life style, economic activity and consumption behavior of a given society (Kaza et al., 2018, Sharma and Jain, 2020). Quantity, type and complexity of solid waste generated in high- and middle-income countries are largely different from the solid waste generated in low-income countries like Ethiopia (Teshome, 2021).

The world generates 2.01 billion tons of municipal solid waste annually, with at least 33% of that is ill managed in a way that is not environmentally safe. Worldwide, waste generated per person per day averages 0.74 kilogram but ranges widely, from 0.11 to 4.54 kilograms (Figure 2.1). Besides ill management, the global MSW generation is estimated to project to 3.40 billion tons by 2050. In fast growing regions of the world the waste generation is expected to increase very rapidly, triple in Sub-Saharan Africa and doubled in South Asia, the Middle East, and North Africa by 2050. In these regions, more than 50% of the generated waste is currently openly dumped, and the trajectories of waste growth is expected to have vast implications for the environment, health, and prosperity, which require urgent action of governments (Kaza et al., 2018).

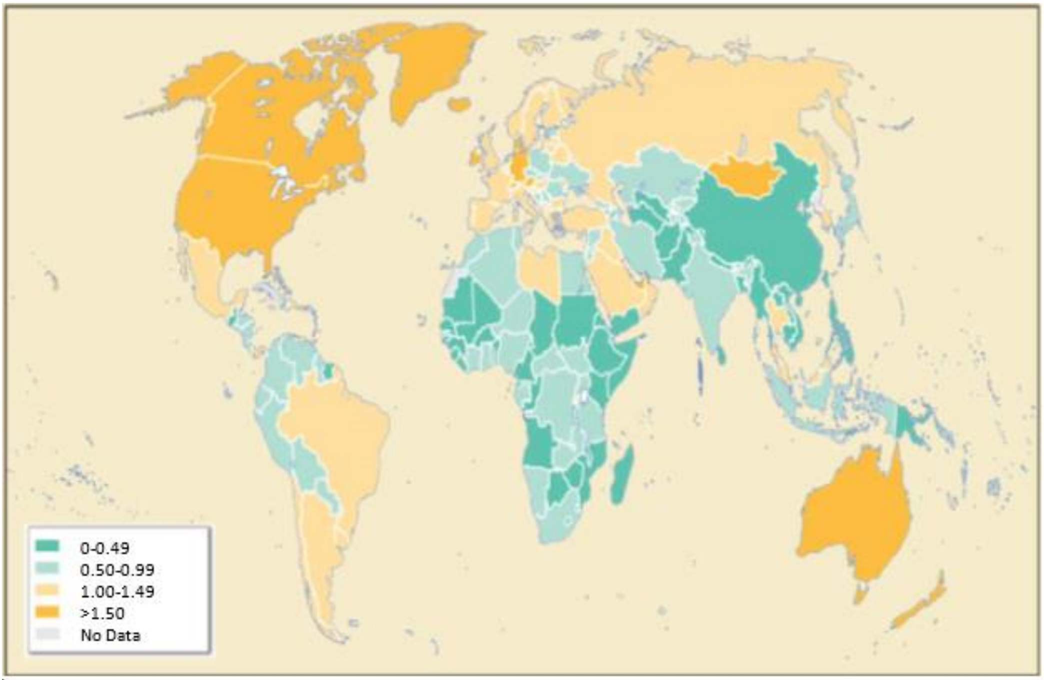

Figure 2.1: Global solid waste generation (kg/capita/day). (Source:(Kaza et al., 2018))

Global solid waste generation varied among regions. East Asia and Pacific generate 468 million tons of MSW annually and contribute to 23% of the global waste, while Sub-Sharan Africa and Middle East and North Africa generate 174 and 129 million tons of and contribute 9 and 6% to the annual global MSW generation, respectively (Table 2.1).

Table 2.1:Global contribution of regions to the annual solid waste generation and share in percentage.

No.	Region	Annual MSW generation (in millions of tons)	Share of MSW generated (by percentage)
1.	East Asia and the Pacific	468	23
2.	Europe and Central Asia	392	20
3.	South Asia	334	17
4.	North America	289	14
5.	Latin America and the Caribbean	231	11
6.	Sub-Sharan Africa	174	9
7.	Middle East and North Africa	129	6

The share of high-income countries to the global MSW generation is higher than middle- and low-income countries. High income countries account for only 16% of the world population. However, they generate around 34% of global solid waste. Upper and lower middle-income countries contribute 32 and 29%, respectively, while low-income countries contribute only 5% to the global annual solid waste generation (Kaza et al., 2018).

2.2 BACKGROUND

The economic advancement of countries from low-income to middle- and high-income levels leads to a change in waste management situations. Growth in prosperity and urbanization are linked to increases in per capita generation of municipal solid waste. Rapid urbanization and ever-increasing population growth create larger population centers all over the world and make the management system from collection to land for treatment and resource recovery as well as final disposal more difficult (Kaza et al., 2018).

The management of municipal solid waste continues to be one of the main problems in urban areas all over the world. The problem is more severe particularly in the rapidly growing cities and towns of developing countries (Addaney and Oppong, 2015, Esmaeilizadeh et al., 2020). Besides factors aggravating the solid waste management challenges like population growth, rapid urbanization and wealth; lack of public awareness, poor governance and lack of political commitment, poor infrastructures and management facilities as well as financial constraints largely contribute to the existing ill management system in the solid waste management sector (Das et al., 2019).

In most of the cities and towns of the developing countries, the functional elements of the municipal solid waste management are not fully functional, especially the collection and disposal services are inferior and majorly contribute to the nuisance arising from mismanagement of solid wastes (Hossain et al., 2022, Joshi and Ahmed, 2016). Like other developing countries, the problem of improper collection and disposal of municipal solid wastes are still major challenges in most of the cities and towns of Ethiopia (Doda and Toma, 2014, Sharma et al., 2013, Nigatu et al., 2011).

In many cities and towns of Ethiopia, the municipal solid waste collection, transport and disposal services are not properly functional due to shortage service providers, collection equipment and materials, transport vehicles and standard disposal sites. In this regard; open and illegal dumping in empty spaces, along road sides, rivers banks and sewerage systems is a common practice (Diriba and Meng, 2021, Mohammed, 2020, Tadesse et al., 2008, Gedefaw, 2015).

Several studies conducted in different cities and towns of Ethiopia reported the solid waste management sector is still neglected and required special emphasis for future improvement from budget allocation to awareness creation and better planning and policy implementation (Diriba and Meng, 2021, Hirpe and Yeom, 2021, Teshome, 2021).

2.3 FUNCTIONAL ELEMENTS OF SOLID WASTE MANAGEMENT

Comprehensive MSW handling is crucial to sustainably manage an ever-increasing generation of the MSW stream. The handling practice from generation to final disposal at sanitary landfill site also known as the basic functional elements of MSWM includes storage and sorting at the source, collection, transfer and transport as well as processing and resource recovery and should be equally dealt and addressed in the system in order to implement more effective, efficient in resource utilization, environmentally safe and sustainable SWM system. (Figure 2.2)

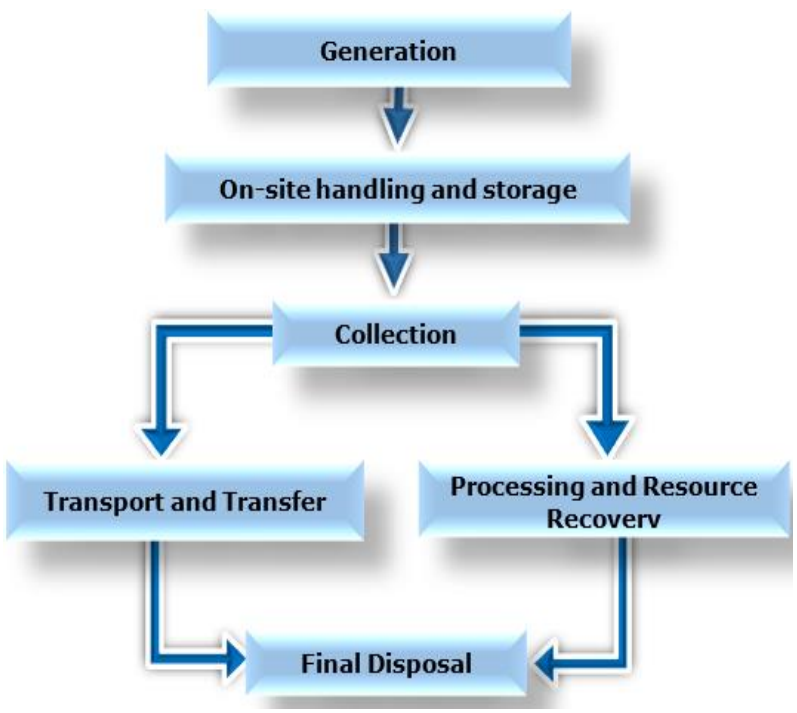

Figure 2.2: Functional elements of municipal solid waste management (MSWM).

2.3.1 Solid Waste Generation

Municipalities are the major source of MSW from households, gardens and parks, institutions, commercial and business centers, open markets, and industries. The rate and type of municipal solid waste generation are primarily determined by the wealth and consumption behavior of the society as well as urbanization pattern of the counties (Kaza et al., 2018).

In solid waste handling models and scenarios, the management practice is expected to start from reduction at the source. Reduction at the source, also known as waste prevention, is the practice of eliminating waste before created and/or using less material to accomplish the same activities in the daily routine. It considers the design, manufacture, purchase and use of materials and products to reduce the amount of what is thrown away (Das et al., 2019). The principle of wise and sustainable use of natural resources also requires to be integrated with the waste handling practices and waste prevention at the source. Several studies also imply the need for the development of waste management policies and strategies that focus on waste reduction at the point of generation (Joshi and Ahmed, 2016, Diriba and Meng, 2021, Idumah and Nwuzor, 2019). Reduction at the source as the first and a primary principle of ISWM, it is required to be coupled with public awareness creation about its importance on the course of SWM as well as conservation of natural resources. Besides; product and service providers are also expected to promote MSW reduction and contribute for the production of more sustainable and environmentally friendly products and services (Khan et al., 2021).

2.3.2 Per Capita Solid Waste Generation Rate

Solid waste is usually quantified in terms of the generation rate, which is the amount of waste generated by a person or a facility per day. Per capita solid waste generation rate which is expressed as Kg/capita/day is the most common mechanism for quantification of municipal solid waste generated from households and used to determine annual solid waste generation from different sources (Kawai and Tasaki, 2016).

United States of America (USA) is the leading producer of municipal solid waste followed by China. In 2018 alone, USA generate 265.2 million metric tons of garbage and China generate 215.2 million metric tons of garbage in 2017 (Stastica, 2020). High and middle-income countries generate more solid waste than low-income countries. Global solid waste generation rate is estimated as 0.74 Kg/capita/day. The lowest goes for low-income countries and the highest goes to high-income countries (Kaza and Yao, 2018). The per capita solid waste generation in generally low in sub-Saharan Africa but spans with a wide range between 0.09 – 3.0 Kg/person/day with an average of 0.65 Kg/person/day. The highest per capita rate is for islands due to high tourism which leads to high generation of solid waste. The per capita solid waste generation in the East Asia and Pacific region is reported between 0.44–4.3 Kg/person/day with an average of 0.95 Kg/person/day. The per capita values range from 1.1–3.7 Kg/person/day with an average of 2.2 Kg/person/day for OECD countries. The per capita solid waste generation rate in Middle East and North Africa region ranges from 0.16 –5.7 kg/person/day and has an average of 1.1 Kg/capita/day (Kaza et al., 2018, Sharma and Jain, 2020).

2.3.3 Municipal Solid Waste Composition

The term municipal solid waste (MSW) is commonly used to the solid waste generated from residential areas/households (garbage, rubbish, and others) and non-residential sources like institutions, commercial centers, industries, street sweepings, construction debris, sanitation residues and municipal services.

The most common wastes from residential areas are food wastes, paper, cardboard, plastics, textiles, leather, yard wastes, wood, glass, metals, ashes, special wastes (e.g., bulky items, consumer electronics, white goods, batteries, oil, tires), and household hazardous wastes (e.g., paints, aerosols, gas tanks, waste containing mercury, motor oil, cleaning agents), e-wastes (e.g., computers, phones, TVs) (Kaza et al., 2018; Aurpa 2021). In general, the composition of MSW mainly varies depending on the source and comprise: -

- **Organic wastes**: - are wastes that can be degraded by microbial actions. Kitchen wastes like wastes from food preparation (vegetables and fruit piles), flowers, leaves, byproducts in marketplaces.
- **Combustibles**: - Paper, wood, dried leaves, packaging for relief items etc. that are highly organic and have low moisture content.
- **Non-combustibles**: - are wastes like metal, tins, cans, bottles, stones, etc.
- **Toxic waste**: - includes old medicines, paints, chemicals, bulbs, spray cans, fertilizer and pesticide containers, batteries, shoe polish.

- **Recyclables**: - like paper, glass, metals, plastics.
- **Ashes or Dust**: - residue from biomass/fires that are used for cooking.
- **Construction waste**: - rubble, roofing, broken concrete, etc. produced during construction activities.
- **Hazardous waste**: - oil, battery acid, medical waste, industrial waste, hospital waste.
- **Dead animals**: - carcasses of dead livestock or other animals.
- **Bulky waste**: - like tree branches, tires, etc.
- **Soiled waste**: - hospital waste such as cloth soiled with blood and other body fluids (Hirpe and Yeom, 2021, Teshome, 2021).

The nature and composition of MSW varies across income levels, lifestyle and consumption behavior of societies. High-income countries generate more dry waste that could be recycled, including plastic, paper, cardboard, metal and glass, which account for 51% of the waste. They produce less organic and green waste, which is around 32% of the total MSW. On the other hand, low-income countries generate around 56% organic (mainly food waste) and green waste. In low-income countries, only 16% of the MSW is recyclable (Table 2.2). In general, the fraction of organic waste decreases with an increase in economic growth and prosperity (Khan et al., 2021, Powell et al., 2018, Sharma and Jain, 2020; Aurpa et al. 2022; Latif et al. 2023).

Table 2.2:Difference between the Fraction of MSW composition between high- and low-income countries.

MSW type	Fraction generated by income level (in percentage)	
	High-income	Low-income
Organic (food and green waste)	32	56
Recyclable (Plastic, paper, cardboard, metal, glass)	51	16

2.3.4 Storage And Segregation At The Source

The second important MSW handling practice is proper storage and segregation of MSW at the source. MSW generated from residential and other sources need to be properly stored at the source.

Sorting/segregation of solid wastes at the source is an important aspect of the management system and very crucial for the proper handling and management of municipal solid waste. It makes the rest of the handling practices easier, especially processing and resource recovery will become less labor and technology intensive (Khan et al., 2021).

Segregation at the source is usually applied to sort organic wastes from recyclables and disposables. In the practice of proper MSW handling; recyclables like plastics, glasses, cans and papers should be separated at the source stored accordingly, organic wastes will also be stored separately and can be used for composting and disposable wastes on the other hand required to be sorted and stored separately (Sharuddin et al., 2017, Wagner et al., 2019).

Regardless of its importance, proper storage and segregation at the source, especially in residential areas is not properly practiced. However, high-income, and developed countries start developing technologies and infrastructures for improved storage, segregation and collection systems. Some cities start using centralized storage units constructed in residential areas. The garbage storage systems are networked and automated waste collection system (AWCS) applied to collect the garbage once or twice a week (

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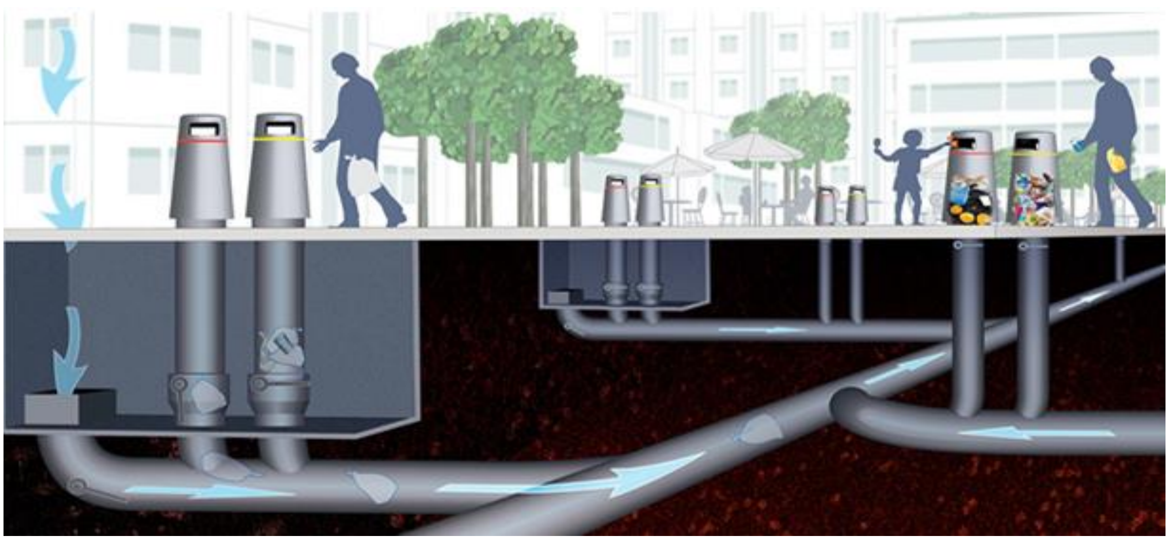

Figure 2.3: Automated Waste Collection System (AWCS) design. (Source: https://catalogue.city/en/solutions/automated-waste-collection-system

The problem of improper storage and segregation of MSW at the source is especially severe in cities and urban areas of the developing countries. In most cities of the developing countries, storage at the household (kitchen), in compounds and in some cases at onsite storage containers are still common practices (SHEDISO, 2017).

2.3.5 Solid Waste Collection

Municipal solid waste collection is an important aspect in maintaining public health in cities and towns all over the world. The solid waste can be collected by several ways. Waste collectors can visit each individual household when the collection system is house-to-house. In community bins, users will bring their garbage into the community bins that are placed in fixed places in the neighborhood and picked by the collection service providers. Curbside pick-up is a collection system where users leave their garbage directly outside their homes based on the city's garbage pick-up schedule and collection service providers will pick it up. Self-delivery is also another way of collection system where the generator delivers the waste to transfer or disposal sites (Hoornweg and Bhada-Tata, 2012).

In developing countries, solid waste collection is the most expensive and labor-intensive component of the handling practices. Collection costs represent 80 to 90% of the municipal solid waste management budget and inefficient collection is the major problem in developing countries and more than 50% of the solid waste generated in the cities of low-income countries remained uncollected. Different studies indicated that lack of infrastructure, poor commitment of institutions, initial cost of solid waste collection vehicles and poor public awareness are the most common factors contributing to the inefficient solid waste collection practice in cities of the developing countries (Ayeleru et al., 2020). Solid waste collection in the cities of the developed countries is more advanced and some countries apply automated waste collection systems. The collection rate is efficient in most cities of Europe, China and the United States (Aldieri et al., 2019, Mukherjee et al., 2020, Zhang et al., 2019).

2.3.6 Transport And Transfer

In mega cities of the world, solid waste transport and transfer is a complex process. Well identified sites for solid waste transfer are constructed. In most cities of the developed world, the transfer sites are used for solid waste processing and resource recovery. Highly efficient and technologically advanced vehicles commonly used to transport tons of solid wastes to the transfer sites (Paul et al., 2019).

2.3.7 Processing, Treatment and Resource Recovery

Waste processing is commonly applied to separate recyclable and useful solid wastes from disposable ones. It is also the point of size and volume reduction for final disposal at landfill sites. Processing sites are also equipped with technologies like large scale incineration for energy recovery as well as volume reduction. Sorting of hazardous and toxic wastes before disposal also practiced in the processing units (EPA, 2016, Mukherjee et al., 2020, Aldieri et al., 2019). However, solid waste processing and resource recovery is not a common practice in the cities of developing countries. Besides lack of legal frameworks enforcing solid waste processing and resource recovery; limitation in financial, technological and human capacity commonly forbid the practice (Dupont-Inglis and Borg, 2018, Nanda and Berruti, 2021, Cofie et al., 2009, Khan et al., 2021).

2.3.8 Final Disposal

After a series of solid waste handling practices, there are still wastes in the stream that need proper disposal. Proper landfill is a very important aspect of the solid waste handling practice. Microbial degradation of organic wastes, leaching of heavy metals and hazardous organic compounds are sources of water and soil contamination. Landfill sites are also sources of greenhouse gases (GHGs) like methane. The public health and environmental impacts are also significant (Gautam and Agrawal, 2021, Vaverková, 2019; Islam et al. 2022).

Most cities of the developing world construct landfill sites far below the standard. In some cities, open dumping is the actual practice. Finance and human capacity are the limiting factors in the construction of standard landfill sites in the developing countries. On the other hand, lack of space is a common problem in cities of the developed world (Marshall and Farahbakhsh, 2013).

2.4 TRENDS OF SOLID WASTE DUMPING SITE AND ITS IMPACT

A landfill site, also known as a dumping site or dumping ground, is a site for the disposal of waste materials. Landfill is the oldest and most common form of waste disposal, although the systematic burial of the waste with daily, intermediate, and final covers only began in the 1940s. Since then, the trend of using more controlled and engineered landfills increased all over the world, especially in the developed countries (Vaverková, 2019).

Recently, modern landfills are well-engineered and managed facilities for the final disposal of solid wastes. Their location, design and operation is highly monitored in order to ensure compliance with federal regulations and also designed to protect the environment from contaminants. Most developed countries construct sanitary landfills with a combination of liners, leak detection, leachate collection systems, and gas collection and treatment systems in order to protection the environment from pollution (Sauve and Van Acker, 2020).

On the other hand; low-technology sites usually open dumping of wastes is a common practice in many of the developing countries (Idowu et al., 2019). The potential threat about municipal solid waste at landfill sites which emits harmful greenhouse gases and leachates eventually leading towards environmental pollution subsequently contaminates the nearby aquifers, water bodies and settlements (Ghosh et al., 2023). The dumping sites often receive hazardous wastes like medical wastes and burning is usually practiced, which creates significant health impacts on residents, hawkers and works of the sites. The trend of open dumping in requires corrective interventions and special attention should be given to sustainably address the environmental and public health impact of open dumping (Idowu et al., 2019).

2.5 INTEGRATED SOLID WASTE MANAGEMENT AND THE CIRCULAR ECONOMY

Integrated Solid Waste Management (ISWM) is a wholistic waste management system encompass planning, engineering, organization, administration, financial and legal aspects of solid waste management practices associated with generation, storage, collection, transfer and transport, processing, and disposal of solid wastes. ISWM is a multidisciplinary field requiring information about the physical, environmental, social, and economic implications of an SWM system. Management planning should consider specific economic, social, and environmental where solid waste planning and policymaking are influenced by the availability of information about these impacts as well as societal values. In most cases, the term MSWM is used to address the principles of ISWM (Das et al., 2019, Khandelwal et al., 2019).

The approach of ISWM is designed to minimize the initial generation of waste through source reduction, then through reusing and recycling to further reduce the volume of materials being sent to processing and landfills, compared to the conventional approach of simply focusing on disposal of solid waste. It uniquely addresses the issue of waste management in an environmentally friendly manner considering the principle of economics, engineering, aesthetics, energy and resource conservation (Das et al., 2019, Elagroudy et al., 2016, EPA, 2016, Khandelwal et al., 2019).

Global experiences – scientific studies as well as actual MSWM practices – indicated that ISWM is the best approach for sustainable management of the ever-increasing solid waste stream across the globe (Redlingshöfer et al., 2020). An ISWM is an approach that favors the 4 R's as better management options and disposal is taken as the least favored management option (Kaza et al., 2018).

The waste hierarchy principle, first applied in the United States of America (USA), has existed for at least four decades and the concept originates in prioritizing waste prevention, reusing, recycling and resource recovery over traditional treatment and disposal to landfill sites (Figure 2.4). The principle of waste hierarchy is the base of ISWM and countries all over the world apply the principle for improved and sustainable MSWM (Pires and Martinho, 2019).

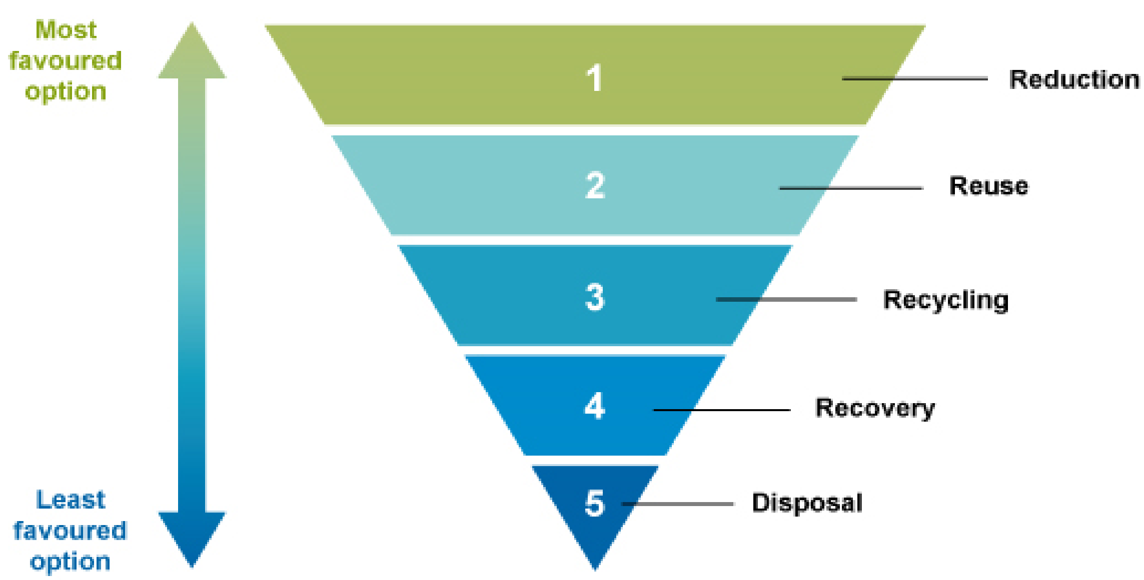

Figure 2.4: Waste hierarchy principle for ISWM. **(Source: https://www.open.edu/openlearncreate/mod/oucontent/view.php?id=80577&printable=1)**

The Circular Economy (CE) the most recent economic principle that attempt to conceptualize the integration of economic activity and environmental wellbeing in a sustainable way (Stahel, 2016). The concept emerged to the global economic system and countries like China adopted it as the basis of their economic development. The concept of the CE basically focuses on closing the loop and operates in three main principles – eliminate waste and pollution, circulate products and materials to their highest values and regenerate nature (Geissdoerfer et al., 2017, Kirchherr et al., 2017). The European Commission (EC) defined the term CE as "an economic space where the value of materials, products and resources is maintained in the economy for as long as possible and waste generation is minimized." (Murray et al., 2017). The CE equally focuses on both renewable and finite natural resources from manufacturing to using of services and products to collection of materials and introducing to the economic loop (Figure 2.5) (Carus and Dammer, 2018).

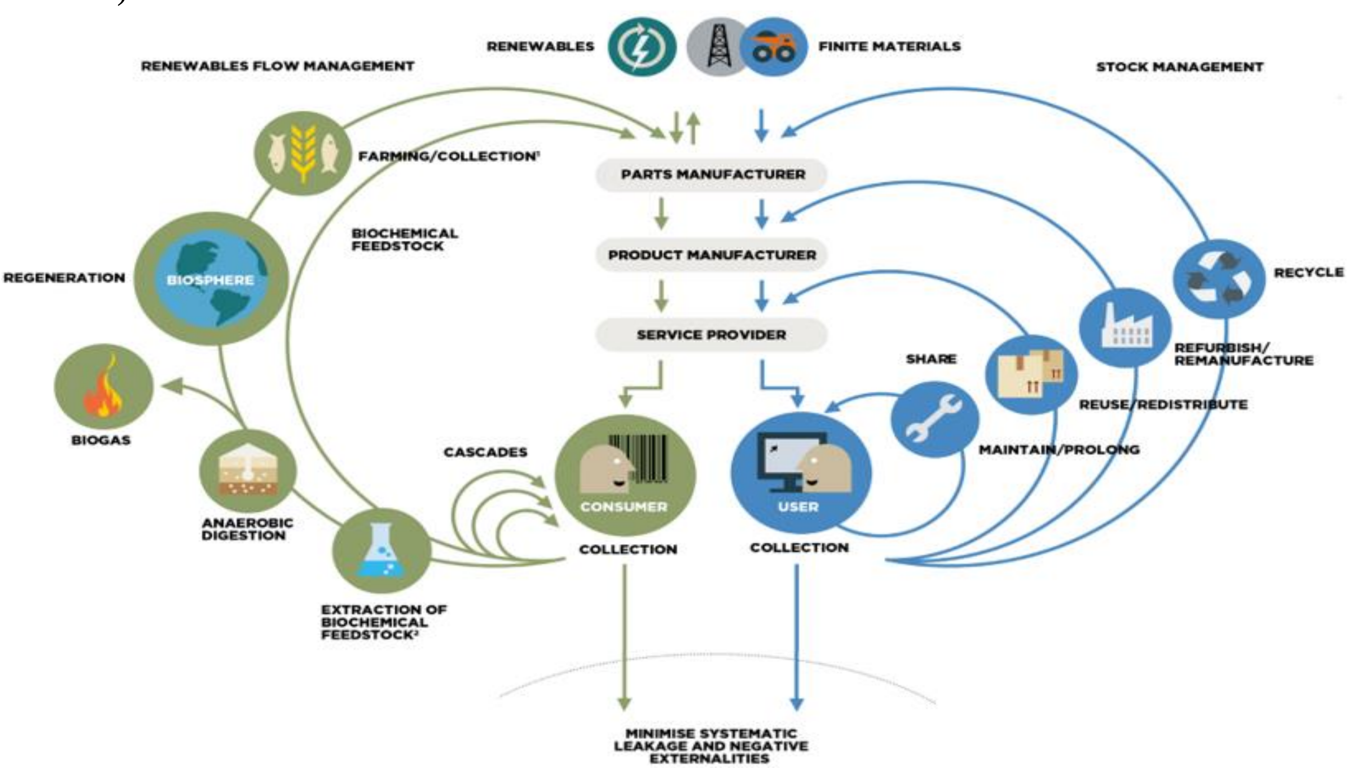

Figure 2.5: The butterfly diagram of the Circular Economy. (Source: https://ellenmacarthurfoundation.org/circular-economy-diagram)

Following the introduction and implementation of the principles of the CE, the waste hierarchy principle, and the concept of ISWM are tightly coupled with CE. Most of the European countries, China and USA already developed a long-term strategic plan to implement the concept of CE not only for waste management but also for sustainable utilization of natural resources, for environmental protection, technological advancements, and economic benefits. Currently, several research and development (R and D) projects including, composting, energy production, waste valorization for the production of value-added products from the organic waste stream are conducted across the globe (Malinauskaite et al., 2017, Pires and Martinho, 2019, Rolewicz-Kalińska et al., 2020, Sharma et al., 2021).

Besides the integration the concept of the CE with ISWM, modelling proper solid waste handling systems using material flow analysis starting from waste prevention to reintroduction of products and materials to the economic loop with their highest possible values are recent priorities of R and D projects, especially in the developed world. In this regard, it is important to model the functional elements of MSWM and apply waste prevention, improved sorting at the source and central processing facilities, improved material recycling, advancing technologies that enhance use of recycled materials as an input instead of virgin raw materials, waste valorization for value added material production from the organic waste steam as well as for regenerating nature (Mukherjee et al., 2020, Rolewicz-Kalińska et al., 2020, Sharuddin et al., 2017, Tisserant et al., 2017).

2.6 SOLID WASTE MANAGEMENT POLICIES AND STRATEGIES

Agenda 2030 for Sustainable Development has been shaping the development policy and action at the global level. Many sustainable development goals (SDGs) are directly related to waste management. SDG 12 deals with ensuring sustainable consumption and production patterns. Target 12.2 (by 2030, achieve the sustainable management and efficient use of natural resources), 12.3 (By 2030, halve per capita global food waste at the retail and consumer levels and reduce food losses along production and supply chains, including post-harvest losses), 12.4 (By 2020, achieve the environmentally sound management of chemicals and all wastes throughout their life cycle, in accordance with agreed international frameworks, and significantly reduce their release to air, water and soil in order to minimize their adverse impacts on human health and the environment) and 12.5 (By 2030, substantially reduce waste generation through prevention, reduction, recycling and reuse) are mainly focused on natural resource management, reduction of food waste, management of hazardous wastes and integrated solid waste management (UN, 2015).

Waste management policy is like any other area of policy. As a policy instrument, it can determine the success or failure of the waste management system. The major components of waste management policy and guidelines include sector-specific norms, standards, and procedures; compliance and enforcement like compulsory recycling; environmental liability by self-responsiveness; green public procurement; taxes and levies; fees and user charges like weight-based waste fees; subsidies and incentives in some services; community-based awareness campaigns; information; and monitoring and feedback system (Jaunich et al., 2019).

It is important to select the relevant and appropriate policy that will lead to an efficient and effective waste management system where it is needed most. The waste management policy should consider the source and type of waste such as municipal, industrial, agricultural, healthcare, etc.; geography and climate; demography, urbanization, and cultural diversity. Furthermore, it should consider consumption and production patterns as well as infrastructure and technological capacity. In this regard, governments and policymakers should consider all these major aspects of policy frameworks that play an important role in dealing with the wider context of waste generation and the intervention required (Jaunich et al., 2019, Das et al., 2019, Khan et al., 2021, Elagroudy et al., 2016). The waste management policy may influence other policies, including public health, environment, land administration, transport, etc. A careful assessment and proper design should also be made on a priority basis to avoid policy collision so that it does not impact the implementation of other policies and public domains. The population density of a town and urban and suburban areas is also closely related to land use planning. For instance, proper implementation of the functional elements of solid waste management from generation to storage, collection, transport and treatment, recovery and final disposal, all are required proper land use planning. Natural resource (including freshwater, energy and food) conservation, preservation and restoration should also be considered in the policy framework and regulations of waste management (Jaunich et al., 2019).

2.7 SOLID WASTE MANAGEMENT IN ETHIOPIA

Solid waste management is a complex process because it involves many technologies and disciplines. It demands greater infrastructure, institutional setup, human resources, commitment, and community engagement. MSWM has become a challenge in Ethiopia, especially the problem is severe in urban and semi-urban areas. Rapid population growth, urbanization and economic growth have led to an increase in solid waste generation both in terms of quantity and complexity (Hirpe and Yeom, 2021, Nigatu et al., 2011, Wondafrash, 2017).

It is estimated that the municipal solid waste generation rate in Ethiopia to be 6 million tons/year in 2015 and is predicted to rise to 10 million tons/year by 2030 and 18 million tons/year by 2050 (Hirpe and Yeom, 2021). A study reported that, the average waste generation in Ethiopia is 0.32 kg/capita/day and is within the limit of waste generation for low-income countries. However, there is an annual increase in waste generation of 5%. The waste collection is below 50%. The waste is dominated by organic biodegradables, which accounted for 67.4%. Despite the high potential of compost with large organic waste, composting is practiced informally and on a small scale. More than half of the population practice open burning of waste in uncontrolled ways to get rid of the waste (Wondafrash, 2017, USAID, 2015, Teshome, 2021).

A review of studies conducted in Ethiopian towns and cities showed that the average rate of solid waste generated by households ranged from 0.23 to 2.03 kilograms. Moreover, the compostable fraction of solid waste was as high as 60%, in the case of Addis Ababa. Moreover, 42.5% of the respondents had poor knowledge on solid waste management. This includes knowledge of households on onsite sorting and waste reduction of solid waste. A large proportion of urban communities have primary solid waste collection system run by micro-enterprise, public assets that have a critical role in urban solid waste management (Doda and Toma, 2014, Sharma et al., 2013, Erasu et al., 2018, Hirpe and Yeom, 2021). (Table 2.3)

Table 2.3:Municipal Solid Waste Generation Rate in different cities and towns of Ethiopia.

City/Town	Average MSW generation rate (Kg/capita/day)	Year	Reference
Addis Ababa	0.45	2021	(Gelan, 2021)
Jimma	0.55	2011	(Getahun et al., 2012)
Hawassa	0.20	2017	(Mohammed, 2020)
Adama	0.42	2021	(Kitila Alemayehu Mijena et al., 2021)
Bahir Dar	0.22	2018	(Tassie Wegedie, 2018)
Mekelle	0.30	2006	(Tadesse et al., 2008)
Jigjiga	0.38	2014	(Birhanu and Berisa, 2015)
Desse	0.45	2012	(Sharma et al., 2013)

Debre Birhan	0.25	2016	(Kebede et al., 2017)
Gonder	0.21	2015	(Gedefaw, 2015)
Aksum	0.54	2014	(Zewdu and Mohammedbirhan, 2014)
Shire	0.49	2014	(Zewdu and Mohammedbirhan, 2014)
Dilla	0.48	2020	(Fereja and Chemeda, 2022)
Debre Markos	0.23	2017	(Birkie et al., 2020)
Yirgalem	0.39	2021	(Teshome et al., 2021)
Wolayita Sodo	0.47	2017	(Goa and Sota, 2017)
Bale Robe	0.26	2017	(Erasu et al., 2018)
Legetafo	0.41	2017	(Assefa and Mohammed, 2017)

2.7.1 Solid Waste Management Policies and Strategies In Ethiopia

The solid waste management system affects several spheres, including environmental, social, and economic activities. In Ethiopia, massive solid waste generation from municipal areas and an unbalanced management system is still a national challenge. In this regard, the government of the Federal Democratic Republic of Ethiopia (FDRE) adopted several policies and legal frameworks that support the enforcement of the SWM system in the country. The municipal solid waste management (MSWM) policies and legal frameworks were adopted with the aim of reducing and eradicating the environmental and human health impacts that arise from ill SWM systems (Hirpe and Yeom, 2021).

Ethiopia has ratified two international waste conventions – the Rotterdam Convention and the Basel Convention via proclamation No. 278/2002 and proclamation No. 357/2003, respectively (Hirpe and Yeom, 2021). The conventions and associated proclamations have a vital role in the improvement of the SWM system in Ethiopia. Proclamation No. 278/2002 Rotterdam Convention Ratification Proclamation was on prior informed consent procedure for certain hazardous chemicals and pesticides in international trade and the Ethiopian Environmental Protection Authority (EPA) was authorized to the implementation of the convention (FDRE, 2002c). Proclamation No. 357/2003; the Basel Protocol Ratification Proclamation adopted the protocol on liability and compensation damage resulting from transboundary movements of hazardous wastes and their disposal and the Ethiopian EPA was authorized to the implementation of the convention (FDRE, 2003).

The 1995 FDRE constitution has been taken as the source of all national policies, including environmental and health policies. The base for several national policies lies under Article 44, sub-article 1 that states "all persons have the right to a clean and healthy environment." (FDRE, 1995). The FDRE 1997 Ethiopian Environmental Policy, Public Health Protection Proclamation No. 200/2000, Environmental Impact Assessment Proclamation No. 299/2002, and Environmental Pollution Control Proclamation 300/2002 were some of the national policy frameworks that directly or indirectly address the waste management system from natural resource, environmental, social, economic and public health aspects. Besides; the most recent Electrical and Electronic Waste Management and Disposal Regulation No. 425/2018 and Hazardous Waste Management and Disposal Control Proclamation No. 1090/2018 were specifically proposed to address the complexity and associated environmental and health risk of special waste types (FDRE, 2018b, FDRE, 2018a, FDRE, 2002b, FDRE, 2002a, FDRE, 1997, FDRE, 2000).

2.7.1.1 The Solid Waste Management Proclamation No. 513/2007

The Solid Waste Management Proclamation No. 513/2007 was the first national policy on SWM in Ethiopia, proclaimed in accordance with Article 55, sub-article 1 of the FDRE constitution. Part one, Article 3 of the proclamation clearly stated the objective of the proclamation as "to enhance at all levels capacities to prevent the possible adverse impacts while creating economically and socially beneficial assets out of solid waste." (FDRE, 2007).

Part two (SWM), Article 4, sub-article 1 put a general obligation on urban administrations to create enabling conditions to promote investment in the provision of SWM services. In Article 5, the SWM planning section, sub-article 1 "urban administrations are expected to ensure the participation of the lowest administrative levels and their respective local communities in designing and implementing their respective SWM plans". Sub-article 2 also stated, "each region and urban administration shall set its own schedule and based on that, prepare its SWM plan and report of implementation". Article 5, sub-article 4a-e has also stated that urban administrations can transfer responsibilities, including formulation and implementation of action plans on SWM, installation of marked waste bins by streets and other public places, ensuring collection of SWs from waste bins, planning and carrying out public awareness raising activities and ensuring that measures are taken to prevent environmental pollution arising from mishandling of SW (FDRE, 2007).

Part three, Article 7 (Glass containers and Tin Cans), sub-article-1 require manufacturers and importers on their own or through others to collect and recycle used glass containers and tin cans. Moreover, sub-article 2 required urban administrations to ensure that pre-collection sites that are designated to collect used glass containers and tin cans and emptied periodically. Article 8, sub-article 1–3 have also stated specifications and import permits for plastic bags. Article 11 (Management of Household Solid Wastes), sub-article 1 gives the responsibility to the head of each household to segregate recyclables from other waste types and sub-article 2 requires urban administrations to ensure the availability of adequate household solid waste collection facilities. Sub-article 3 has also prohibited disposing of litter on streets, waterways, parks, bus stops and other public places. Part 4, Article 13 and 14 have also clearly stated the solid waste transportation and construction requirements of the disposal sites. Article 14, sub-article 3 required urban administrations to ensure the construction and proper use of solid waste disposal sites (FDRE, 2007).

2.8 JOB CREATION AND MUNICIPAL SOLID WASTE MANAGEMENT

A well-managed solid waste management sector can create jobs and strengthen a national economy by keeping the money and materials circulating in the economic system. The circular economy considers job creation and economic development as one its strategy and it became effective in countries like USA and China (Geissdoerfer et al., 2017).

Municipal solid waste management system which focuses on reuse, effective collection, recycling, and composting materials from the waste stream creates more job than landfills and incineration per ton of materials handled. At the global level, the solid waste management sector creates a job opportunity for millions who engaged in solid waste collection service provision. Reuse, recycling and composting also creates many jobs (Godfrey et al., 2017). Recycling and reclamation workers collect recyclable materials from curbside for delivery to recycling facilities. They prepare and sort materials such as metals, glass, paper, and plastics for recycling, load them onto conveyors, and load bundles onto trucks using forklifts. For instance; the US recycling industry generates $117 billion in economic activity annually and creates 681,000 job opportunity (eco-cycle, 2023).

The solid waste management sector is known for its huge potential of job creation; however, it is still underutilized in most developing countries, including Ethiopia. In many cities and towns of Ethiopia, the private sector is not engaged in solid waste management service provision and only local authorities – municipalities – are engaged in the collection and disposal service with a negligible number of works. The recycling and resource recovery sector is also poorly developed and almost creates no job as expected (Diriba and Meng, 2021).

2.9 MAJOR CHALLENGES OF MUNICIPAL SOLID WASTE MANAGEMENT

Rapid increase in solid waste generation is already an issue of almost all the developing countries. In most developing countries, including Ethiopia; lack of an efficient and suitable municipal solid waste collection method, lack of the standby solid waste disposal capacity and landfills and lack of awareness on impacts of illegal and open dumping are severely challenging the municipal solid waste management system in cities and towns as well in rural areas (Das et al., 2019, Kaza and Yao, 2018).

2.9.1 Financial Constraint

Lack of fundraising is one of the root causes of the challenge in many of the developing countries and severely impedes the regularity of the waste collection service. Besides budget constraint to buy waste collection vehicles, lack of funds also affects waste collection service delivery of the existing vehicles due to regular breakdown and lack of budget to maintenance and repair. Lack of funding has also an implication on enough workforce and equipment to properly manage the increasing amount of waste generated from municipalities (Luong et al., 2013, Joshi and Ahmed, 2016).

2.9.2 Lack Of Infrastructure

In developing countries, lack of appropriate infrastructure, including suitable road networks, transfer centers, incineration facilities and landfill sites are major problems of the municipal solid waste management sector and challenges the quality of collection and disposal service delivery. Besides, long distance to community bins is another challenge which forces households to practice illegal dumping (Mohammed, 2020, Zhen-Shan et al., 2009, Teshome, 2021).

2.9.3 Poor Enforcement of Legislations

Lack of enforcing legislation is another challenge of the municipal solid waste management sector in most of the developing countries. In most cities and towns of the developing countries like Ethiopia, households are free to practice illegal dumping and open burning of solid wastes. Households are also not enforced to practice segregation at the source. Product stewardship is not common in most developing countries and considerable quantity of recyclables enters to the solid waste streams and is discarded (Das et al., 2019).

2.9.4 Lack Of Technical Know-How

Lack of technical capacity is one of the major obstacles in the implementation of proper solid waste management system in the developing world. Lack of technical professionals to operate large-scale waste management technologies like composting, anerobic digestion and incineration facilities are common challenges of the waste management sector. The gap in technical know-how greatly contribute to illegal dumping and open burning which is commonly practice in the cities and towns of most developing countries (Hossain et al., 2022).

2.9.5 Poor Public Awareness

Lack of awareness about the adverse environmental and health impacts of open burning and illegal dumping of solid wastes implies that people living in developing countries often resort to such practices. In the cities and towns of Ethiopia, including the capital city Addis Ababa, open burning and illegal dumping is a common practice. Besides, small children practices scavenging for recyclables in open dumping sites due to lack of awareness on its health impact like infection and other communicable and vector-borne diseases (Diriba and Meng, 2021).

2.10 THE CONCEPT OF ROADMAP FOR MUNICIPAL SOLID WASTE MANAGEMENT

The world is striving to develop more sustainable approaches that will account not only the need of the present generation but also the needs of the future generation. The global document; Transforming Our World: Agenda 2030 for Sustainable Development A/RES/70/1, recognizes the need for sustainable urban development and management to ensure quality of life to the world population. The document clearly stated the need of sound environmental management including reducing and recycling of solid waste in most efficient way as well the need of creating positive linking among the economic, social and environmental issues (UN, 2015). In this regard, strengthening international, regional, and national development planning and efficient implementation is regarded as mandatory.

In Ethiopia, urban solid waste management is one of the national priority issues. The growth and transformation plan II (GTP II) stated urban waste management as one of the intervention area and goal 6.2 stated as follows: “Improve urban waste management and sewerage system” (National Planning Commission, 2016).

International experiences implied the need to develop well designed national roadmap to ensure the implementation of the SDGs and more specifically to effectively implement sustainable municipal solid waste management as well as to continually improve efficient natural resource utilization, environmental protection and economic growth (Hossain et al., 2022, Brears, 2018, Levine, 2018).

Several international reports implied the roadmap of sustainable municipal solid waste management is very vital to address the following major issues:

- Designate and empower a professional institutional leader for sector development and reforms.
- Introduce adequate incentives and regulatory oversight.
- Establish a permanent platform for dialogue in the sector with key stakeholders.
- Develop a national waste management strategy and/or implementation plan to ensure access to waste management services and environmental protection.
- Advance institutional improvements at regional and municipal levels.
- Once a basic level of services is functioning adequately, examine what the sector can realistically afford to move up in the waste hierarchy and the timeframe required to achieve the move.
- Advance cost assessment and fee setting practices.
- After having established a well-functioning collection and disposal system, and after understanding the costs in terms of both consequences and financing, a system of separation at source may be developed for dry recyclables (paper/cardboard, plastics, metals/cans, glass) and possibly other priority waste streams like electrical/electronic waste.

- Consider treatment of residual waste and/or the introduction of separation at source for organic waste.
- Other treatment: incineration with electricity/heat production.
- Continuous monitoring, regulatory frameworks, and economic incentives are needed to steer the sector in the desired direction (Hossain et al., 2022, Brears, 2018, Levine, 2018).

2.11 LIMITATION OF PREVIOUS STUDIES

Regarding municipal solid waste management, thousands of scientific studies are conducted at the international, regional, and national level. Municipal solid waste management is still the focus of the scientific community – global to national level.

Regardless of the number of studies conducted and published in international and reputable journals; most of the studies focus on:

- Determination of households' solid waste generation rate,
- Physical composition and characterization of municipal solid wastes,
- Challenges and opportunities of the municipal solid waste management sector, and
- Environmental and health impacts of solid waste dumping sites.

In Ethiopia, almost all studies conducted in major cities and towns are focusing on

- Determination of households' solid waste generation rate,
- Characterization of solid waste physical composition,

The studies conducted in Ethiopia are limited in terms of addressing trends of municipal solid waste generation, collection, disposal as well as the trend of open dumping and environmental impacts of dumping sites. Almost none is studied regarding the job creation potential of the solid waste management sector and its contribution to economic growth and circular economy. Similarly, the existing studies neglected the need to develop well designed roadmap and strategic approach to sustainable municipal solid waste management.

In this regard, in addition to the geographical area covered, generation of more recent data on solid waste generation and physical composition and existing challenges of the municipal solid waste management sector at the national level, this study is uniquely addressing limitation of other studies from the following aspects:

- Investigating trends of municipal solid waste generation, collection and disposal and impact of dumping sites on the environment,
- Assessing the job creation opportunity of the municipal solid waste management sector and its contribution to the national circular economy, and
- Developing a roadmap framework for municipal solid waste management that will be used by relevant decision makers at the federal, regional, and local authorities' level.

CHAPTER 3

DETERMINATION OF PER CAPITA SOLID WASTE GENERATION RATE AND COMPOSITION OF SOLID WASTE GENERATED IN THE CITIES AT HOUSEHOLD LEVEL

Author: ASEGID GETACHEW YIMENU

ABSTRACT

Solid Waste Management (SWM) is a global issue in its socio-environmental and economic aspects. Poor SWM is one of the major causes of resource degradation, environmental pollution, and public health problems. In this study, households' solid waste generation and characterization was determined for selected cities of Ethiopia. Both quantitative and qualitative study methods were applied to collect primary and secondary data that were used to determine household's MSW generation rate and to characterize the physical composition of the waste type. The households' daily MSW generation rate in Bole and Kirkos sub-cities, Addis Ababa were found 0.54 and 0.26 Kg/capita/day, respectively and the average became 0.40 Kg/capita/day. The annual MSW generation from residential households were found 67,000, 51,060, 56,095, 54,000, and 789,509 tons/day for Adama, Bahir Dar, Hawassa, Jimma and Addis Ababa, respectively. The per capita daily MSW generation rate of residential households in the five cities were found between 0.36 – 0.59 with an average of 0.46 Kg/day. The national daily MSW generation for urban residential households was estimated as 0.37 Kg/capita/day. The major composition of the MSW in Bole and Kirkos sub-cities of Addis Ababa was 65.9% of organic followed by 9.5% of plastics, 7.7% textiles and 6.2% paper wastes. Besides, 0.7% of the fraction was found to have hazardous waste materials, including old medicines, paints, chemicals, bulbs, spray cans and batteries. It was found that there is significant positive correlation between households MSW generation and their monthly income ($r = 0.525$, $p < 0.01$) and expense ($r = 0.409$, $p < 0.01$). The binary logistic regression analysis conducted for selected explanatory variables also implied sorting at the source, households MSW disposal system and respondents' profession were determinant factors of households MSW generation ($p < 0.05$).

***Keywords**: Solid waste generation rate, physical composition, solid waste characterization, annual generation*

3.1 INTRODUCTION

Humans generate waste in their day-to-day activities. SWM is a global issue from natural resource conservation, environmental protection, and public health aspect. The change in consumption behavior and lifestyle of the society, rapid population, and economic growth as well as urbanization are known as major driving forces for an ever-increasing generation of MSW at the global level. Among other sources, residential areas are one of the major sources of municipal solid waste (MSW) (Murray et al., 2017, Kaza et al., 2018, Sharma and Jain, 2020).

The global municipal solid waste generation was 2.01 billion tons in 2016 and expected to project to 3.40 billion tons in 2050. High-income countries contribute around 34% to the global MSW generation. In developing countries, rapid urbanization is a common phenomenon and it is estimated that around two-third of the population will live in urban areas by 2025 (Kaza et al., 2018). Besides, the fast economic growth and rapid population growth in the developing world leads to an increase in MSW generation, especially in urban areas. By 2050, the MSW generation in the developing countries is expected to triple and in Africa the generation rate doubles every 15 – 20 years. However, SWM in developing countries is still poor and around 50% of the urban waste remains uncollected. The circumstances are even more complex in Africa where more than half of the MSW generated is not properly collected and disposed in roadsides, sewerage systems, open dumping sites and river banks (Cofie et al., 2009, ESCAP, 2010, Hoornweg and Bhada-Tata, 2012).

Ethiopia is one of the fastest growing countries in sub-Saharan Africa. The country is known for rapid population growth, and it is the second highly populated country in Africa next to Nigeria. The urban population in Ethiopia is expected to be doubled in the coming two decades. Besides rapid population growth and urbanization, economic growth and change in lifestyle of the population is major driving forces for an ever-increasing MSW generation in the country. In this regard, the annual MSW generation of the country is expected to increase from 6.5 million tons in 2015 to 10 million tons in 2030 and 18 million tons in 2050 (Hirpe and Yeom, 2021, Nigatu et al., 2011, EPA, 2008, Teshome, 2021).

Regardless of the increasing MSW generation, more than 50% of the country's MSW is ill-managed and goes to open dump. Even in the capital city (Addis Ababa), around 30% of the MSW is uncontrolled. In general, SWM is one of the major environmental and public health challenge in Ethiopia, especially in larger cities including, Addis Ababa and regional capital cities like Mekelle, Bahir Dar, Adama and Hawassa. This study therefore aimed to assess the generation and physical composition of SW generated from households in selected cities in Ethiopia (Mohammed, 2020, Tassie Wegedie, 2018, Kitila Alemayehu Mijena et al., 2021, Tadesse et al., 2008, Gelan, 2021, USAID, 2015, Teshome, 2021).

3.2 METHODOLOGY

3.2.1 Study Area

The study was conducted in five cities of Ethiopia – Addis Ababa, Bahir Dar, Jimma, Adama and Hawassa (Figure 3.1). **Addis Ababa** is the capital city of Ethiopia. The city is the seat of regional and international organizations. The city is located at 9° 1' 48" N, 38° 44' 24" E at an elevation of 2,355 meters above sea level (asl). The city administration has organized it into eleven sub-cities. According to CSA 2022 population size estimation, the city has a total population of 3,860,000 (2,038,000 of them are Females). **Bahir Dar** is the capital city of Amhara Regional State, Ethiopia, found 578 km northwest of Addis Ababa. The city is one of the leading tourist destinations in Ethiopia. It has a variety of attractions, including Lake Tana and Blue Nile River. The city is located at 11° 36' 0" N, 37° 23' 0" E at an elevation of 1,800 meters asl. The city has organized into six sub-administrative sub cities with a total population size of 349,995 (175,571 of them are Females) (CSA, 2022). **Hawassa** is the capital city of the Southern Nations, Nationalities and People Regional State (SNNPR) and the newly emerged Sidama Regional State, Ethiopia, found 273 km south of Addis Ababa. The city is situated on the shore of Lake Hawassa in the Great Rift Valley. The city is located at 7° 3' 0" N, 38° 28' 0" E at an elevation of 1,708 meters asl. The city has organized into eight sub-administrative sub cities. According to CSA 2022, the total population size of the city estimated to be 422,202 (213,432 of them are Females). **Adama**, formerly known as Nazreth is a city in the central Oromia Region of Ethiopia. The city is located 99 km southeast of Addis Ababa at the base of an escarpment to the west and the Great Rift Valley to the east. The city is located at 8° 30' 52" N, 39° 16' 9 " E at an elevation of 1,712 meters asl. The city has organized into 10 sub cities with a total population size of 458,868 (233,308 of them are Females)

(CSA, 2022). **Jimma** is the largest city in the southwestern Oromia Region, Ethiopia. The city is located 350 km southwest of Addis Ababa. It is located at 7° 40' 0" N, 36° 50' 0 " E at an elevation of 1,780 meters asl. Jimma is a forested region known for its coffee plantations and serves as the commercial center for the region, handling coffee and other products. The city has organized into 18 sub-administrative Kebeles and according to CSA 2022, the total population size estimated to be 250,909 (126,012 of them are Females).

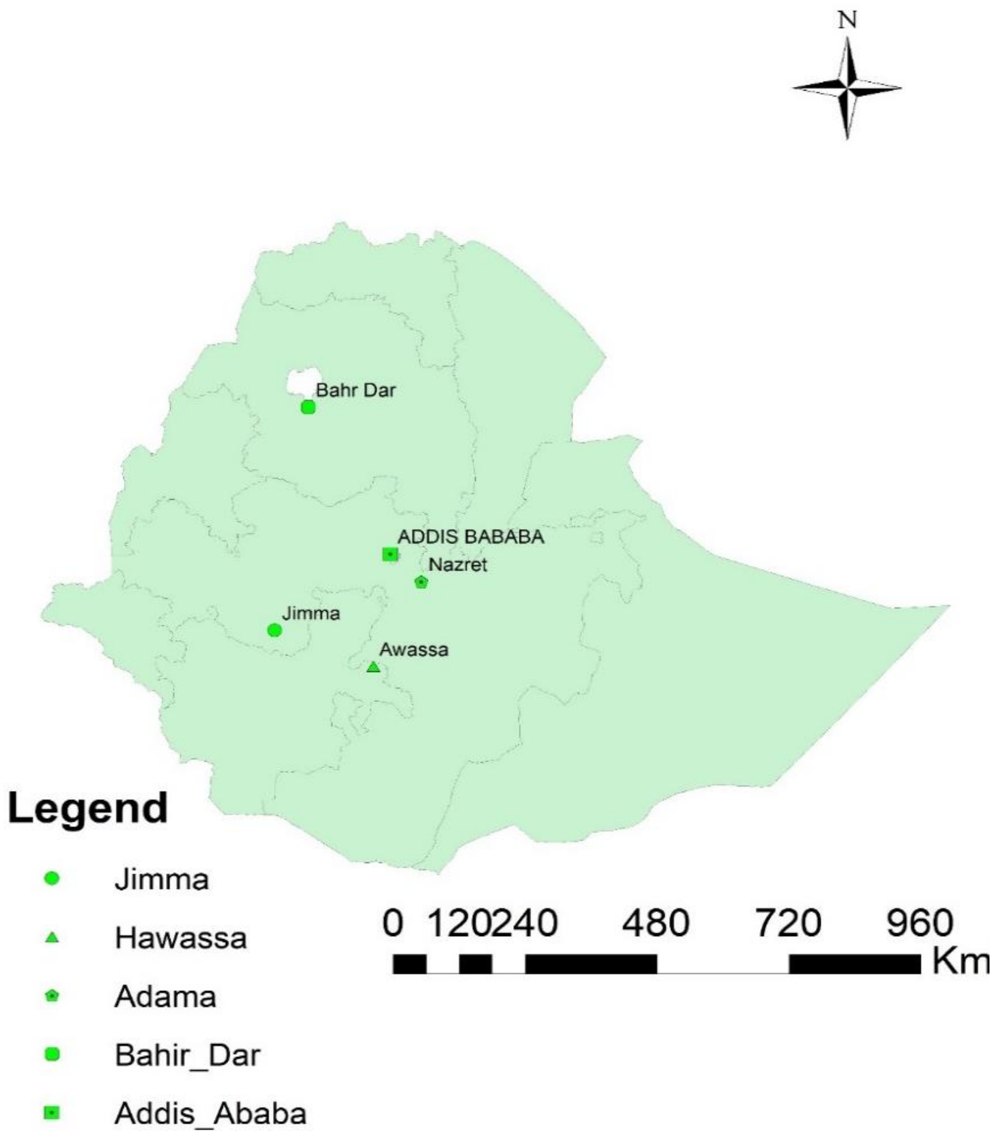

Figure 3.1:Map of the study area.

Among the five cities under study,

- Addis Ababa is the capital of the country with the highest population of about 4.8 million.
- Adama City is the second largest city next to Addis Ababa with a population of about 500,000.
- Bahirdar city is the regional capital of Amhara Regional Government with a population of about 349,000.
- Hawasa city is the capital city of Southern Ethiopia with population of about 422,000.
- Jimma city is the one of the smallest but vibrant cities of Oromia regional government with a total population of about 300,000.

3.2.2 Instrumentation Plan

A cross-sectional study was conducted between October – November 2022 to assess household's solid waste generation rate, physical composition, and characterization in order to categorize and quantify the MSW generated in Addis Ababa. Households' socio-demographic characteristics was also addressed in the quantitative study. Both primary and secondary data were collected in order to assess households' SW generation, physical composition and characterization. Primary data was collected from households of Addis Ababa city and secondary data was used for the rest of the cities. Standard questionnaire developed for Computer Assisted Personal Interview (CAPI), in kobo toolbox, was used to assess households' socio-economic characteristics. The survey questions were deployed in to ODK application and the data was collected using tables. Secondary data collected from document review including, related scientific articles published in an international and reputable journals and documents from relevant government offices were used to address the MSW generation rate, waste fraction and current SWM practices of the cities. Observation was also made to assess the current SWM practices of the cities.

3.2.2.1 Solid Waste Generation Rate and Characterization

Households MSW generation and physical composition of the MSW was determined using a MSW sample collected from households in 8 consecutive days. The MSW collected in the first day was used for demonstration while the 7-day MSW sample was used to determine households per Capita

MSW generation rate and to characterize the MSW physical composition, mass fraction and bulk density. The MSW from each household was collected using plastic bags, weighted, and recorded. The MSW collected from the households were manually sorted into a set of categories as shown in (Table 3.1)

Table 3.1:MSW type for physical composition and characterization.

No.	Waste type
1	Organic wastes: all type of kitchen wastes including vegetable and fruit piles, surplus foods, meat and eggshell, soft bones and others
2	Combustibles: Paper, cartoons for packaging, tissues
3	Textile: Worn cloths, diaper, and other textiles
4	Plastics
5	Combustibles: Grass, wood, dried leaves, chat
6	Non-combustibles: like metal, tins, cans, bottles, stones, etc.
7	Glass/ceramics
8	Ashes or Dust: Residue from biomass/fires that are used for cooking
9	Hazardous wastes: like old medicines, paints, chemicals, bulbs, spray cans, fertilizer and pesticide containers, batteries, shoe polish
10	Miscellaneous: 1. Animal waste (Organic) 2. Other garbage 3. Other rubbishes 4. Others if any (remaining weight) ______
	Total

3.2.2.2 Sample Size Determination

The sample size was determined using a statistical method of Cochran to determine the minimum sample size. A *p* value of 0.7 was used as the MSW collection of Addis Ababa City is estimated as 70% and a 9% of margin of error (d) was taken assuming determination of MSW generation rate and physical composition of the waste type is more experimental. A Z value (critical value from the nominal distribution) of 1.96 was used to determine the sample size.

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

Where, n= Estimated minimum sample size

N= Population size of Addis Ababa city (3,860,000; CSA 2022 projection)

P= 70%, reported MSW collection in Addis Ababa

Z = 1.96, critical value from the normal distribution with level of significance at α =0.05 and 95% confidence level

d= Margin of error (9%)

Using the above formula, the minimum sample size became 99.59 ~ 100. Therefore; 100 randomly selected households, 50 from Bole Sub-city Woreda 8 and 50 from Kirkos Sub-city Woreda 10 were addressed for household survey and determination of their MSW generation rate and characterization of the physical composition.

3.2.2.3 Data Analysis

Before data analysis, data cleaning was carried out using two types of data cleaning techniques. The first one was possible-code cleaning, which is a process of checking to see that only the codes assigned to the answer choices for each question (possible codes) appear in the data file. Thus, a series of cross-tabulations, frequency tables, and raw data checkups were carried out using this data cleaning technique. Contingency cleaning is the process of checking that only those cases that should have data on a particular variable was checked.

SPSS Version 25 Statistical Software was used to manage all statistical analyses. Descriptive statistics such as mean, standard deviation and range were used to summarize variables with scale measurement. Similarly, frequencies and proportions were used to summarize nominal variables.

The average mass fraction and weight percent of MSW components were computed using-

$$m_{fi} = \sum \frac{w_i}{w_t}$$

Where, m_{fi} = average mass fraction for each MSW component

w_i = weight of the MSW component

w_t= total weight of the MSW collected for the study.

$$p_i = m_{fi} x100$$

Where, p_i = percent weight of the MSW component

m_{fi} = average mass fraction for each MSW component

The bulk density of the MSW sample was computed using the following formula:

$$\rho = \sum \frac{w_i}{v_i}$$

Where, ρ = average bulk density of the MSW

w_i = weight of the randomly selected MSW sample

V_i = volume of the randomly selected MSW sample

The average MSW generation rate of was determined as kilogram/capita/day the average weight of the 7-day MSW sample collected from the households.

Besides, comparisons across various groups such as sex, age, educational status and the socio-economic status of the households were conducted for key variable – solid waste generation rate. The collected data were analyzed based on the mean average of the total waste collected from consistent individual households and total waste collected per day, and per week for each household unit. The individual components of the MSW stream and their relative distribution based on the percentage composition were presented using tables and charts. The relationship between solid waste generation rate and household income and family size were described with Pearson correlation test ($p<0.05$, at 95% CI). Paired-samples t-test was used to compare findings between the two sub-cities when necessary. Binary logistic regression (Hosmer and Lemeshow test of model fit (χ^2(df) = y, $p<0.05$ at CI = 95%) was applied to determine explanatory variables (at 95% CI, $p<0.05$) that affect the solid waste generation. Finally, narrations, tables, and different pictures were used to present the findings of the study.

3.3 RESULTS AND DISCUSSION

In this study, a total of 100 households participated from Bole and Kirkos Sub-cities of Addis Ababa city with a 100% response rate. Secondary data from published articles and documents from relevant government offices were used to present the SWM system of the other cities.

3.3.1 Socio-Demographic Characteristics Of Respondents

Regarding the socio-economic and demographic characteristics of the study participants and household units; about 84% of the respondents were females while 16% of them were male. The age of respondents' range between 18 and 75 years old where 37% of them were above 45 years while 29% of them were between the age of 18 and 25. About 52% of the respondents were married while 35% of them were single and the rest were either separated or widowed. Majority of the respondents, 75%, were Orthodox Christians and the rest were Muslim and Protestant. About 9% of the household heads had no formal education while the rest had the highest education ranging from primary school to Bachler's degree and above. Regarding occupation, 27% of the study participants were housewives followed by 16% private employes, 15% no employment, 12% government employees and 10% running their own business. The households' family size ranged between 1 and 9 and 68% of them had a family size ≤ 5. Among the households, 3% had monthly income ≤ 1,000.00 while 37% of them had 1,001.00 – 5,000.00, 34% of them had 5,001.00 – 10,000.00 and 26% of them had > 10,000.00 ETB. Almost all households (99%) had a monthly expenditure that was less than or equal to their monthly income (Table 3.2).

Table 3.2:Households socio-economic and demographic characteristics for SWM study in Addis Ababa, Ethiopia, October 2022

Variable		Frequency (%)
Sex	Male	16 (16)
	Female	84 (84)
Age	18 – 25	29 (29)
	26 – 35	23 (23)
	36 – 45	11 (11)
	>45	37 (37)
Marital status	Married	52 (52)
	Single	35 (35)
	Divorced/Widowed	13 (13)

Religion	Orthodox	75 (75)
	Protestant	13 (13)
	Muslim	12 (12)
HH head highest educational level	No formal education	9 (9)
	Primary school	17 (17)
	Secondary school	29 (29)
	Certificate/Diploma	21 (21)
	Bachler degree and above	24 (24)
Occupation	Government employee	12 (12)
	Private employee	16 (16)
	Business	10 (10)
	Housewife	27 (27)
	Student	11 (11)
	Not employed	15 (15)
	Other	9 (9)
Family size	≤ 5	68 (68)
	> 5	32 (32)
HH monthly income (ETB)	≤1,000	3 (3)
	1,001 – 5,000	37 (37)
	5,001 – 10,000	34 (34)
	>10,000	26 (26)
HH monthly expenditure (ETB)	≤1,000	4 (4)
	1,000 – 5,000	45 (45)
	5,001 – 10,000	32 (32)
	>10,000	19 (19)
Income Vs Expenditure	Expenditure ≤ Income	99 (99)
	Expenditure > Income	1 (1)

3.3.2 Solid Waste Generation

The average per Capita MSW generation rate was determined based on the seven-day MSW samples collected from 100 residential households in Bole and Kirkos sub-cities, Addis Ababa. Findings from interviews made with city municipalities were used to present the average daily and annual MSW generation. Besides, population size was used to estimate the per capita MSW generation rate of residential households for each city. Findings from recently published similar articles are also used to estimate the daily average MSW generation rate at the national level.

As shown in Table 3.3, during the seven-day MSW sample weighing, the daily MSW generated from households had a weight ranged from 113.1 to 159.1 Kg with a total generation of 946.3 Kg/week for Bole sub-city and a weight ranged from 52.3 to 92.1 Kg with a total generation of

446.2 Kg/week for Kirkos sub-city. The total weekly generation from the sampling units was 1392.5 Kg with an average ± STDEV daily solid waste generation of 198.9±17.3 Kg.

Paired-sample t-test was made to compare the mean weekly MSW generation between the two sub-cities and it was found that the weekly MSW generation of Bole sub-city is statistically significantly higher than that of Kirkos sub-city ($p<0.01$). Similarly monthly income was compared and significant difference, mean monthly income of Bole greater than Kirkos were found ($p<0.01$). Several studies implied that income is one of the main factors that determine MSW generation rate (Assefa and Mohammed, 2017, Birhanu and Berisa, 2015, Das et al., 2019, Doda and Toma, 2014).

Table 3.3:Daily and Weekly Weight (Kg) of MSW generated from the selected HHs of Bole and Kirkos sub-cities, Addis Ababa, Ethiopia, October 2022.

Sub-City	**Total family size of surveyed HHs***	**Daily generated MSW, weight in Kg**							**Weekly weight (Kg)**	**Average weight ± STDEV**
		Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7		
Bole	251	127.3	137.6	159.1	147.4	113.1	133	128.8	946.3	135.2±13.7
Kirkos	245	92.1	77.8	52.3	57	55.6	53.2	58.2	446.2	63.7±14.1
Total	496	219.4	215.4	211.4	204.4	168.7	186.2	187	1392.5	198.9±17.3

The daily BD of MSW samples collected from Bole sub-city ranged from 0.26 – 0.42 Kg/L with an average BD of 0.36±0.06 Kg/L and that of Kirkos sub-city was 0.16 – 0.30 Kg/L with an average of 0.22±0.05 Kg/L. The average bulk density of the total MSW samples collected from the household units were found 0.29±0.04 Kg/L (Table 3.4). Similar studies also reported an average BD between 0.25 – 0.46 Kg/L (Assefa and Mohammed, 2017, Birhanu and Berisa, 2015, Das et al., 2019, Doda and Toma, 2014, Fereja and Chemeda, 2022, Gebreeyessus et al., 2019, Gelan, 2021). MSW density between 010 – 0.15 Kg/L commonly reported for industrialized countries, 0.175 – 0.33 Kg/L for middle income countries and 0.30 – 0.60 Kg/L for low income countries (Alabdraba and Al-Qaraghully, 2013).

Table 3.4: Average bulk density BD (Kg/L) of the MSW samples collected from the selected HHs of Bole and Kirkos sub-cities, Addis Ababa, October 2022

Sub-City	Daily generated MSW, bulk density (BD) in Kg/L							Average BD ± STDEV
	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7	
Bole	0.42	0.37	0.37	0.41	0.40	0.26	0.29	0.36 ± 0.06
Kirkos	0.30	0.26	0.26	0.18	0.17	0.16	0.21	0.22 ± 0.05
Total	0.34	0.32	0.31	0.29	0.29	0.21	0.25	0.29 ± 0.04

The per capita average daily MSW generation rate (kg/capita/day) for residential households was determined by dividing the total weight of the MSW generated by the total family size of households and by the number of MSW sampling days. The average daily MSW generation rate of residential households from Bole and Kirkos sub-cities were 0.54 and 0.26 Kg/capita/day, respectively. The average daily MSW generation rate of the total household units was found to be 0.40 Kg/capita/day.

The annual MSW generated from different sources and the fraction from residential households were assessed from annual reports and interviews made with municipalities of each city and Addis Ababa Solid Waste Management Agency (AASWMA). It is found that from the annual total MSW generated in the cities, about 60 – 80% was generated from residential households and the rest from commercial and business centers, institutions, and industries. As shown in Figure 3.2, the annual MSW generated in Adama city reported as 97,000 tons (67,900 tons from residential households), Bahir Dar 85,100 tons (51,060 tons from residential households), Hawassa 86,300 tons (56,095 tons from residential households), Jimma 90,000 tons (54,000 tons from residential households) and Addis Ababa 1,007,662.9 tons (789,509 tons from residential households).

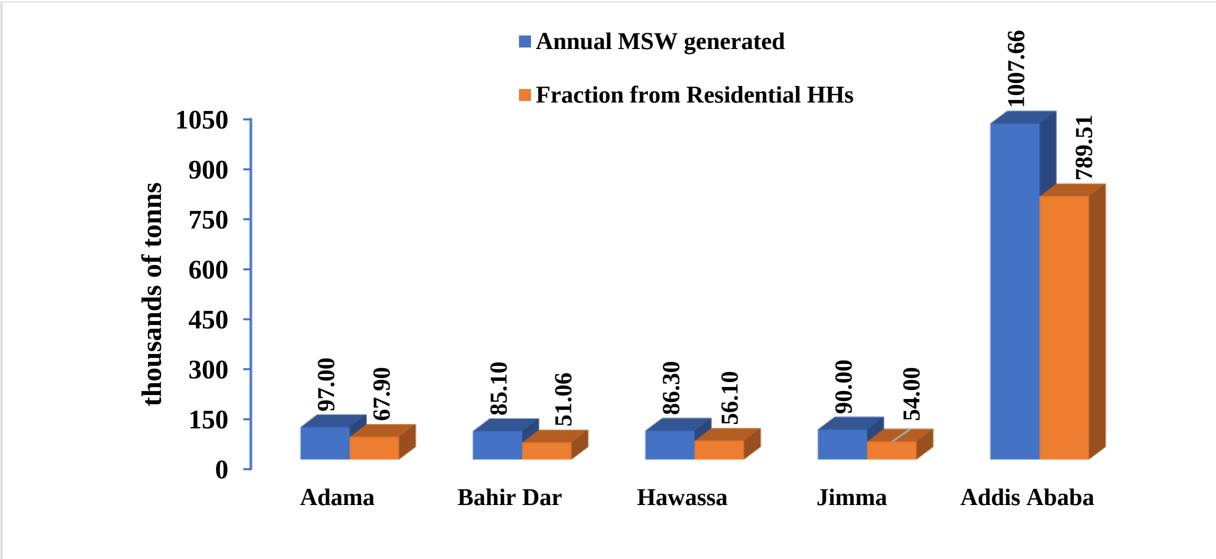

Figure 3.2:Annual MSW generation reported for selected cities in Ethiopia, October 2022.

Based on the reported annual MSW generation, the daily MSW generated from residential households were estimated and used to calculate the average MSW generation rate of residential households for each city. As shown in Figure 3.3, the daily MSW generated from residential households found around 2163 tons for Addis Ababa and between 140 and 186 tons for the rest of the cities.

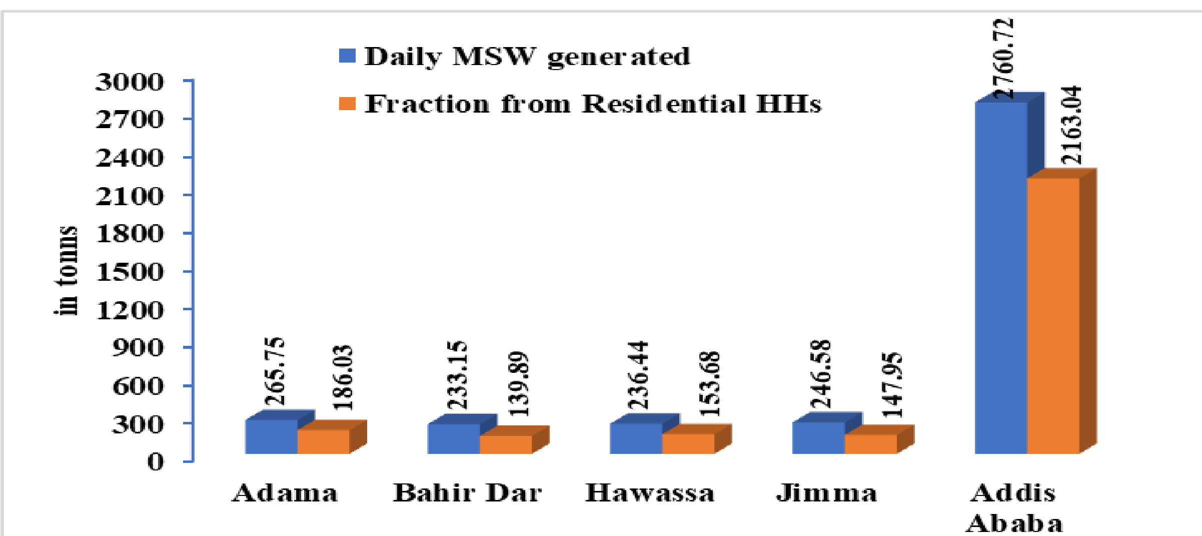

Figure 3.3:Estimated daily MSW generation and fraction from residential HHs for selected cities, Ethiopia, October 2022

The average daily MSW generation rate of Adama, Bahir Dar, Hawassa, Jimma and Addis Ababa cities were estimated from the calculated daily generation and population size taken from CSA July 2022 report. Findings from similar studies were also presented. The per Capita MSW generation rate from residential households ranged from 0.36 – 0.59 Kg/day based on estimation made from the daily generation report. Findings from similar studies also reported the per Capita MSW generation rate between 0.20 – 0.55 Kg/day (Table 3.5). The estimated households' daily MSW generation rate for Bahir Dar (0.40 Kg/capita/day) and Hawassa (0.36 Kg/capita/day) were found higher than those reported in similar studies, 0.22 Kg/capita/day for Bahir Dar (Tassie Wegedie, 2018) and 0.20 Kg/capita/day for Hawassa (Mohammed, 2020). On the other hand; the estimated daily MSW generation for Addis Ababa (0.56 Kg/capita/day) was found from the rate reported by (Gelan, 2021). The findings for Adama and Jimma were comparable.

Table 3.5: Average daily MSW generation rate of residential households in Adama, Bahir Dar, Hawassa, Jimma and Addis Ababa cities, Ethiopia.

City	**Average MSW generation rate (Kg/capita/day)**		
	Estimated from daily generation	**From similar studies**	
Adama	0.41	0.42	(Kitila Alemayehu Mijena et al., 2021)
Bahir Dar	0.40	0.22	(Tassie Wegedie, 2018)
Hawassa	0.36	0.20	(Mohammed, 2020)
Jimma	0.59	0.55	(Getahun et al., 2012)
Addis Ababa	0.56	0.45	(Gelan, 2021)
Average	**0.46**	**0.34**	

From the overall study, it was found that the national urban residential households average WS generation rate ranged from 0.20 – 0.55 with a mean value of 0.37 Kg/Capita/day (computed from Table 2.3). The finding is in line with other reports on the national daily MSW generation rate for urban areas (Hirpe and Yeom, 2021, Teshome, 2021).

3.3.3 Physical Composition of Municipal Solid Waste

The physical composition of SW samples collected from the two sub-cities was analyzed and the mass fraction and percentage weight of major MSW types were determined. The type of solid waste generated from residential households was manually sorted to determine the physical composition and to characterize the types of solid waste generated. The most common solid waste types generated from municipal areas were used for categorization and characterization.

Figure 3.4:Manual sorting of the collected MSW during the study, October 2022.

As shown in table 3.6, the highest mass fraction from the total solid waste samples collected in seven-days was organic kitchen wastes (785 Kg/week) followed by plastics (131.6 Kg/week), textiles like worn cloths, dipper and others (107.4 Kg/week) and grass, woods, dried leaves, khat, and other combustibles (104 Kg/week).

Table 3.6: Physical composition and weekly generation, average generated weight, mass fraction and percentage weight of different solid waste types generated from HHs of Bole and Kirkos sub-cities Addis Ababa, Ethiopia, October 2022.

Waste type	Physical composition of MSW collected form residential HHs (Kg)							
	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7	Weekly
Organic wastes: all type of kitchen wastes including vegetable and fruit piles, surplus foods, meat and eggshell, soft bones and others	135.9	133.4	114.8	112.5	93.3	94.8	100.3	785
Combustibles: Paper, cartoons for packaging, tissues	12.1	12.8	15.7	14.2	8.5	10.7	11.7	85.7
Textile: Worn cloths, diaper and other textiles	16.6	17.7	15.7	14.9	11.1	15.5	15.9	107.4
Plastics	19.2	18.6	21	19.3	18.9	17.1	17.5	131.6
Combustibles: Grass, wood, dried leaves, chat	13.1	11.2	18.5	10.4	13.9	20	16.9	104

Non-combustibles: like metal, tins, cans, bottles, stones, etc.	1.8	2	1.9	2.7	1.1	1.8	2.6	13.9
Glass/ceramics	1.1	2.1	2	6.3	4.5	6	2.3	24.3
Ashes or Dust: Residue from biomass/fires that are used for cooking	8.2	5.8	9.6	9.8	6.6	7.7	6	53.7
Hazardous wastes: like old medicines, paints, chemicals, bulbs, spray cans, fertilizer and pesticide containers, batteries, shoe polish	2.4	2	1.1	1.3	0.6	1.3	1.5	10.2
Miscellaneous:								
Animal waste (Organic)	0.4	0.5	1	2	0.9	0.1	1	5.9
Other garbage	2.5	2.1	4.2	3.8	2.6	4	4.2	23.4
Other rubbishes	4.3	5	3.5	4	4.9	4.1	3.9	29.7
Remaining weight	1.8	2.2	2.4	3.2	1.8	3.1	3.2	17.7
Total	219.4	215.4	211.4	204.4	168.7	186.2	187	1392.5

Residential households that participated in this study were asked to mention the most common MSW types they generate in their day-to-day activities. All respondents (100%) replied that organic wastes from the kitchen and majority (83%) of them replied plastic wastes are the most common types of waste generated from their day-to-day activities (Table 3.7).

Table 3.7: The most common MSW types listed by respondents in Bole and Kirkos sub-cities, Addis Ababa, Ethiopia, October 2022

Variable	Common MSW types from residential HHs	Frequency (%)
The most common MSW type generated from day-to-day activities responded **YES**	Kitchen wastes including vegetable and fruit piles, surplus foods, meat and eggshell, soft bones and others	100 (100)
	Paper, cartoons for packaging, tissues, etc..	56 (56)
	Plastics	83 (83)
	Grass, wood, dried leaves, Khat	46 (46)
	Metals	3 (3)
	Textile: Worn out cloths, diapers and other textiles	37 (37)
	Glass and Ceramics	13 (13)
	Total	**100 (100%)**

The solid waste generated in the town was categorized into major waste types. The average percentage weight of various waste types was 65.9% organic, 6.2% paper, 7.7% textiles, 1.0%

metals, 95% plastics, 1.7% glasses, 3.9% ash and dust, 0.7% hazardous wastes and 3.4% other rubbishes (Figure 3.5). It is found that organic wastes contribute to the largest fraction followed by plastics and textile wastes.

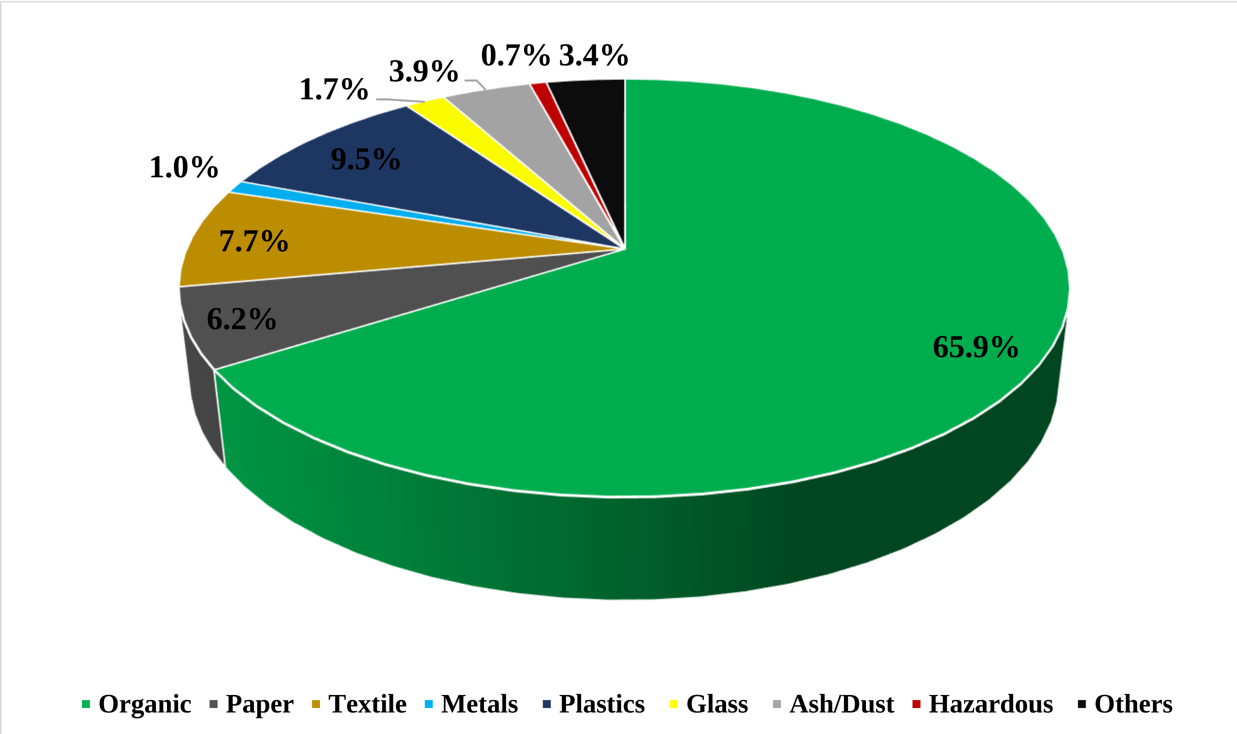

Figure 3.5: Percentage fraction type from the MSW collected in the seven-days experiment in Bole and Kirkos sub-cities, Addis Ababa, Ethiopia, October 2022.

The physical composition of the MSW generated from residential households in the five cities were also assessed from annual reports of the city municipalities and similar studies conducted in the study areas (Figure 3.5, 3.6, 3.7). According to the 2021 report of the cities, organic wastes are the most predominant contributors ranging from 64.5 – 74.2% with an average of 68.0% followed by plastic wastes that contribute 8.4 – 10.5% of the total fraction with an average of 9.5% (Table 3.8)

Table 3.8: Physical composition of MSW generated from residential HHs according to the 2021 report of city municipalities, Ethiopia, October 2022.

MSW type	% Fraction by type					Average (%)
	Adama	Bahir Dar	Hawassa	Jimma	Addis Ababa	
Organic	64.5	67.2	70.5	63.7	74.2	68.0
Paper	4.2	3.7	2.5	3.3	4.8	3.7
Textile	3.1	6.8	4.2	5.1	2.2	4.3
Metals	1.1	1.5	0.9	1.3	1.3	1.2
Plastics	10.5	8.4	10.5	8.5	9.4	9.5
Glasses	1.8	1.2	1.6	1.2	1.2	1.4
Ash/Dust	6.4	8.2	-	9.7	-	4.9
Hazardous	-	-	-	-	-	-
Others	8.4	3	9.8	7.2	6.9	7.1

Similar studies conducted in different cities and towns of Ethiopia also reported comparable findings where the larger fraction of MSW was organic (56 – 75%) (Assefa and Mohammed, 2017, Birhanu and Berisa, 2015, Birkie et al., 2020, Doda and Toma, 2014, Gedefaw, 2015, Gelan, 2021, Goa and Sota, 2017, Hussen et al., 2021, Kebede et al., 2017, Sharma et al., 2013, Teshome et al., 2021).

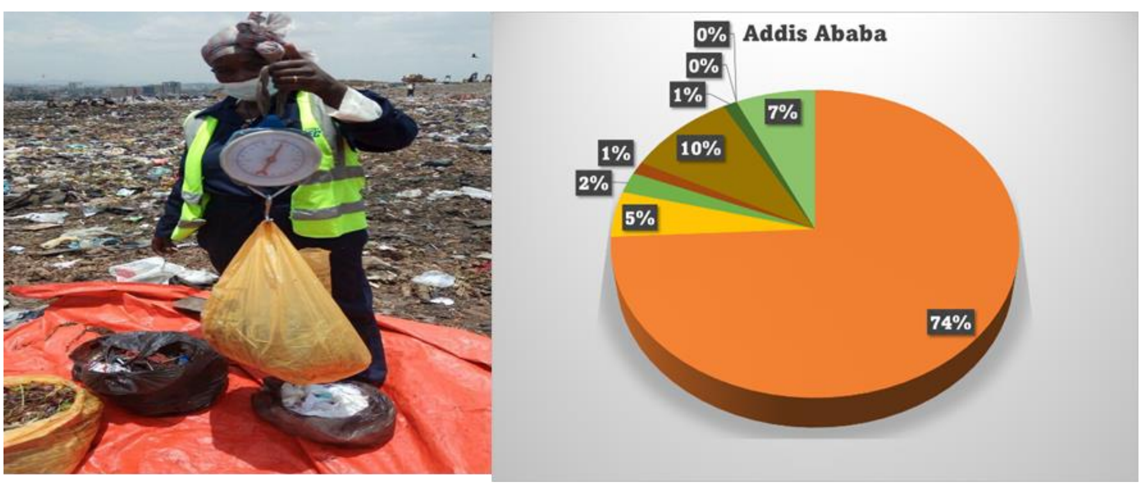

Figure 3.6: Per Capita Solid Waste Generation Rate for Household in Addis Ababa

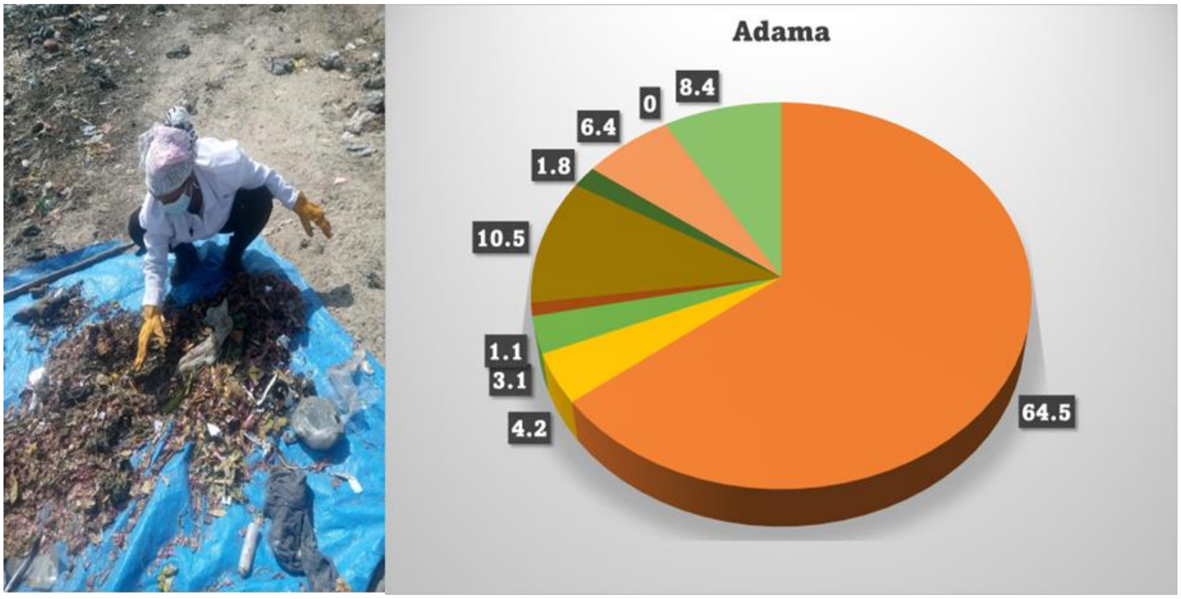

Figure 3.7: Per Capita Solid Waste Generation Rate for Household in Adama

3.3.4 Factors Affecting Solid Waste Generation

The study participants were asked about their on-site handling including proper storage, sorting by type at the source and their reusing and resource recovery practices. They were also asked about the impact of poor MSW handling practices on the environment and human health. As shown in Table 3.9, 46% of the households store their MSW anywhere in their compound or outside their vicinity and 33% of them uses sacks to store their MSW. Of the total households, 41% of them practice sorting at the source, 34% reuse MSW mainly plastics and 14% of them replied that they use their kitchen waste for compost.

Regarding their MSW disposal system, only 34% of the households replied that their MSW is collected by waste collectors while 24% of them dispose in the nearby waste containers/dustbins, 8% of them dispose in their compound/private pits and the rest either disposed along the roadside, in nearby empty space or ditches (Table 3.9).

Among the study participants, 68% of them strongly agreed and 25% agreed that poor SW disposal has an environmental and health impact. On the other hand, 9% of them strongly agreed and 23% of them agreed that burning of solid waste is a better SWM option (Table 3.10).

Table 3.9 :Respondents' on-site MSW handling, reusing and disposal practices and knowledge about the impact of poor MSW handling in Bole and Kirkos sub-cities, Addis Ababa, Ethiopia, October 2022

Variable	Frequency (%)
On-site storage site	
Kitchen	24 (24)
At the backyard	30 (30)
Anywhere in the compound	37 (37)
Outside the compound	9 (9)
MSW storage material	
Plastic bags	26 (26)
Garbage bins	9 (9)
Bucket	32 (32)
Sacks	33 (33)
Sorting at the source	
Yes	41 (41)
No	59 (59)
Reusing	
Yes	34 (34)
No	66 (66)
Composting kitchen waste	
Yes	14 (14)
No	86 (86)
Disposal system	
Collected by waste collectors	36 (36)
Private pit/Inside the compound	8 (8)
Nearby waste container/dustbin	24 (24)
Along the roadside	13 (13)
Nearby empty space	18 (18)
Nearby ditches	1 (1)
Disposing MSW anywhere can affect the environment and human health	
Strongly Agree	68 (68)
Agree	25 (25)
Not sure	5 (5)
Disagree	2 (2)
Strongly Disagree	-
Burning MSW is a better SWM system	
Strongly Agree	9 (9)
Agree	23 (23)
Not sure	5 (5)
Disagree	29 (29)
Strongly Disagree	34 (34)
Total	**100 (100)**

In order to analyze factors affecting households solid waste generation, relevant continuous and categorical variables were selected and computed using the average per capita solid waste generation rate as dependent variable. Pearson's correlation test was done to determine any correlation between the MSW generation of households and selected continuous independent variables – respondents age, households' family size, monthly income and expenditure and the current monthly fee for SWM services.

Table 3.10: Pearson correlation for continuous variables and MSW generation of HHs in Bole and Kirkos sub-cities, Addis Ababa, Ethiopia, October 2022

		Age	Family size	Monthly income	Monthly expenditure	Monthly fee for SWM
Average daily MSW generation from HHs	Pearson Correlation	-0.089	0.139	0.525**	0.409**	-.055
	Sig. (2-tailed)	0.376	0.167	0.000	0.000	.370
	N	100	100	100	100	100

****Correlation is significant at the 0.01 level (2-tailed).**

It was found that there is significant positive correlation between households MSW generation and their monthly income ($r = 0.525$, $p < 0.01$) and expenditure ($r = 0.409$, $p < 0.01$) ().

Most studies indicated that family size and monthly income of households are the two main factors that determine waste generation rate (Mohammed, 2020, Tassie Wegedie, 2018, Kitila Alemayehu Mijena et al., 2021, Birhanu and Berisa, 2015, Gedefaw, 2015)

Binary logistic regression analysis was made to identify nominal and ordinal factors that affect households' daily solid waste generation. Educational level, occupation, knowledge about on-site MSW handling, improper disposal and value of waste were tested as explanatory factors.

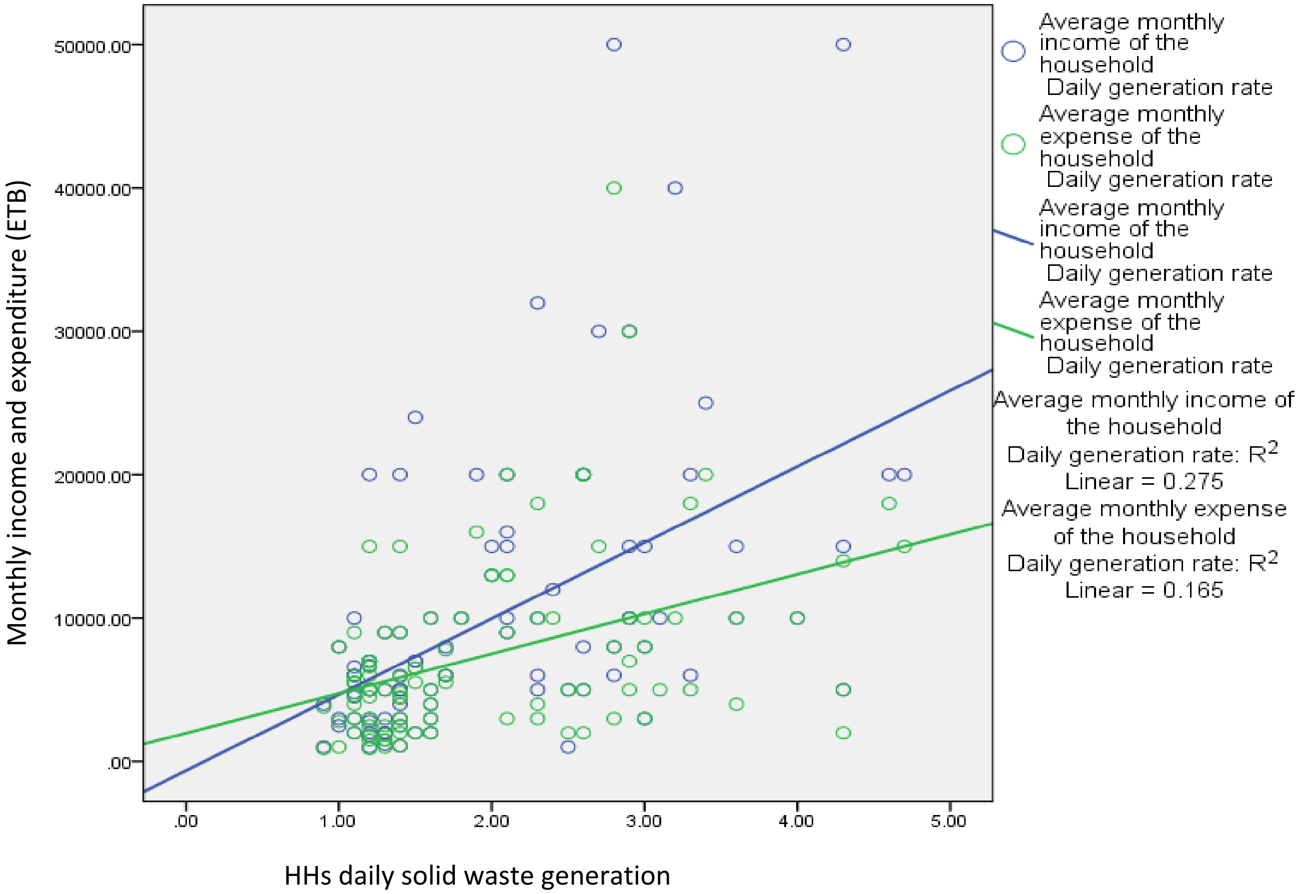

Figure 3.8: Scatter plot of the Pearson correlation between daily SW generation vs income and expenditure.

The chi-square test result from the Hosmer and Lemeshow test is an indicator of fit in the model in terms of significant improvement in fit relative to an intercept-only model (χ^2(df) = y, p<0.05 at CI = 95%). In the binary logistic regression analysis of this study, the Hosmer and Lemeshow test result was ($\chi^2(8) = 8.42$, p=0.394 at CI = 95%), which implies the model is an adequately-specified model with an acceptable fit to the data. From the selected explanatory variables, sorting at the source, households MSW disposal system and respondents' profession were found significant factors that affect households MSW generation (p<0.05). This finding also supported by other similar studies (Goa and Sota, 2017, Hussen et al., 2021, FEREDE, 2018, Gelan, 2021).

3.4 CONCLUSIONS

The following conclusions were drawn from the study.

1. The average daily MSW generation rate of the total household units was found to be 0.40 Kg/capita/day. In the five selected cities, the per capita MSW generation rate from residential households ranged from 0.36 – 0.59 Kg/day based on estimation made from the daily generation report. From the overall study, it was found that the national urban residential households average WS generation rate ranged from 0.20 – 0.55 with a mean value of 0.37 Kg/Capita/day.
2. The daily BD of MSW samples collected from Bole sub-city ranged from 0.26 – 0.42 Kg/L with an average BD of 0.36±0.06 Kg/L and that of Kirkos sub-city was 0.16 – 0.30 Kg/L with an average of 0.22±0.05 Kg/L. The average bulk density of the total MSW samples collected from the household units were found to be 0.29±0.04 Kg/L.
3. Income was found to be the main determinant factor that statistically significant effect on households' MSW generation rate.
4. The annual MSW generated in Adama City reported as 97,000 tons (67,900 tons from residential households), Bahir Dar 85,100 tons (51,060 tons from residential households), Hawassa 86,300 tons (56,095 tons from residential households), Jimma 90,000 tons (54,000 tons from residential households) and Addis Ababa 1,007,662.9 tons (789,509 tons from residential households).
5. In the study area, the average percentage weight of various waste types was 65.9% organic, 6.2% paper, 7.7% textiles, 1.0% metals, 95% plastics, 1.7% glasses, 3.9% ash and dust, 0.7% hazardous wastes and 3.4% other rubbishes.

CHAPTER 4

TREND ANALYSIS OF DUMPING SITES AND THE IMPACT OF MISMANAGEMENT OF SOLID WASTE ON URBAN ENVIRONMENTS

Author: ASEGID GETACHEW YIMENU

ABSTRACT

The global municipal solid waste generation is expected to project to 3.40 billion tons by 2050 and estimated to be tripled in developing countries. The municipal solid waste generation rate in Ethiopia was 6 million tons/year in 2015 and is predicted to rise to 10 million tons/year by 2030 and 18 million tons/year by 2050. In this regard, it is important to clearly understand the trend of household's solid waste generation rate in large cities of Ethiopia in order to address major challenges of the MSW management system, its impact in urban environment and to set effective management system. The aim of this chapter is therefore to analyze the trend of household solid waste generation and respective service provision as well as major challenges in SWM service provision and the impact of MSW mismanagement in the urban environment. Both quantitative and qualitative methods were applied to collect all relevant data from the five cities and trend analysis was done to determine the generation rate as well as service provision between 2016 and 2021. Households' MSW generation were also extrapolated between 2022 and 2050. Descriptive statistics were done using SPSS version 25 to present findings with graphs. The annual household's solid waste generation increased from 52.60 – 67.90 x 10^3 tons with an average annual incremental rate of 5% in Adama city. Similarly, from 32.90 – 51.06 x 10^3 ton with an average annual incremental rate of 5% Bahir Dar city, from 42.20 – 56.10 x 10^3 ton with an average annual incremental rate of 6% in Hawassa city, from 37.90 – 54.00 x 10^3 ton with an average incremental annual rate of 7% in Jimma town and from 667.00 – 789.51 x 10^3 ton with an average annual incremental rate of 3% in Addis Ababa city. The average solid waste generation rate of the five cities increased by 5% annually. Based on the projected data the households solid waste generation rate will be quadrupled by 2050. The cities collection capacity increased from 45 – 65%, 48 –

65%, 52 – 68%, 42 – 65% and 71 – 84% between 2016 and 2022 in Adama, Bahir Dar, Hawassa, Jima and Addis Ababa cities, respectively.

It was found none of the cities have sanitary landfill sites constructed according to the national standard for final solid waste disposal. Besides their quality, the existing disposal sites served between 20 – 60 years and are currently forced to serve beyond their capacity. All the flaws of the management system had an impact on the environment – water, land and air as well as on public health.

***Keywords**: trend analysis, solid waste collection service, sanitary landfill, environmental impact*

4.1 INTRODUCTION

Since the industrial revolution in the middle decades of the 18th-century, the worldwide MSW generation hugely increased (Abdel-Shafy and Mansour, 2018). Rapid population growth and urbanization, global economic prosperity and associated change in the production and consumption behavior of the society are major deriving forces for an ever-increasing generation of MSW at the global level (Powell et al., 2018). Besides, rapid technological advancement and the impact of globalization leads to the introduction of more complex and hazardous waste types, including plastic and electronic wastes (Shittu et al., 2021, Idumah and Nwuzor, 2019).

The global MSW generation is expected to project to 3.40 billion tons by 2050 and estimated to be tripled in developing countries (Kaza et al., 2018).

The municipal solid waste generation rate in Ethiopia was 6 million tons/year in 2015 and is predicted to rise to 10 million tons/year by 2030 and 18 million tons/year by 2050 (Hirpe and Yeom, 2021). A study reported that, the average waste generation in Ethiopia is 0.32 kg/capita/day and is within the limit of waste generation for low-income countries. However, there is an annual increase in waste generation of 5%. The waste collection is below 50%. The waste is dominated by organic biodegradables, which accounted for 67.4%. Despite the high potential of compost with large organic waste, composting is practiced informally and on a small scale. More than half of the population practice open burning of waste in uncontrolled ways to get rid of the waste (Wondafrash, 2017, USAID, 2015, Teshome, 2021). In this study, the trend of MSWM from generation, collection and disposal aspect were evaluated.

4.2 METHODOLOGY

4.2.1 Study Area

The study was conducted in five cities of Ethiopia – Addis Ababa, Bahir Dar, Jimma, Adama and Hawassa. **Addis Ababa** is the capital city of Ethiopia. The city is the seat of regional and international organizations. The city is located at 9° 1’ 48” N, 38° 44’ 24” E at an elevation of 2,355 meters above sea level (asl). The city administration has organized it into eleven sub-cities. According to CSA 2022 population size estimation; the city has a total population of 3,860,000 (2,038,000 of them are Females). **Bahir Dar** is the capital city of Amhara Regional State, Ethiopia, found 578 km northwest of Addis Ababa. The city is one of the leading tourist destinations in Ethiopia. It has a variety of attractions including Lake Tana and Blue Nile River. The city is located at 11° 36' 0" N, 37° 23' 0" E at an elevation of 1,800 meters asl. The city has organized into six sub-administrative sub cities with a total population size of 349,995 (175,571 of them are Females) (CSA, 2022). **Hawassa** is the capital city of the Southern Nations, Nationalities and People Regional State (SNNPR) and the newly emerged Sidama Regional State, Ethiopia, found 273 km south of Addis Ababa. The city is situated on the shore of Lake Hawassa in the Great Rift Valley. The city is located at 7° 3' 0" N, 38° 28' 0" E at an elevation of 1,708 meters asl. The city has organized into eight sub-administrative sub cities. According to CSA 2022, the total population size of the city estimated to be 422,202 (213,432 of them are Females). **Adama**, formerly known as Nazreth is a city in the central Oromia Region of Ethiopia. The city is located 99 km southeast of Addis Ababa at the base of an escarpment to the west and the Great Rift Valley to the east. The city is located at 8°30' 52" N, 39° 16' 9 " E at an elevation of 1,712 meters asl. The city has organized into 10 sub cities with a total population size of 458,868 (233,308 of them are Females) (CSA, 2022). **Jimma** is the largest city in the southwestern Oromia Region, Ethiopia. The city is located 350 km southwest of Addis Ababa. It is located at 7° 40' 0" N, 36° 50' 0 " E at an elevation of 1,780 meters asl. Jimma is a forested region known for its coffee plantations and serves as the commercial center for the region, handling coffee and other products. The city has organized into 18 sub-administrative Kebeles and according to CSA 2022, the total population size estimated to be 250,909 (126,012 of them are Females).

4.2.2 Instrumentation Plan

Trend analysis is an important statistical tool that can be used to determine future changes of a given variable based on its historical trends. It is used to predict future behavior (change) of a given variable based on past data. In this regard, trend analysis of the MSWM of the cities selected for this study as well as the national management system was made to present the MSWM trend. Besides, prediction of the future MSWM generation trend was made applying population growth projection coupled with recent progresses and strategic plans for MSWM of the selected cities and the country in general.

MSWM data from 2015 – 2022 was used to analyze the MSW generation, collection and disposal practices of the selected cities and the country. The data was collected from annual reports and scientific articles to conduct the trend analysis. Future population size projection was also used to estimate future changes in the MSWM.

The impact of open dumping sites in the urban environment and public health were also analyzed using document reviews and observations. Findings were further discussed to elaborate the impact of open dumping sites on the urban environment and public health.

The primary and secondary data collected regarding MSW generation, collection and disposal was analyzed to determine the trend of the MSWM in the study area as well as at the national level. Findings were presented using graphs and charts to narrate findings.

4.3 RESULTS AND DISCUSSION

4.3.1 Annual Solid Waste Generation from Residential Areas

The cities per capita solid waste generation rate (Kg/capita/day) ranged between 0.36 and 0.59 with an average of 0.46 Kg/capita/day. Addis Ababa and Jimma has the highest, 0.56 and 0.59 Kg/capita/day generation of municipal solid waste while Hawassa, Bahir Dar, and Adama has 0.36, 0.40 and 0.41 Kg/capita/day generation of municipal solid waste (Figure 4.1).

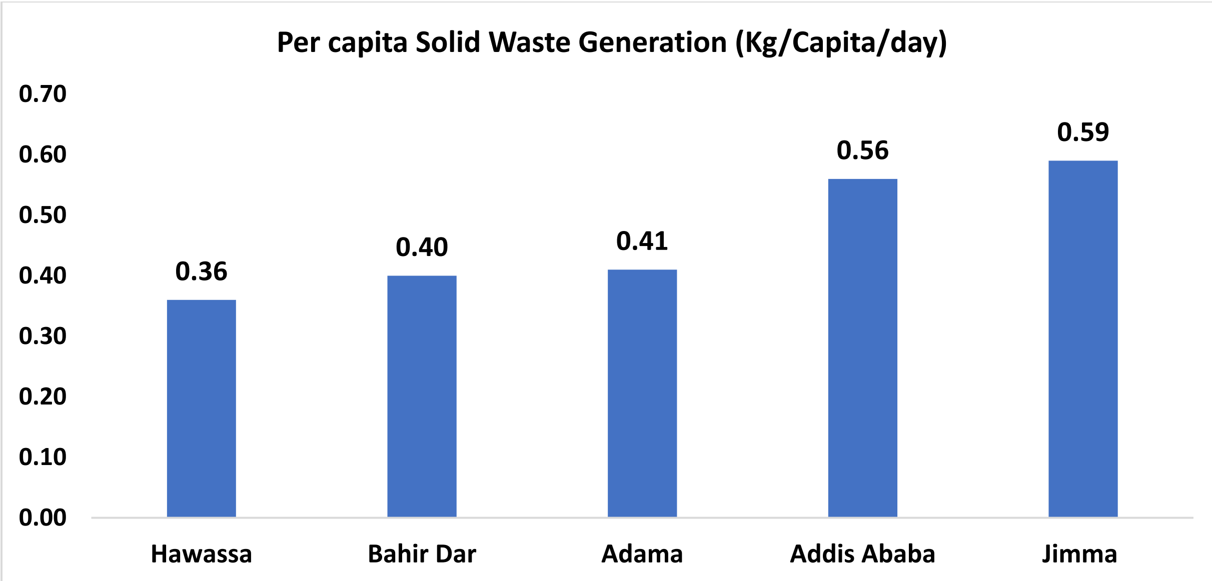

Figure 4.1: Per Capita Solid Waste Generation Rate of the Cities (Kg/Capita/Day).

The city's household solid waste generation trend was analyzed from 2016 to 2021 based on the data found form annual reports of the city's municipalities, from in-depth interview and review of related literatures.

As shown in Figure 4.2, the solid waste generation rate of the five cities increased linearly between 2016 and 2021. The annual household's solid waste generation increased from 52.60 thousand – 67.90 thousand ton with an average annual incremental rate of 5% in Adama city. Similarly, from 32.90 thousand – 51.06 thousand ton with an average annual incremental rate of 5% Bahir Dar city, from 42.20 thousand – 56.10 thousand ton with an average annual incremental rate of 6% in Hawassa city, from 37.90 thousand – 54.00 thousand ton with an average incremental annual rate of 7% in Jimma town and from 667.00 thousand – 789.51 thousand ton with an average annual incremental rate of 3% in Addis Ababa city. The average solid waste generation rate of the five cities increased by 5% annually. It is reported that in most cities of the low-income countries the generation rate is increased by 5% annually (Sharma and Jain, 2020).

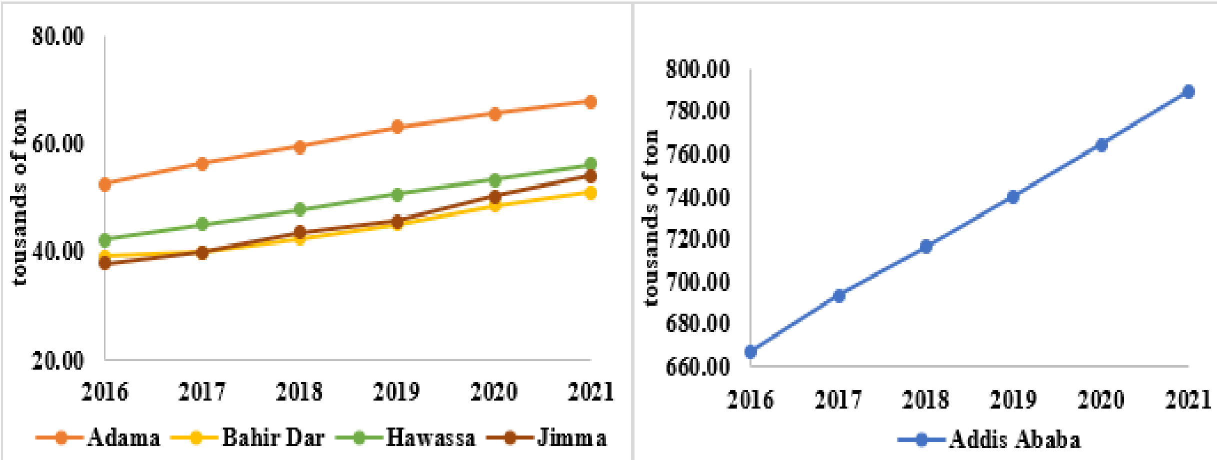

Figure 4.2:Households' annual solid waste generation between 2016 – 2021 for the five cities.

The future projection of households' solid waste generation from 2021 to 2050 was estimated based on the average per capita solid waste generation rate calculated from findings for the five cities (0.46 Kg/capita/day) and the annual incremental of the generation rate, 5%, found from the five cities annual generation reported between 2016 and 2021.

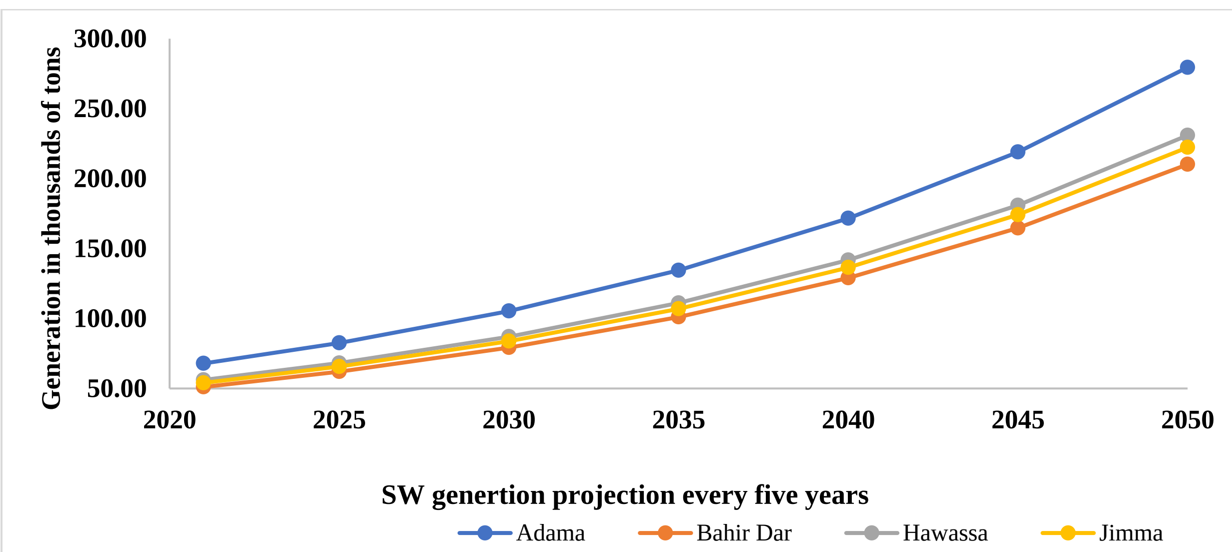

Figure 4.3: Projection of households' annual solid waste generation between 2021 – 2050.

The annual solid waste generation projected between 2021 and 2050 indicated that linear modality of generation will be the common phenomenon in the all the five cities (Figure 4.3, 4.4)

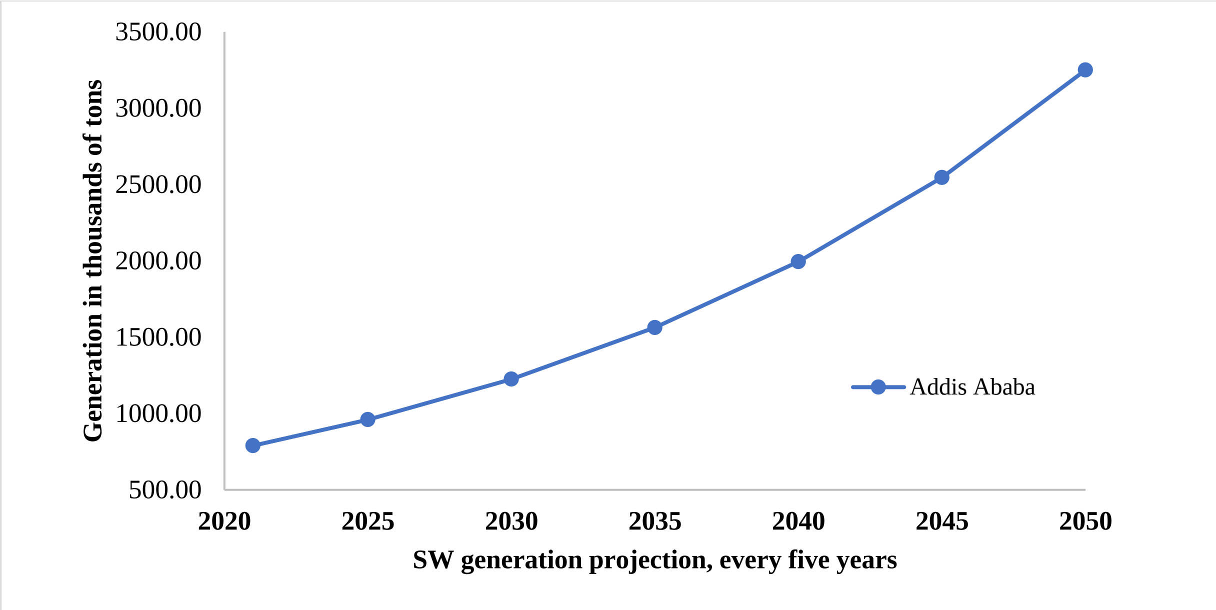

Figure 4.4: Projection of households' annual solid waste generation between 2021 – 2050 in Addis Ababa.

The current households' annual solid waste generation is estimated to project from 67.90 thousand – 279.49 thousand ton in Adama, 51.06 thousand – 210.17 thousand tons in Bahir Dar, 56.10 thousand – 230.92 thousand ton in Hawassa, 54.00 thousand – 222.27 thousand ton in Jimma, 789.51 thousand – 3249.73 thousand ton in Addis Ababa. Based on the projected data, the households solid waste generation rate will be quadrupled by 2050. According to (Kaza et al., 2018), the annual municipal solid waste generation rate of low-income countries is expected to be tripled by 2050, which supports the finding of this study.

4.3.2 SOLID WASTE COLLECTION

The solid waste collection service is one of the major issues of the management system. There is an increase in the capacity of the solid waste collection in terms of service providers and collection facilities. According to the recent data collected from the municipalities of each city; 24, 14, 18, 26 and 90 micro- and small-scale enterprises (MSEs) provide municipal MSW collection in Adama, Bahir Dar, Hawassa, Jima and Addis Ababa cities in 2022, respectively. In Addis Ababa city, 130 private sectors are engaged in MSW collection service provision and additional 30 private sectors engaged in providing trucks for collection (Table 4.1).

Table 4.1:Daily and annual MSW collection and type of service providers in the five cities, October 2022

City	MSEs	No of Trucks	Truck capacity
Adama	24	14	n.i
Bahir Dar	14	15	n.i
Hawassa	18	5	n.i
Jima	26	3	Sino trucks
Addis Ababa	90 and 34 private collectors	30 from private transport providers and 48 from city municipality	City municipality Old trucks:3000 Kg New trucks: 8000 Kg

n.i: not identified.

With the existing solid waste collection service providers in the five cities, the annual report of the cities implied that the collection trend between 2016 and 2022 is increasing. In Adama city, the annual MSW generation increased from 52.60 thousand tons in 2016 to 71.30 thousand tons in 2022 while the annual collection increased from 23.67 thousand tons in 2016 to 46.34 thousand ton in 2022. Similarly; the annual MSW generation in Bahir Dar, Hawassa, Jima and Addis Ababa increased from 39.20, 42.20, 37.90, 667.00 thousand tons in 2016 to 53.61, 58.91, 56.70, 828.98 thousand tons in 2022, respectively while the annual collection increased from 18.82, 21.94, 15.92, 473.57 thousand tons in 2016 to 34.85, 40.06, 36.86, 696.35 thousand tons in 2022, respectively (Table 4.2).

Table 4.2 :Annual MSW generation and collection between 2016 and 2022 in the five cities.

	Annual Household MSW generation ($x10^3$ ton)							Annual MSW collection ($x10^3$ ton)						
City	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**
Adama	52.60	56.30	59.42	63.01	65.51	67.90	71.30	23.67	27.02	30.30	34.66	38.00	40.74	46.34
Bahir Dar	39.20	40.00	42.35	45.08	48.51	51.06	53.61	18.82	20.00	22.87	27.05	30.07	31.66	34.85
Hawassa	42.20	45.00	47.80	50.63	53.30	56.10	58.91	21.94	24.75	27.72	30.38	34.64	36.47	40.06
Jimma	37.90	40.00	43.60	45.74	50.30	54.00	56.70	15.92	18.00	22.24	25.16	30.68	33.48	36.86
Addis Ababa	667.00	693.36	716.24	739.87	764.29	789.51	828.98	473.57	513.08	537.18	577.10	611.43	663.9	696.35

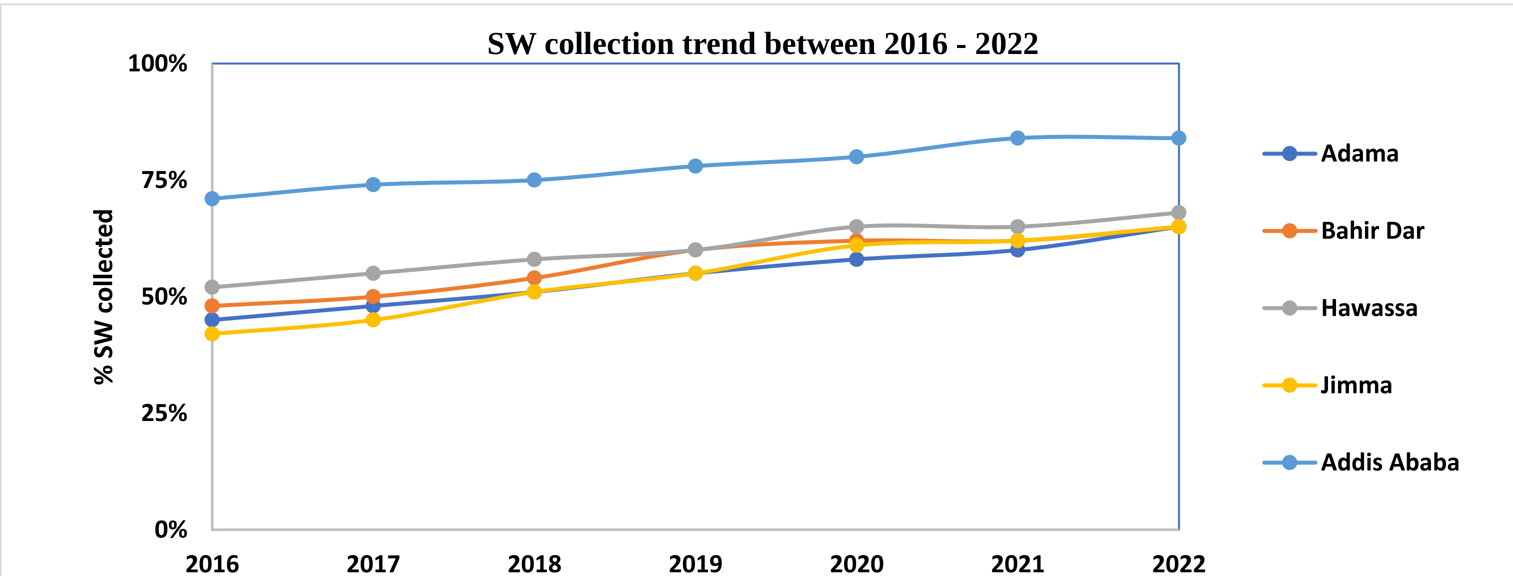

Figure 4.5: Percentage of the annual MSW collected from the total MSW generated from households in the five cities.

The annual MSW collection capacity of Adama, Bahir Dar, Hawassa, Jima and Addis Ababa cities increased by 20, 17, 16, 23 and 18% between 2016 and 2022, respectively. Recently the annual collection capacity of the cities ranged between 65 and 84% (Figure 4.5).

4.3.3 Trend Of Open Dumping and Its Environmental Impacts

In most of the developing countries, including Ethiopia, mismanagement of municipal solid waste is a common cause of environmental impacts practically observed in urban areas. The main factors contributing to the mismanagement includes lack of proper awareness among the community, less social involvement in properly disposing of solid wastes, absence of equipment to handle the solid waste generated from municipalities and improper funding to collect, transport and dispose of the solid waste in a safe manner regularly and properly.

Improper SWM has an impact on the environment as well as on public health. In this study it is found that in 2022 alone, 16 – 35% of the MSW generated from households are uncollected. (Figure 4.6).

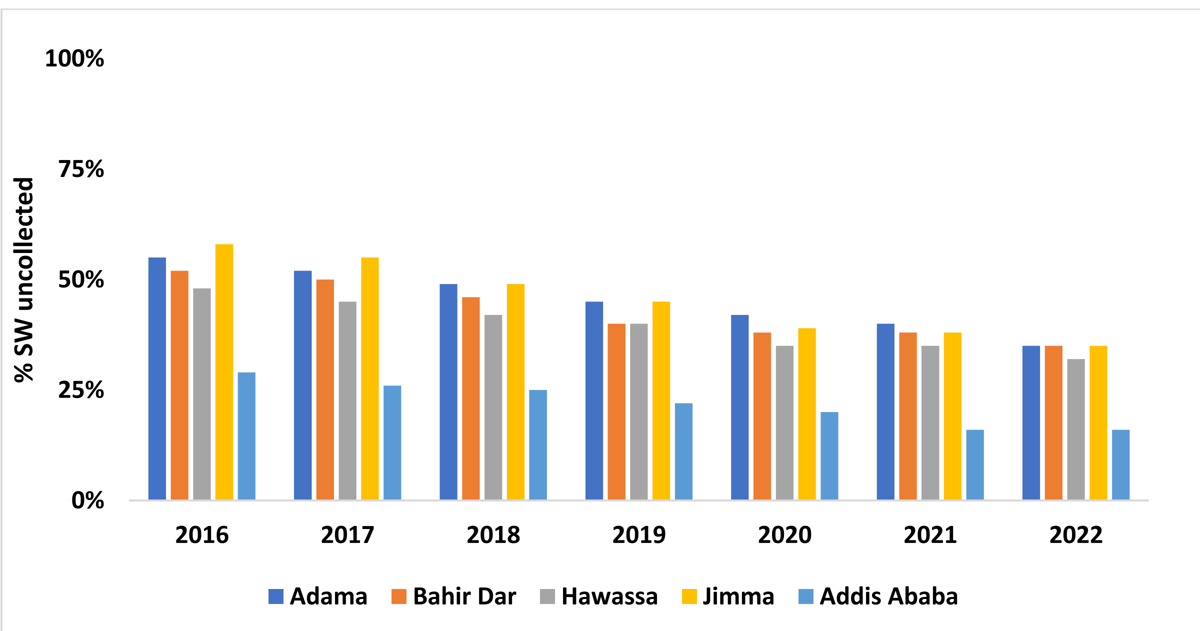

Figure 4.6: Percentage of MSW not collected between 2016 and 2022 in the five cities, Ethiopia.

Lack of proper solid waste collection service and household's improper solid waste disposal are one of the contributors to improper solid waste dumping practice in the towns and cities of Ethiopia. As shown in Figure 4.7, only 36.0% of households reported that their solid waste is collected by formal waste collectors while 24.0% of them disposed in the nearby waste containers. The rest disposed of their solid waste either in their compound (8.0%) or along the roadside, in open spaces or ditches (32.0%).

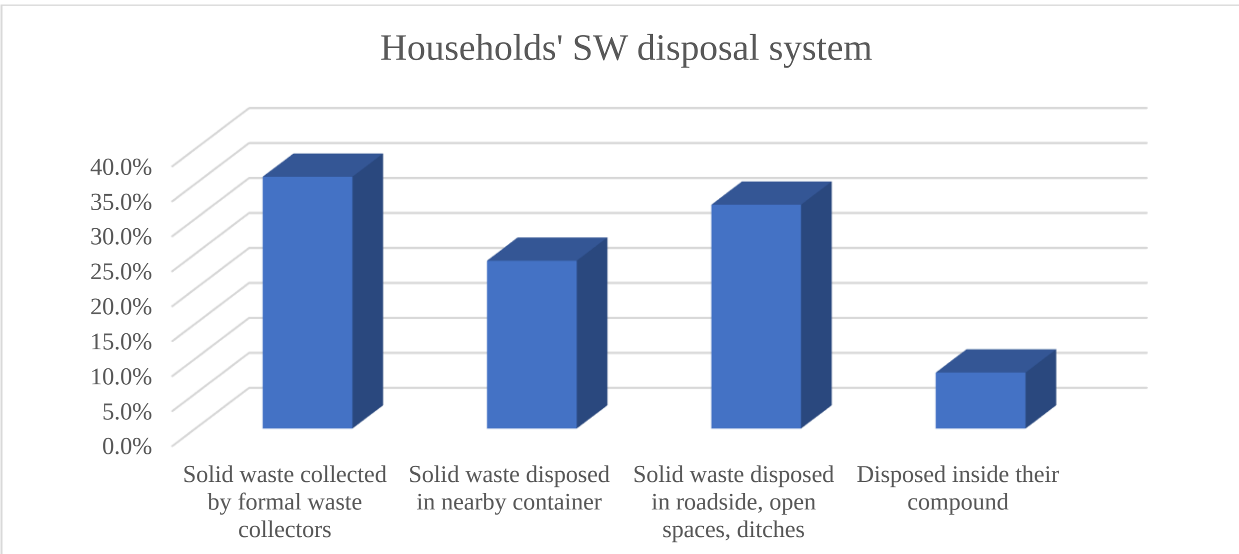

Figure* 4.7: Households*' solid waste disposal system in Bole and Kirkos sub-cities, Addis Ababa, Ethiopia, October 2022.

During the qualitative study, it was found that lack of facilities for solid waste collection, transport and proper disposal as well as budget constraints to full fill all the required human resources and solid waste collection facilities are some of the reasons mentioned as contributing factors for solid waste mismanagement observed in all the study areas (Figure 4.8).

> "Shortage of well-organized and formal solid waste collectors from the private sectors, poor infrastructure and facilities to provide consistent solid waste collection service by the municipalities as well as illegal solid waste disposal practiced by the community are currently contributing to the observed mismanagement in Addis Ababa." *[KII, Male, AA SWM Agency]*

Similar studies conducted in different cities of sub-Saharan countries also indicated that the annual solid waste generation is increasing while the collection capacity is still limited. For instance; recent studies reported that less than 50% of the municipal solid waste in Nairobi and around 60% in Cairo is formally collected and the rest is goes to uncontrolled dumping (Alsobky et al., 2023, Ogutu et al., 2020).

Figure 4.8:MSW collection in the capital city Addis Ababa.

Lack of public awareness on the environmental impact of solid waste mismanagement as well as household's perception about the value of waste also contribute to the current mismanagement practices. Around 45.0% of the study participants for Bole and Kirkos sub-cities in Addis Ababa said that the current solid waste disposal system is not polluting the environment and 32.0% of them said that burning is a good way of solid waste management. Similarly, only 27.0% of households perceived waste as a resource (Figure 4.9).

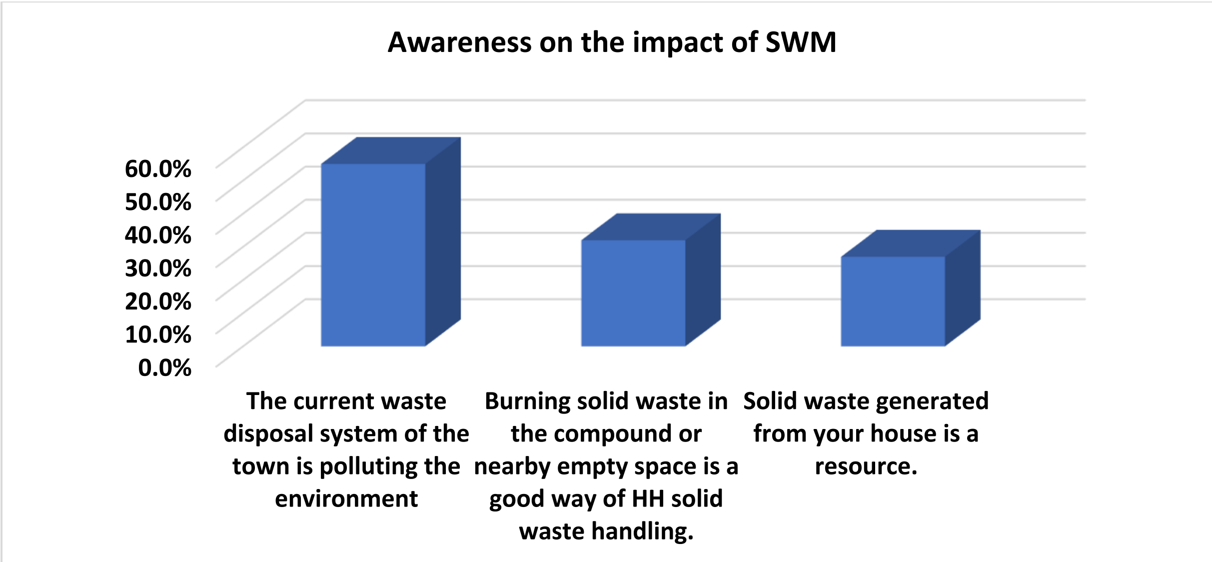

Figure* 4.9: Households*' perception on the environmental impact of solid waste mismanagement in Bole and Kirkos sub-cities, Addis Ababa, Ethiopia, October 2022.

Lack of Sanitary Landfill Sites: Based on this study none of the five cities have properly constructed sanitary landfill site for final solid waste disposal. According to the Addis Ababa SWM agency, the current disposal site is found in the area known as "Reppi/Koshe" and the total area covers 36 hectares. The site has served for more than 60 years and it is an environmental, public health and disaster hazard in the locality. Similarly, the other cities have a final disposal site, uncontrolled open dumping sites, served for at least 20 years and currently the disposal sites are known to accumulate wastes beyond their capacity. The observation done in the study areas confirmed that the current MSWM system is poor and creates nuisance and environmental pollution. All the dumping sites were found uncontrolled with no design to reduce the environmental and public health problems from gas emission and (Figure 4.10). Besides, in 2017, the landslide occurred in "Reppi" open dumping site created a huge disaster and killed more than 110 people.

Figure 4.10 : Uncontrolled solid waste disposal in the study areas.

It is found that uncontrolled open dumping and illegal disposal is commonly practiced in the five cities and cause several environmental impacts: including nuisance, vector manifestation, contamination of land and settlement areas and nearby water bodies and aquifers. According to the KII participants, illegal solid waste dumping also causes short-term and long-term public health issues in the towns, including asthma, congenital illnesses, stress and anxiety, headaches, dizziness and nausea and eye and respiratory infections.

The solid waste dumped in wrong places and not properly collected commonly causes blockage of cities sewage and drainage systems, which leads to water stagnation and flooding. The stagnated water is also known for its cause of public health effects. Improper dumping is also a source of various disease vectors including files and rodents, which in turn causes occurrence of vector borne diseases. Burning of solid waste materials is also one of the causes of air pollution in urban areas (Figure 4.11).

Figure 4.11: Results of MSW Mismanagement in the study area.

Several studies also implied that uncontrolled dumping sites are the primary cause of GHGs like methane (CH_4) and carbon dioxide (CO_2) and contribute to global warming and climate change (Ghosh et al., 2023, Sauve and Van Acker, 2020, Vaverková, 2019, Gautam and Agrawal, 2021).

Large-sized open dumping sites were also the major source of contaminants from their leachates, including heavy metals, persistent organic pollutants, phosphates (PO^{3-}_4) and oxides of nitrogen (NO_x) which severely affect the ecosystem and human health (Ghosh et al., 2023, Vaverková, 2019).

4.4 CONCLUSIONS

The following major conclusions are drawn:

1. The trend of the annual municipal solid waste generation rate from residential areas in the five cities increased linearly between 2016 and 2021. The annual increase in municipal solid waste generation ranged between 3 – 7% with an average increase of 5%/year.
2. The future projection analyzed from 2021 and 2050 indicated that the solid waste generation in the five cities will be quadrupled by 2050.
3. There is an increase in the solid waste collection service provision. The recent annual solid waste collection capacity in Adama, Bahir Dar and Jima cities reached 65%, while 68% in Hawassa and 84% in Addis Ababa.
4. None of the five cities have modern sanitary landfill sites. The existing final disposal sites are uncontrolled and open dumping sites.
5. The cities practiced 16 – 35% uncontrolled and illegal solid waste dumping in roadsides, water bodies, sewerage lines and open spaces. Uncontrolled practices in open dumping sites were found to have an impact on surface- and groundwater bodies, on settlement areas and the disposal lands, on the ecosystem and affect public health. Uncontrolled disposal of municipal solid waste contributes to the emission of greenhouse gases like CO_2 and CH_4. The leachates also contaminate the nearby surface water, aquifers, and settlements.

CHAPTER 5

ESTIMATION OF JOB CREATION FROM THE SOLID WASTE MANAGEMENT SECTOR IN THE CITIES

Author: ASEGID GETACHEW YIMENU

ABSTRACT

The municipal solid waste management sector is becoming a development sector for its contribution towards economic growth and job creation opportunities. The solid waste collection, recycling and resource recovery sectors are contributing not only for integrated solid waste management but also for their job opportunity. However, in most developing countries, including Ethiopia the municipal solid waste management sector is neglected and underutilized for its contribution to the national economy, job creation and resource conservation. In this study, the number of jobs created in the municipal solid waste management sector in the five cities were investigated and future job creation potential of the sector is estimated.

The municipal solid waste collection sector created a total of 46,000jobs for primary waste collectors in the five cities. The recycling and composting sector created 4,043 jobs in Addis Ababa city. The sector also created many jobs for informal waste collectors, especially for those engaged in collection of recyclables like plastics and metals. In this study, it was found that the current job created by the sector is very limited; however, by the end of 2030 it has a potential of creating 52,000 – 260,002 jobs in the five cities if the waste management system is improved and integrated with the economic and development activities of the cities. The solid waste management sector can also contribute to the circular economy of the five cities by developing the recycling, remanufacturing, and resource recovery sector and by creating private partnerships.

***Keywords**: Job creation, recycling, resource recovery, circular economy*

5.1INTRODUCTION

Recently, municipal solid waste management has become one of the major development sectors for its global contribution towards economic growth and job creation opportunities. The rapid increase in the annual generation of municipal solid waste is requiring a huge labor and workforce for efficient collection, transfer and transport, recycling and resource recovery as well as for proper final disposal (eco-cycle, 2023).

In the developed countries, the municipal solid waste management sector is more practically integrated with the circular economy. In countries like USA, Germany, Holland, Norway and China; integration of municipal solid waste management with their national circular economy is already enforced with their national policies and strategies for its significance for efficient utilization of resources from the waste stream, environmental and public health benefits as well as for its contribution towards economic growth and job creation (Elagroudy et al., 2016, Bolaane and Isaac, 2015, Wagner et al., 2019, Sharma et al., 2021).

In 2021, the global waste management market size was $989.2 billion, and the revenue is forecasted to be 1,685.5 billion by 2030. The urban waste management takes the second largest fraction next to industrial waste management market (Grand View Research, 2023).

However; in most developing countries, including Ethiopia the municipal solid waste management sector is neglected and underutilized for its contribution to the national economy, job creation and resource conservation (Kituku et al., 2020, Nzeadibe, 2009, Das et al., 2019, Zhang et al., 2010). Besides, little is studied to identify the job creation potential of the sector for solid waste collection service provision, recycling, biogas production and composting, landfill disposal and other related services.

This chapter therefore aimed to explore the job creation potential of the municipal solid waste management sector in the five cities as well as in Ethiopia.

5.2 METHODOLOGY

5.2.1 Study Area

The study was conducted in five cities of Ethiopia – Addis Ababa, Bahir Dar, Jimma, Adama and Hawassa. **Addis Ababa** is the capital city of Ethiopia. The city is the seat of regional and international organizations. The city is located at 9° 1’ 48” N, 38° 44’ 24” E at an elevation of 2,355 meters above sea level (asl). The city administration has organized it into eleven sub-cities. According to CSA 2022 population size estimation; the city has a total population of 3,860,000 (2,038,000 of them are Females). **Bahir Dar** is the capital city of Amhara Regional State, Ethiopia, found 578 km northwest of Addis Ababa. The city is one of the leading tourist destinations in Ethiopia. It has a variety of attractions including Lake Tana and Blue Nile River. The city is located at 11° 36' 0" N, 37° 23' 0" E at an elevation of 1,800 meters asl. The city has organized into six sub-administrative sub cities with a total population size of 349,995 (175,571 of them are Females) (CSA, 2022). **Hawassa** is the capital city of the Southern Nations, Nationalities and People Regional State (SNNPR) and the newly emerged Sidama Regional State, Ethiopia, found 273 km south of Addis Ababa. The city is situated on the shore of Lake Hawassa in the Great Rift Valley. The city is located at 7° 3' 0" N, 38° 28' 0" E at an elevation of 1,708 meters asl. The city has organized into eight sub-administrative sub cities. According to CSA 2022, the total population size of the city estimated to be 422,202 (213,432 of them are Females). **Adama**, formerly known as Nazreth is a city in the central Oromia Region of Ethiopia. The city is located 99 km southeast of Addis Ababa at the base of an escarpment to the west and the Great Rift Valley to the east. The city is located at 8° 30' 52" N, 39° 16' 9 " E at an elevation of 1,712 meters asl. The city has organized into 10 sub cities with a total population size of 458,868 (233,308 of them are Females) (CSA, 2022). **Jimma** is the largest city in the southwestern Oromia Region, Ethiopia. The city is located 350 km southwest of Addis Ababa. It is located at 7° 40' 0" N, 36° 50' 0 " E at an elevation of 1,780 meters asl. Jimma is a forested region known for its coffee plantations and serves as the commercial center for the region, handling coffee and other products. The city has organized into 18 sub-administrative Kebeles and according to CSA 2022, the total population size estimated to be 250,909 (126,012 of them are Females).

5.2.2 Data Collection

Municipal solid waste management as one of the major sectors of sustainability was assessed for its current job creation potential in the five cities and used to estimate future job creation capacity of the sector. In this regard, both primary and secondary data collected from relevant stakeholders and document review were used to estimate the job creation potential of the municipal solid waste management sector in the five cities and to extrapolate its capacity at the national level.

The contribution of the sector towards the circular economy and national economic growth were also assessed in this section of the study. Descriptive statistical analysis was done, and graphs and figures were used to narrate major findings of the study. Results were further discussed by comparing international and national reports and published articles.

5.3RESULTS AND DISCUSSION

The current municipal solid waste management service provision and the number of jobs created for solid waste collection service, recycling of materials, composting and landfill service were analyzed for the five cities.

5.3.1 Municipal Solid Waste Collection Service

The MSWM sector has the potential to create many job opportunity at the national level. In Adama city, 24 formally organized MSEs with 1,200 primary waste collectors are providing house to house solid and collection from dustbins. In Addis Ababa City, 90 MSEs with 36,770 members and 34 private associations are engaged in MSW collection and transport service provision in 6,000 collection zonings. Besides, around 4000 workers are engaged in transfer and sorting in 400 selected sites. In Bahir Dar City, 14 MSEs with 1,280 primary waste collectors are providing the solid waste collection service. Similarly, 18 MSEs with 1,120 workers and 26 MSEs with 1,630 workers are providing the solid waste collection service in Hawassa city and Jima town, respectively (Table 5.1). In general, the municipal solid waste collection sector creates a job opportunity for more than 12,000 individuals.

Table 5.1: Number of enterprises, private sectors and number of primary waste collection workers in the MSW collection service in the five towns, Ethiopia, October 2022.

City	MSEs	No of primary waste collectors
Adama	60	1,200
Bahir Dar	50	1,280
Hawassa	50	1,120
Jima	30	1,630
Addis Ababa	500	40,770 operating in 6000 zonings

	34 private companies	n.i
	n.i	4,000 operating in 400 transfer sites
Total	**690**	**4600**

n.i: not indicated.

5.3.2 Recycling and Composting

Recycling and remanufacturing industries can create huge job opportunities if the municipal solid waste management system is well organized and follow the integrated solid waste management approach. In Ethiopia, recycling and remanufacturing is not well developed and only small number of private companies are engaged in the sector.

The informal waste collection system plays a significant role in the recycling sector. Recyclables, including plastic bottles, cardboard, papers, and scrap metals are commonly collected by scavengers from landfill sites and waste collection areas. Informal collectors locally known as "Korale" buy materials like old shoes, large jerrycans, broken appliances and other reusables from community and sell to wholesalers and private recycling companies. The informal waste collection sector plays an important role in the five cities experiencing inadequate formal waste collection service provision (Baudouin et al., 2010). It contributes to the economic activities of the cities by supplying raw materials for remanufacturing and other industries. It has a positive impact on the environment and natural resource utilization.

Regarding the number of jobs created in the recycling and remanufacturing industries; the number of jobs created for recyclable material collection from the waste stream is not well documented in the five cities since majority of the workers engaged in sector are informal waste collectors.

In Addis Ababa city, 96 private sectors with 1,157 workers are engaged in paper recycling while 120 private sectors with 1,226 workers are engaged in plastic recycling. In Adama city, 2 private sectors are engaged in paper recycling and in Bahir Dar city 1 private sector is engaged in plastic recycling. In Jima town, 1 private sector is engaged in plastic recycling. Similarly, 1 private sector is engaged in plastic recycling in Hawassa city. Regardless of its huge potential, the number of jobs created in the waste recycling and remanufacturing sector is very limited and not well documented.

In the five cities, the major fraction of solid waste generated from households are organic wastes and composting can be taken as an option for resource recovery from the waste stream as well as for its job creation potential. In Addis Ababa city, 160 private sectors with 1,660 members are formally engaged in compost preparation. In the other 4 cities, MSEs are also engaged in compost preparation from the municipal organic waste fraction.

5.3.3 Future Job Creation Potential of The Municipal Solid Waste Management Sector

The 2030 Agenda for sustainable development promotes sustained and inclusive economic growth, full and productive employment and decent work (UN, 2015). However, the high unemployment rate is still one of the major challenges of the economy in most of the developing countries with an emerging economy (Benanav, 2019).

In Ethiopia, the emerging economy and the rapid population growth should be properly managed with efficient utilization of the work force. In this regard, the potential of the economy to absorb the ever-increasing labor force required proper design and implementation of national policies and strategies with regular monitoring system.

According to the recent survey conducted by CSA Ethiopia, the national unemployment rate is 8% where the urban unemployment rate is 17.9% (25.4% Female and 11.2% Male). The unemployment rate in the five cities, where this study was conducted, were found 20.1% (30.0% Female and 11.3% Male) (CSA Ethiopia, 2021).

Table 5.2 :Unemployment rate in the five cities, Ethiopia. Source: (CSA Ethiopia, 2021)

City/Town	Unemployed population			Unemployment rate		
	Male	Female	Total	Male	Female	Total
Adama	15,786	45,136	60,922	13.2	42.4	26.9
Bahir Dar	13,080	33,632	46,713	8.3	23.6	15.6
Hawassa	8,371	22,174	30,544	8.3	27.6	16.9
Jima	6,721	15,279	22,000	11.3	27.6	19.2
Addis Ababa	145,821	271,782	417,603	15.3	29.0	22.1
Total	**189,779**	**388,003**	**577,782**	**11.3**	**30.0**	**20.1**

As shown in Table 5.2, the highest unemployment rate (26.9%) was reported for Adama city while the lowest (15.6%) was reported for Bahir Dar city. In all the five cities, female unemployment rate is found higher than male unemployment rate and the highest female unemployment rate (42.4%) was reported for Adama city and the lowest (23.6%) was reported for Bahir Dar city.

On the other hand; it is reported that MSEs are major drivers of economic growth and job creation in the global economy and labor market, especially, contribution of MSEs to absorb the large labor force in the developing countries were found significant (Godfrey et al., 2017, Endris and Kassegn, 2022).

In Ethiopia, MSEs are the second largest job creating sector next to the agricultural sector. According to the Entrepreneurship Development Center (EDC) of Ethiopia, there are 1.5 million MSEs employing 4.5 million people and generating 40.7 billion ETB in monthly sale in 2020 and most of the MSEs are engaged in manufacturing sector. The Job Creation Commission (JCC) of Ethiopia has developed a plan of action to create 14 million new jobs between 2020 – 2025 by designing a holistic intervention to absorb around 2 million new job seekers entering to the market every year.

In this regard, several studies conducted at global and regional level implied that the municipal solid waste management sector has a huge potential to absorb a large fraction of unemployed labor force with multiple benefits; including economic growth, job creation, environmental protection, natural resource conservation and public health (Grand View Research, 2023, eco-cycle, 2023, Tripathi et al., 2022).

Municipal solid waste collection usually requires many laborers to improve the basic solid waste collection service provision and efficiency of the system. Recycling, resource recovery and landfills can also absorb significant labor force and can be taken as important sector for their job creation potential as well as for their significant contribution to the circular economy (Pires and Martinho, 2019, Wagner et al., 2019, Sharma et al., 2021).

The International Labor Organization (ILO) estimates that the global employment can grow by 6 million jobs if the traditional economic model is replaced by the circular economy that includes activities like recycling, repair, re-manufacturing and resource recovery from the waste stream (ILO, 2022). In Europe, where most countries integrate the principle of the circular economy in their national policy, the solid waste management sector created 2.9 million jobs (Zero Waste Europe, 2023). In USA, the solid waste management and remediation services sector engaged 480,500 labor in the national market in 2022 with an increasing rate of 3.85% compared with 2021 (eco-cycle, 2023).

In Ethiopia, the solid waste management sector is neglected and not properly utilized for its job creation potential. In this regard, the economic growth and job creation policies and strategies of Ethiopia should consider the solid waste management sector as one of the potential labor force absorbing sectors. In this regard, the municipal solid waste collection sector can create a huge job opportunity if effective solid waste management system is designed, integrated with other relevant sectors and appropriate policy and strategies that are geared towards a national circular economy should be developed at the national and regional levels as well as properly cascaded by local authorities, mainly municipalities.

In order to significantly improve the municipal solid waste collection service provision of the five cities, to engage the informal waste collection and recycling sector currently operating in the cities as well as to improve the recycling, resource recovery, and landfill services with short- and long-term implementation strategies; a large number of labor force should be engaged in the solid waste management sector.

In this study, from the total economic and development sectors (like manufacturing, agriculture, service providers) operating in the five cities, it is assumed that the solid waste management sector can contribute a minimum of 1% and a maximum of 5% for the annual job created. The assumption considers the status of the solid waste management service provision of the cities, major challenges hindering the cities' municipal solid waste management system, future policies and strategies of the sector as well as the circular economic activities of the cities.

Table 5.3:Number of additional jobs that can be created from the municipal solid waste management sector by 2030 in five cities, Ethiopia.

City/Town	Unemployed population in 2021			Estimated new job by 2030 with 1% annual contribution			Estimated new job by 2030 with a 5% annual contribution		
	Male	Female	Total	Male	Female	Total	Male	Female	Total

Adama	15,786	45,136	60,922	1,421	4,062	5,483	7,104	20,311	27,415
Bahir Dar	13,080	33,632	46,713	1,177	3,027	4,204	5,886	15,134	21,021
Hawassa	8,371	22,174	30,544	753	1,996	2,749	3,767	9,978	13,745
Jima	6,721	15,279	22,000	605	1,375	1,980	3,024	6,876	9,900
Addis Ababa	145,821	271,782	417,603	13,124	24,460	37,584	65,619	122,302	187,921
Total	**189,779**	**388,003**	**577,782**	**17,080**	**34,920**	**52,000**	**85,401**	**174,601**	**260,002**

As shown in Table 5.3, it is estimated that the municipal solid waste management sector can create a minimum of 52,000 jobs (17,080 for females) and a maximum of 260,002 jobs (85,401 for females) in the five cities by the year 2030.

The MSWM sector is estimated to contribute to 9.0 – 45.0% of new employment by 2030 with the assumption of a 1 – 5% annual contribution of job creation in at the national level (Figure 5.1).

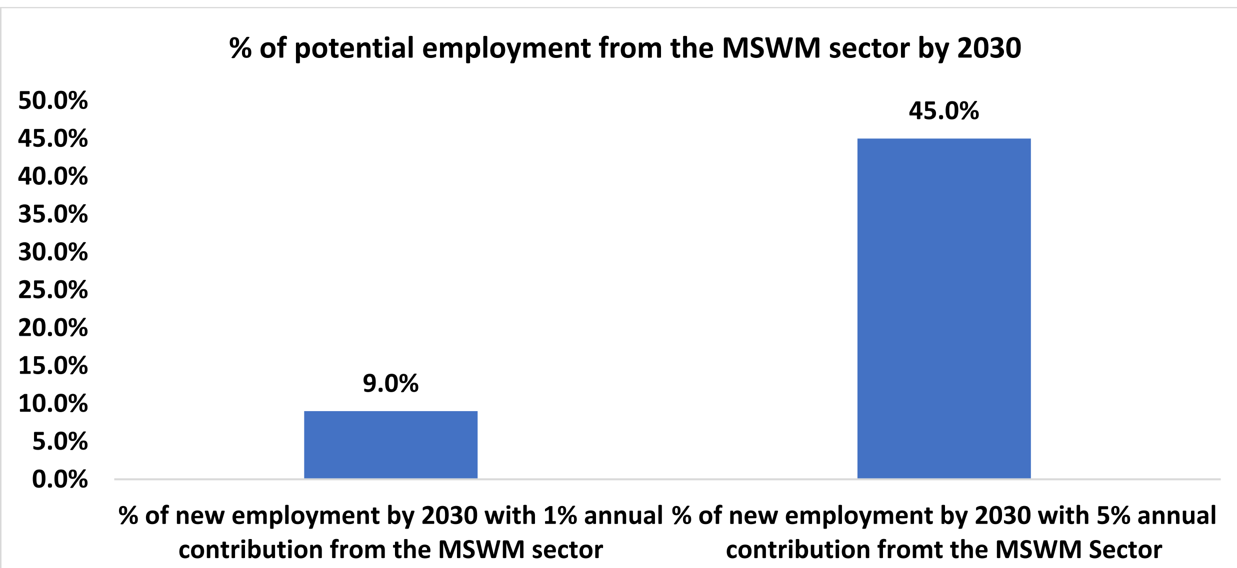

Figure 5.1: Percentage of potential employment from the MSWM sector by 2030.

The solid waste management sector usually requires the engagement of youths with different qualifications. The solid waste collection sector usually requires less qualification, and it can be done with short-term skill-based trainings. On the other hand, recycling, resource recovery and some managerial works usually required qualifications, including certificate or diploma form technic and vocation schools or degree from universities. In this regard, the job creation potential of the solid waste management sector to youths with high school certificate, diploma and degree from higher institutions is more relevant and requires specific attention during implementation.

In Ethiopia, the youth unemployment rate is reported as 6.33% in 2022 and more specifically, the unemployment rate for graduates of public universities in Ethiopia is 42.0% (CSA Ethiopia, 2021). In this regard, the road map needs to consider the following scenario during implementation. Of the total unemployed population, at least 50% should consider the youth. Since the solid waste collection sector required more labor, 70% of the youth from high school graduates should be considered for the solid waste collection jobs and 30% of the youth graduated from higher institutions should be considered for recycling, resource recovery and managerial jobs.

Table 5.4:Number of jobs that can be created for different qualifications by the municipal solid waste management sector by 2030 in the five cities, Ethiopia.

City/Town	Estimated new job by 2030 with 1% annual contribution						Estimated new job by 2030 with 5% annual contribution					
	Male			Female			Male			Female		
	High school	Higher education	Others	High school	Higher education	Others	High school	Higher education	Others	High school	Higher education	Others
Adama	497	213	711	1,422	609	2,031	2,486	1,066	3,552	7,109	3,047	10,156
Bahir Dar	412	177	589	1,059	454	1,514	2,060	883	2,943	5,297	2,270	7,567
Hawassa	264	113	377	699	299	998	1318	565	1,884	3,492	1,497	4,989
Jima	212	91	303	481	206	688	1,058	454	1,512	2,407	1,031	3,438
Addis Ababa	4,593	1,969	6,562	8,561	3,669	12,230	22,967	9,843	32,810	42806	18,345	61,151
Total	**5,978**	**2,562**	**8,540**	**12,222**	**5,238**	**17,460**	**29,890**	**12,810**	**42,701**	**61,110**	**26,190**	**87,301**

As shown in Table 5.4, it is estimated that the municipal solid waste management sector can create a minimum of 7,000 jobs (5,238 for females) and a maximum of 39,000 jobs (26,190 for females) for higher education graduates and a minimum of 18,200 jobs (12,222 for females) and a maximum of 91,000 jobs (61,110 for females) for high school graduates in the five cities by the year 2030. The MSM sector can create 3.2 – 15.7% of new employment for high school graduates and 1.4 – 6.8% for higher education graduates (Figure 5.2). However, the implementation should be supported by all relevant stakeholders, mainly policy- and decision-makers.

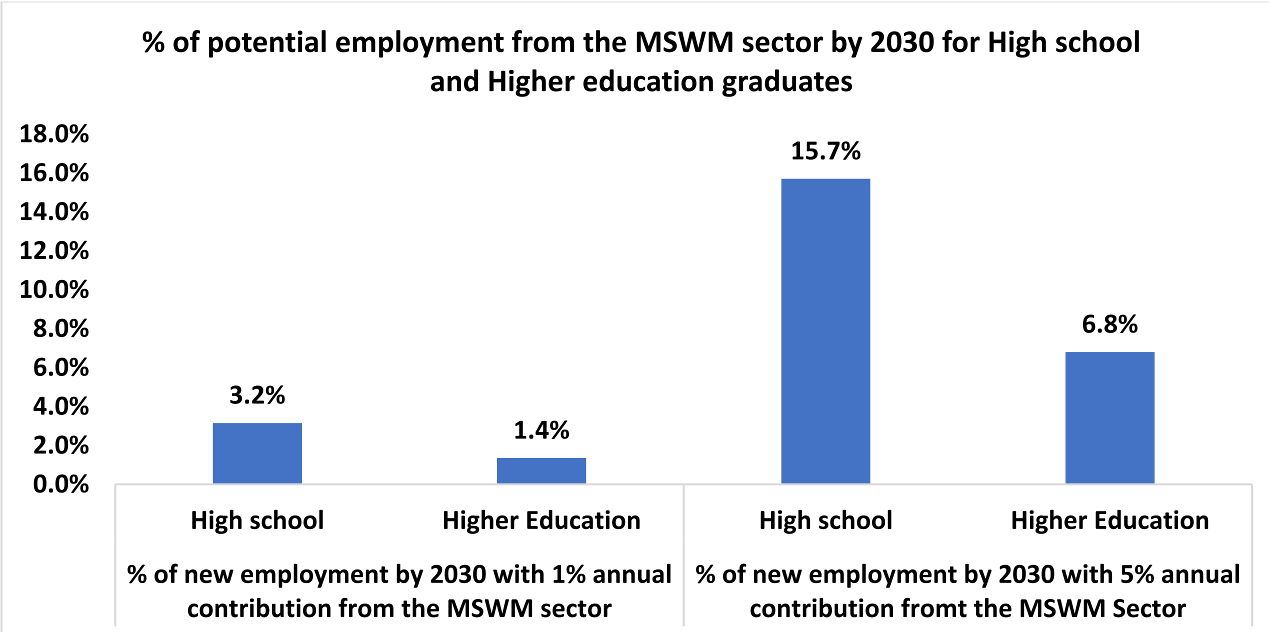

Figure 5.2: Percentage of potential employment from the MSWM sector by 2030 for high school and higher education graduates

7.3 CONCLUSIONS

It is concluded that.

1. The municipal solid waste collection sector created 18,000 jobs for individuals organized in 206 legal MSEs in the five cities.
2. From the total job created in the MSWM sector, the recycling and composting sector created 1,157 (6.1%) jobs in paper recycling sector, 1,226 (6.8%) jobs in plastic recycling and 1,660 (8.4%) job in compost preparation.
3. The municipal solid waste sector can create a job opportunity for 52,000 – 260,002 job seekers by the year 2030 who can contribute to improve the municipal solid waste service provision of the five cities. The sector can also engage 50.0% of unemployed youths, where 70.0% for high school graduates and 30.0% for higher education graduates.
4. Informal waste recyclers largely contribute to the collection of recyclable materials, including paper, plastics and metals.
5. The collection, recycling and composting sectors are contributing to the economic activity and the circular economy of the five cities. However, it requires special policy level attention to enhance the economic benefit of the sector.

CHAPTER 6

MAJOR CHALLENGES OF THE MUNICIPAL SOLID WASTE MANAGEMENT PRACTICES IN THE CITES

Author: ASEGID GETACHEW YIMENU

ABSTRACT

Municipal solid waste management is a global challenge due to the increase in solid waste generation and complexity of the waste type and characteristics. In most developing countries, the functional elements of the solid waste management system are not properly functional, and the service provision is challenged by several problems.

In this study, it is found that lack of an efficient and suitable municipal solid waste collection method due to financial and technical problems, poor infrastructure, including lack of the standby solid waste disposal capacity and landfills as well as poor public awareness on the impact of ill management on the environment and human health are severely challenging the municipal solid waste management system of the five cities addressed in this study. Furthermore, the management system was found equally challenged from poor enforcement of legislation. The roles and responsibilities stated in the national solid waste management proclamation of Ethiopia were found to be poorly implemented by local authorities of the cities.

Keywords*: Waste management challenges, financial constraint, poor governance, solid waste policy framework*

6.1 INTRODUCTION

Municipal solid waste management is a global challenge due to the increase in waste generation and the complexity of the waste type. The process and practice of proper solid waste management is not equally advanced with the increase in the generation rate as well as the type and complexity of the solid waste generated (Das et al., 2019, Powell et al., 2018).

In most developing countries, the functional elements of the solid waste management system are not properly functional, and the service provision is challenged by several problems. Lack of an efficient and suitable municipal solid waste collection method, lack of the standby solid waste disposal capacity and landfills and lack of awareness on impacts of illegal and open dumping are severely challenging the municipal solid waste management system in cities and towns as well in rural areas (Das et al., 2019, Kaza and Yao, 2018).

In Ethiopia; rapid population growth, urbanization and economic growth have led to an increase in solid waste generation both in terms of quantity and complexity (Hirpe and Yeom, 2021, Nigatu et al., 2011, Wondafrash, 2017). The solid waste management system of Ethiopia is challenged by several factors including, poor public awareness, inadequate solid waste collection service provision, lack of vehicles for transportation and lack of transfer sites, lack of treatment facilities and lack of sanitary landfill sites for final disposal. Besides; poor implementation of policies, strategies and legislations are also challenging the overall management system (Diriba and Meng, 2021, Teshome, 2021).

In this study, major challenges of the municipal solid waste management system of the five cities were addressed in order to recommend measures for future improvement of the sector.

6.2 METHODOLOGY

6.2.1 Study Area

The study was conducted in five cities of Ethiopia – Addis Ababa, Bahir Dar, Jimma, Adama and Hawassa. **Addis Ababa** is the capital city of Ethiopia. The city is the seat of regional and international organizations. The city is located at 9° 1’ 48” N, 38° 44’ 24” E at an elevation of 2,355 meters above sea level (asl). The city administration has organized it into eleven sub-cities. According to CSA 2022 population size estimation; the city has a total population of 3,860,000 (2,038,000 of them are Females). **Bahir Dar** is the capital city of Amhara Regional State, Ethiopia, found 578 km northwest of Addis Ababa. The city is one of the leading tourist destinations in Ethiopia. It has a variety of attractions including Lake Tana and Blue Nile River. The city is located at 11° 36' 0" N, 37° 23' 0" E at an elevation of 1,800 meters asl. The city has organized into six sub-administrative sub cities with a total population size of 349,995 (175,571 of them are Females) (CSA, 2022). **Hawassa** is the capital city of the Southern Nations, Nationalities and People

Regional State (SNNPR) and the newly emerged Sidama Regional State, Ethiopia, found 273 km south of Addis Ababa. The city is situated on the shore of Lake Hawassa in the Great Rift Valley. The city is located at 7° 3' 0" N, 38° 28' 0" E at an elevation of 1,708 meters asl. The city has organized into eight sub-administrative sub cities. According to CSA 2022, the total population size of the city estimated to be 422,202 (213,432 of them are Females). **Adama**, formerly known as Nazareth is a city in the central Oromia Region of Ethiopia. The city is located 99 km southeast of Addis Ababa at the base of an escarpment to the west and the Great Rift Valley to the east. The city is located at 8° 30' 52" N, 39° 16' 9 " E at an elevation of 1,712 meters asl. The city has been organized into ten sub cities with a total population size of 458,868 (233,308 of them are Females) (CSA, 2022). **Jimma** is the largest city in the southwestern Oromia Region, Ethiopia. The city is located 350 km southwest of Addis Ababa. It is located at 7° 40' 0 " N, 36° 50' 0 " E at an elevation of 1,780 meters asl. Jimma is a forested region known for its coffee plantations and serves as the commercial center for the region, handling coffee and other products. The city has organized into 18 sub-administrative Kebeles and according to CSA 2022, the total population size estimated to be 250,909 (126,012 of them are Females).

6.2.2 Data Collection

In this section, major challenges of the municipal solid waste management in five cities were addressed. Both primary and secondary data collected using quantitative and qualitative study methods were used to address very crucial challenges of the sector in the five cites. Findings from key stakeholders of the sector and document review were narrated and analyzed to identify key problems and challenges of the municipal solid waste management sector in the five cities as well as to present a way forward for future action and improvement.

6.3 RESULTS AND DISCUSSION

The current SWM services, associated challenges, factors that contribute to the poor SWM system as well as the impact of mismanagement in the urban environment were addressed with quantitative, qualitative and observation methods.

6.3.1 Public Awareness

Regarding households' MSW removal practices, the study participants from Addis Ababa City Administration, Kirkos and Bole sub-cities replied that they dispose their MSW along the road side (13%), in the nearby open space (15%), inside their compound (8%) and in the nearby ditches (4%). On the other hand, 36% of them said their waste is collected by waste collector service providers and 24% of them replied that they dispose their waste in the nearby MSW containers and collected by the service providers Figure 6.1). The finding clearly indicated that around 40% of the households practice a poor MSW removal system.

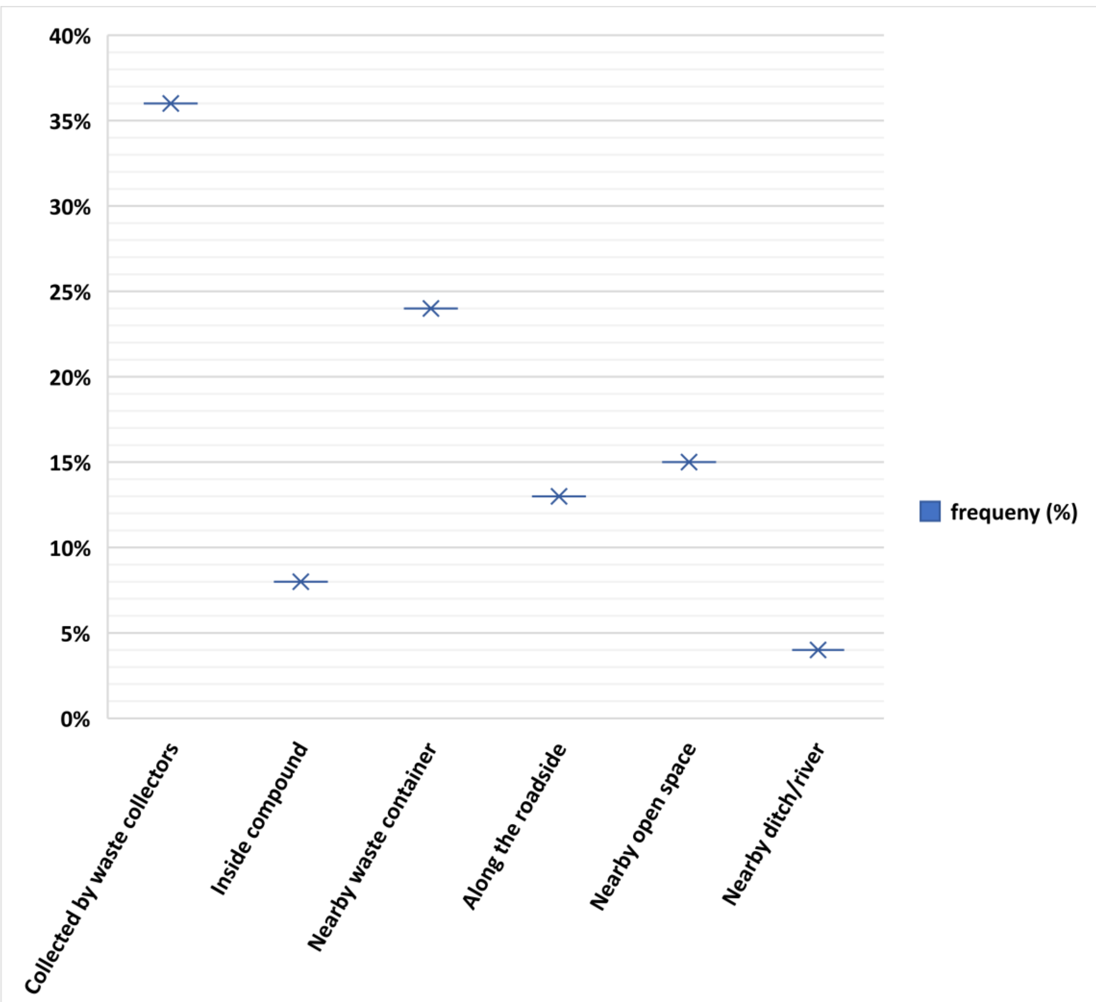

Figure 6.1:Participants' Household solid waste removal practice in Kirkos and Bole sub-cities, Addis Ababa, Ethiopia, October 2022

Similarly, the qualitative study participants also mentioned that households' lack of knowledge, poor awareness and poor SWM practice are major challenges for the provision of effective and efficient SWM system in the cities. Almost all the key informant interview (KII) participants from the municipalities greenery and waste management offices indicated that improper waste disposal including disposal along the roadside, in the nearby open spaces and sewerage ditches and riverbanks are major problems that affect the SWM system. Besides, households commonly practice waste disposal other than the collection days set by the service providers.

> *"*One of the major challenges in the SWM is poor public awareness. Society do not properly dispose their MSW generated from their day-to-day activity. Most of the time they carelessly dispose their waste in the nearby open space, and they are not willing to give their waste to collectors who provide the service 3 – 4 times a week*"*. ***[KII, Male, AA SWM Agency]***

> *"*In our city, the municipality and MSEs are the major MSW collection service providers. However, the community prefers to remove their waste through informal waste collectors and dispose it in the sewerage ditches*"*. ***[KII, Male, Adama City Municipality]***

The KII participants also explained that continuous teaching and promotion were given to the committee on SWM, including on-site storage, sorting at the source, reuse, recycling, resource recovery and proper disposal. However, the change in behaviour is still poor and society still don't practice sorting at the source as well as improper disposal.

> *"*Our office in collaboration with the health extension workers always provides awareness creation to the society. Regardless of the awareness creation works, the society still practices improper solid waste disposal*"*. ***[KII, Male, Bahir Dar City Municipality]***

Regarding household's on-site sorting, reuse practice and composting organic waste; 59%, 66% and 86% of the study participants from Addis Ababa replied that they don't practice on-site sorting, reuse of valuable materials and composting of kitchen and other organic wastes, respectively (Figure 6.2). The KII participants also mentioned that household's awareness and practice of sorting, reuse and composting is poor.

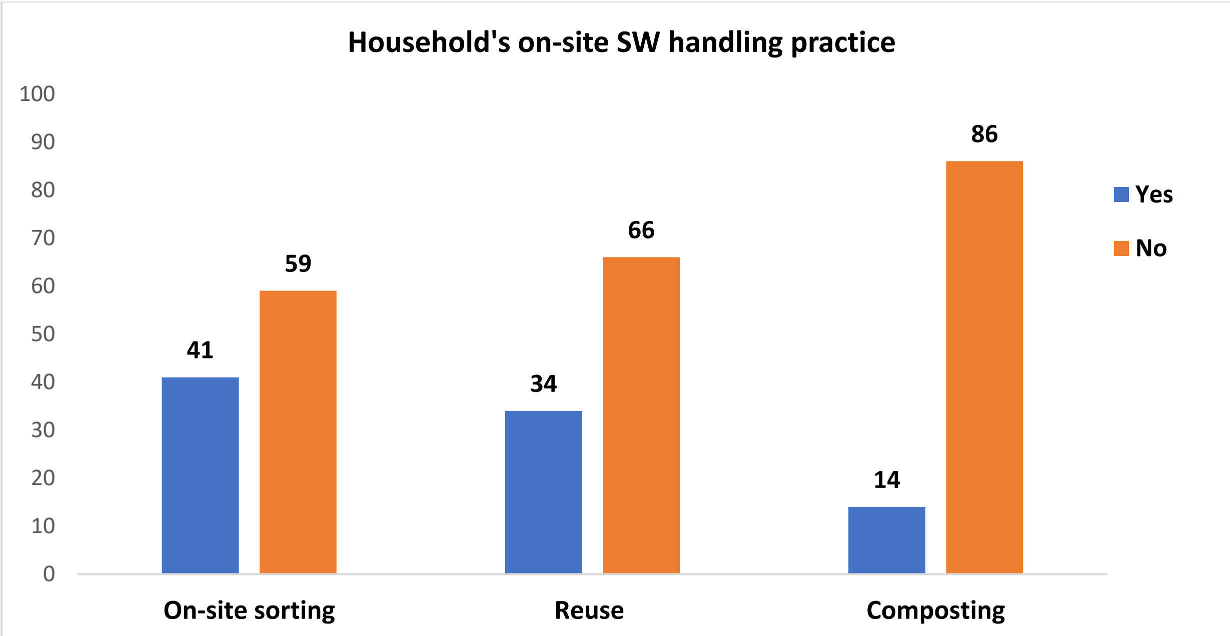

Figure 6.2:Households' MSW on-site sorting, reuse, and composting practice in Kirkos and Bole sub-cities, Addis Ababa, Ethiopia, October 2022

Several studies also indicated that lack of public awareness, especially in developing countries, is one of the major challenges of the municipal solid waste management system (Das et al., 2019, Luong et al., 2013, Joshi and Ahmed, 2016).

6.3.2 Financial Issues

The KII study participants explained that the MSW collection service provision is challenged from multiple factors; including lack of facilities to provide adequate MSW collection service, lack of adequate trucks for transport, lack of facilities for transfer, sorting and resource recovery and lack of sanitary landfill site constructed to the standard.

It is reported that the annual budget allocated in 2020/2021 for the solid waste management sector was 1.1 billion ETB (34 million $), 2.24 million ETB (40,706 $) and 10 million ETB (181,724 $) for Addis Ababa, Bahir Dar and Jima city municipalities. The municipality offices stated that the annual budget allocated for the sector is very small to effectively manage the rapidly increasing municipal solid waste generated from households, institutions, commercial and business centers. The annual budget allocated for solid waste management budget of African cities like Nairobi, Kenya and Pretoria, South Africa were reported as 0.7 million $ in 2020 (Nairobi City County, 2022) and 1.5 million $ in 2021 (CSIR, 2020), respectively. The annual budget of cities in the developed countries like Washington DC, USA was reported as 87.2 million $ (Department of Public Works, 2022) for 2021 alone. The annual budget allocated for Addis Ababa City is higher than other African Cities like Nairobi and Pretoria. However, the management system is still poor and incapable of properly addressing at least the collection and disposal services in a well-organized manner.

All the participants implied that financial constraint is the root cause of all the problems currently occurring in the waste management system of the cities.

> "One of the major problems we have faced to properly implement the SWM service is shortage of budget. As you know, the MSW collection, transport and disposal process is very costly and requires facilities, equipment, and materials to implement proper management system. For instance, heavy vehicles for solid waste collection are very costly and we can't afford to buy them due to financial constraints. The transport system also consumes fuel and shortage of budget to the routine fuel need of the vehicles also disrupt the transport service provision." **[KII, Male, Jima Town Municipality]**

> "The city municipality has a plan to construct standard sanitary landfill. However, the cost of construction is very expensive and still trying to find finance to start the construction" **[KII, Male, Hawassa City, Municipality]**

Several studies conducted to address the waste management challenges of cities and towns of the developing countries also indicated that financial problems and poor fund raising capacities of municipalities are significantly contributing to the existing ill solid waste management practices (Kaushal et al., 2012, Das et al., 2019, Diriba and Meng, 2021, Nigatu et al., 2011).

6.3.3 Lack Of Infrastructure

In developing countries like Ethiopia, lack of appropriate infrastructures like road networks, waste transfer and treatment centers, incineration facilities and landfill sites critically challenge the municipal solid waste management system. In the five cities, lack of properly designed transfer and treatment centers, lack of infrastructures to resource and energy recovery and lack of standard landfills are reported as major challenges of the cities' effective and efficient waste management service provision.

According to the AASWM agency, there is only one waste-to-energy facility constructed in Addis Ababa "Reppi" open dumping site. However, the facility is not fully operational due to lack of technical know-how on operation, maintenance, and repair.

6.3.4 Poor Enforcement Of Legislations

Poor governance as well as poor awareness of the service providers are also contributing factors to the current poor SWM practices of the cities. The Solid Waste Management Proclamation No. 513/2007 clearly stated the urban administrations to install marked waste bins by streets and other public places, ensuring collection of solid wastes from waste bins, planning and carrying out public awareness raising activities and ensuring that measures are taken to prevent environmental pollution arising from mishandling of solid wastes and also put a general obligation on urban administrations to create enabling conditions to promote investment in the provision of SWM services. It also prohibited disposing of litter on streets, waterways, parks, bus stops and other public places. However, due to lack of proper enforcement of the proclamation, the urban administrations are not providing the basic solid waste management services and households are free to practice illegal dumping and open burning of solid wastes. Households are also not enforced to practice segregation at the source.

Product stewardship is not common in most developing countries and considerable quantity of recyclables enters to the solid waste streams and is discarded (Das et al., 2019). The proclamation requires glass containers and tin cans manufacturers and importers to collect and recycle glass containers and tin cans on their own or through others. It also stated specifications and import permits for plastic bags. Regardless of the legislations, product stewardship in not properly enforced in the five cities where this study was conducted. In general experts of the city/town municipalities described that the national Solid Waste Management Proclamation No. 513/2007 is not properly adopted and cascaded to define duties and responsibilities of each stakeholder of the waste management system and mentioned the gap as major challenge of sector.

6.3.5 Lack Of Professionals

In the five cities, lack adequate number of professionals to address the management system from planning and implementing to monitoring and evaluating the performance of the sector. The study participants describe lack of expertise as one of the major obstacles in the implementation of proper solid waste management system. Besides, lack of technical professionals to design large-scale waste management facilities and technologies are common challenges of the waste management sector at the national level as well as in the five cities, including the countries capital city Addis Ababa.

Table 6.1 :Number of professionals under the city municipalities of the five cites, by job category.

City/Town	MSM Sector professionals by type		
	Managerial and office work, at least with First Degree	Trained SW collection truck operators	Trained Sanitary Landfill Site Operators
Adama	8	2	0
Bahir Dar	7	1	0
Hawassa	4	1	0
Jimma	2	0	0
Addis Ababa	57	20	0

As shown in Table 6.1, the number of qualified professionals working in the sector of MSW were very limited. For instance, the total number of professionals engaged in managerial, and office works in the sector of MSWM with at least first degree were 57 in Addis Ababa city for the 11 sub-cities which have a total of 116 districts/woredas. However, at least 2 professionals (1 for managerial work and 1 for expertise work) are required per district/woreda which requires a minimum of 232 professionals. Similarly, Bahir Dar city has 40 districts/Kebeles. However, the municipality is leading the SWM sector with 7 professionals which at least requires 80 professionals.

Different studies also indicated that the gap in technical know-how greatly contributes to poor development of recycling and resource recovery facilities, energy production form the waste stream and construction of sanitary landfill sites. The gap greatly contributed to illegal dumping and open burning which is commonly practiced in the cities and towns of most developing countries (Hossain et al., 2022).

In addition to lack of technical know-how, the waste management sector is challenged due to inadequate involvement of the academia in research and innovation that can support provision of integrated solid waste management in the cities.

6.4 CONCLUSIONS

It is concluded that poor public awareness, inadequate finance, shortage of budget, poor fund-raising activities, lack of infrastructures, poor enforcement of the national solid waste management proclamation and lack of adequate professionals were found the major challenges of the municipal solid waste management system of the five cities.

The over solid waste management system of the cities was challenged with ill management of the collection service provision, insufficient recycling and resource recovery activities and open landfill. Illegal waste disposal was also found to be an important indicator of poor public awareness.

CHAPTER 7

SOLID WASTE MANAGEMENT ROADMAP FOR DECISION MAKERS

Author: ASEGID GETACHEW YIMENU

SUMMARY

Waste management is one of the major sectors of the globe, especially for its relevance in the three pillars of sustainable development – environment, society, and economic growth. The current global production and consumption pattern creates high pressure in the natural resources of the earth. The usual landfilling and open burning practice aggravate loss of valuable and finite resources of the earth. Recently, natural resources extracted at high cost from the environment, converted into products through industrial processes, which also emit and discharge pollutants to the environment, and thrown away to the environment are major challenges of humanity and future sustainability.

The waste management sector is one of the underdeveloped sectors in Ethiopia and requires very special attention for both recent and future implementation more advanced and effective management system at the national, regional and at the city level across the country. In this regard, it is important to develop a long-term strategy to ensure sustainable.

7.1 INTRODUCTION

7.1.1 Background

Waste management is one of the major sectors of the globe, especially for its relevance in the three pillars of sustainable development – environment, society, and economic growth. The sector is vital to resolve many natural resource, environment, climate and public health-related problems as well to benefit from its positive outcome on global economic and social impacts if properly managed (Brears, 2018).

However, the sector is not well developed in many countries, regions, and cities, especially in developing countries. In many countries, waste is still perceived as something useless, and it is simply thrown away. It is common to see litters in streets and roads, alone river, and sea banks. The hidden impacts of ill waste management are even greater than the visual aesthetic nuisance. Leaching from plastics and other hazardous wastes causes persistent pollution of soil, surface and groundwater and severely affect the natural ecosystem as well as human health. Biodegradation of organic wastes release GHGs like CH_4 and CO_2 that contribute to climate change. Open burning, which commonly practiced in many of the developing countries all over the world, emits toxic gases that pollute the atmosphere and cause public health problems (Idumah and Nwuzor, 2019, Jaunich et al., 2019, Tisserant et al., 2017).

The current global production and consumption pattern creates high pressure in the natural resources of the earth. The usual landfilling and open burning practice aggravate loss of valuable and finite resources of the earth. Recently, natural resources extracted at high cost from the environment, converted into products through industrial processes, which also emit and discharge pollutants to the environment, and thrown away to the environment are major challenges of humanity and future sustainability (Chen et al., 2015, Luong et al., 2013, Idumah and Nwuzor, 2019).

The waste management sector, therefore, requires special attention at the global, regional, and national level in order to assure sustainable waste management and to reduce its impact on the environment, society and economic growth. In this regard; systematic, advanced and highly effective waste management system is vital to sustainability address the impact of waste generation on the environment, natural resource utilization and public health (Levine, 2018).

The waste management sector is one of the underdeveloped sectors in Ethiopia and requires very special attention for both recent and future implementation more advanced and effective management system at the national, regional and at the city level across the country.

7.1.2 Target Audience

The target audience of this roadmap are federal and regional level policy- and decision-makers, including Ministry of Environmental Protection Agency, Ministry of Health, Waste Management Agencies, Ministry of Economy and Finance, Ministry of industry and Ministry of technology. Senior teams of environmental and social units, national to local development partners, practitioners at all levels, including waste managers, municipalities, private waste and sanitation service providers, CBOs, NGOs as well as environmental protection activists and other relevant stakeholders of the waste management sectors.

7.2 GOAL AND SCOPE

The primary goal of this chapter is to conduct strength, weakness, opportunity and threat analysis of the national solid waste management system and to list key national to local level stakeholders of the solid waste management sector and to identify major themes and strategic objectives for reform and for future implementation of better management system at the national level.

The management system of municipal solid waste generated from households is the focus and this roadmap is specifically deal with scientific concepts, principles and approaches of the solid waste management system that can be used by policy makers and decision makers operating national to local level. The scope of this work is therefore to provide important directions to policy and decision makers about sustainable solid waste management based on the principles of integrated solid waste management (ISWM) and circular economy.

7.3 SWOT ANALYSIS

The strength, weakness, opportunities, and threats (SWOT) of the current municipal solid waste management (MSWM) system at the national level is analyzed based on findings of this study for the five cities, reports from national sectors as well as published articles. It is then organized for selected factors that will be used to develop strategic objectives for future action. The SWOT analysis is presented into two sections: i) Internal environment analysis addressing the strength and weakness of the existing management system and ii) External environmental analysis dealing with the opportunities and threats of the management system.

7.3.1 Internal Environment Analysis

Table 7.1:Internal environment analysis to identify the strengths and weakness of the existing WSM service at the national level.

No.	Factors	Strengths	Weaknesses
1	Structure/institutional governance	• Established hierarchy of command from national to local level • Presence of government policies • Cascading policies at regional, zonal, woreda and city level	• Malfunction of the structure • Lack of accountability • Lack of fully identified and organized roles and responsibilities • Limited staff representation in decision making. • Loose partnership with the immediate local community
2	Strategy	• Adoption of international development plans at the national level • Availability of strategic plan and different guidelines national to local level	• Lacking strategic thinking and orientations in tackling existing problems • Focusing on routine tasks • Lack of institutional uniqueness in the waste management sector • Role confusion among stakeholders • Failure to link international development goals with the vision of sustainable development. • Inadequate linkage and limited collaboration among sectors
3	System	• Improving the routine solid waste management system into ISWM • Need to integrate the SWM system with the concept of the circular economy. • Incorporating the private sector in the SWM system	• Weak implementation system • Weak monitoring and evaluation system • Poor service delivery system • Absence of incentive and reward system • Insufficient data generation and recording system. • Weak budget utilization system

4	Service	• Provision of large size containers for temporary waste disposal service • House-to-house collection service • 2 – 3 times solid waste collection service • Street swiping service • Solid waste transport service • Disposal service	• Insufficient collection frequency • Shortage of vehicles for collection and transport • Lack of transfer and recovery sites and facilities • Lack of standard sanitary landfill sites • Poor implementation on recycling and resource recovery • Poor collaboration with the private sector towards better service delivery
5	Skill and human resource	• Willingness to hire well qualified and skilled manpower	• Shortage of qualified manpower • Inadequate on job training • Inadequate sense of ownership

7.3.2 External Environment Analysis

Table 7.2:External environment analysis to identify the opportunities and threats of the WSM service at the national level.

No.	Factors	Opportunities	Threats
1	Political and Legal	• Supportive government policies and strategies • Commitment of the government to address the issue of waste. • Peaceful and stable political system • The new reform of the government to change.	• Lack of good governance • Corruption • Lack of accountability to the appropriate body • Bureaucratic budgeting system • Poor awareness of leaders
2	Economic	• Conducive policy to use internally generated income. • Increasing demand for SWM service • Increasing demand for recycling and resource recovery • Promising economic growth (GDP) in the country • Increasing awareness to integrated SWM with the concept of circular economy	• Shortage of foreign currency • Weak entrepreneurial attitude • Low disposable income • Financial constraint at all levels of the government system

3	Socio-cultural	• Willingness to pay for improved SWM service. • Moral value towards clean environment	• Poor SW handling culture • Poor social awareness about SWM • Poor social awareness on the value of natural resources
4	Technological	• Fast expansion of advanced technology in the sector of SWM from collection, transportation to final disposal • Introduction of effective technologies for recycling and resource recovery • Advancement of the technology to improved biomass valorization. • Ease of access to recent technologies of SWM	• Lack of qualified and skilled human resources to use advanced technologies. • Incompatibility to cope up with the dynamism of the global technology. • Requirement of huge investment to expand and adopt technology. • Fast technological change • Poor research and technology adoption practice in the sector
5	Environmental	• Unexploited potential research areas in the SWM sector • Global attention towards environmental protection • Global advancement towards effective and efficient utilization of natural resources	• Scarce resources • Polluted environment • Polluted urban environment from ill SWM practice. • Resource loss due to poor management system

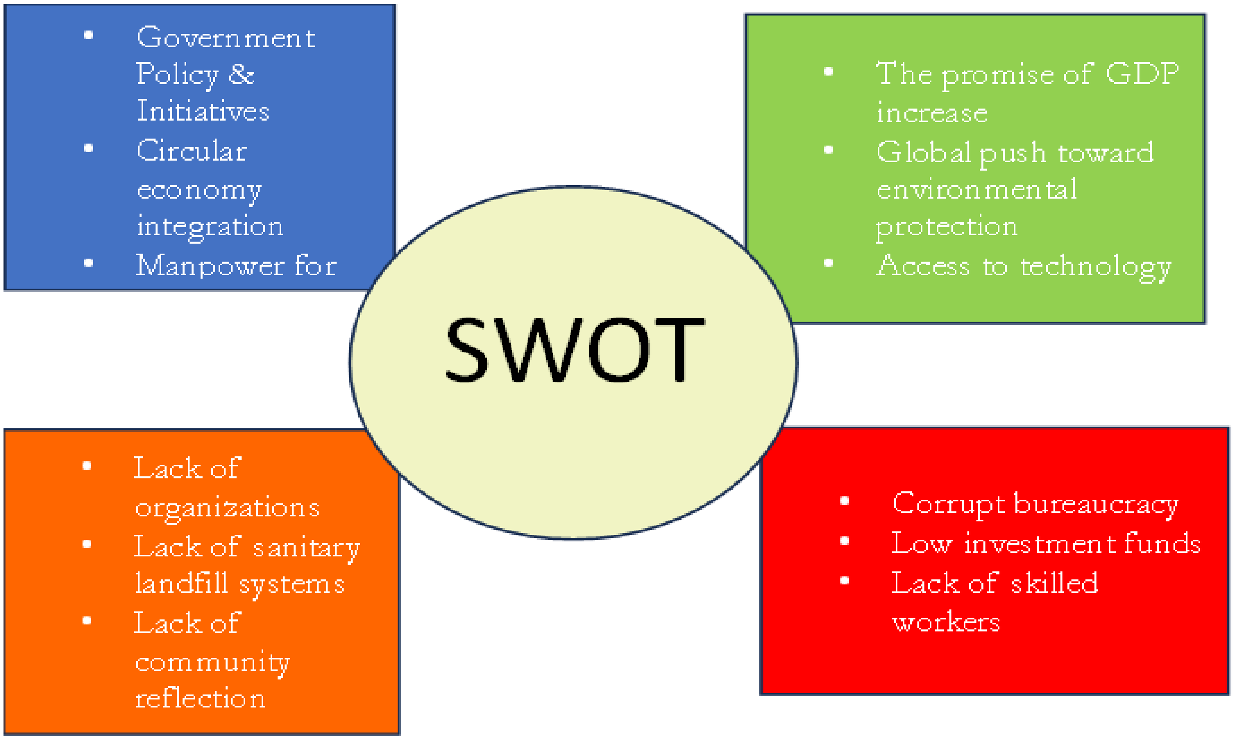

Figure 7.1: SWOT Analysis of SWM to Identify the Factors

7.4 STRATEGIES FOR SUSTAINABLE SOLID WASTE MANAGEMENT

Global experiences implied that the strategy for sustainable municipal solid waste management considered the principles of ISWM and the waste hierarchy and more recently the concept of circular economy is introduced to the solid waste management sector (Brears, 2018, Levine, 2018, Pires and Martinho, 2019). In this regard, MSWM priorities, pillars of the management system and strategic objectives are identified.

7.4.1 Priority Issues For Strategic MSWM

The following priority issues are identified for sustainable and integrated MSWM based on waste hierarchy:

a) Facilitating sustainable practice

The current consumption and production pattern in Ethiopia is not sustainable. Population growth, economic growth and change in lifestyle aggravate the rate of municipal solid waste generation. Cost and convenience are also driving waste generation practice (Diriba and Meng, 2021, Idumah and Nwuzor, 2019). The economic growth at the national level also increases easy access to affordable products and materials, which is good for the economy. However; inexpensive and convenient solid waste collection service is not equally progress to prevent ill solid waste disposal practice and protection of environmental pollution (Hossain et al., 2022).

In this regard, facilitating sustainable practice towards improved consumption pattern of products and materials as well as proper disposal is the priority issue for sustainable management of MSW. Continuous awareness creation and promotion of positive behaviors at all levels is one of the strategic objectives towards ensuring a better MSWM system at the national level.

b) Product stewardship/ Extended producer responsibility

Extended Producer Responsibility (EPR) also known as Product stewardship, is a policy approach in which manufacturers expected to take a shared responsibility for the impacts and management costs of their products at the end of the product life cycle (Levine, 2018). The Solid Waste Management Proclamation No. 513/2007 stated the implementation of EPR under section-3, article-7 for manufacturers and importers of glass containers and tin cans. It stated that the manufacturers and importers are responsible to collect and recycle used glass containers and tin cans by their own or through others (FDRE, 2007).

However, the implementation is very limited to specific sectors like soft and alcoholic beverage producers, and it does not enforce other manufacturing sectors. The national MSWM roadmap should consider full implementation of the EPR as well as revision of the proclamation to expand list of products to be part of the EPR. Encouraging EPR in manufacturing consumer products is crucial for sustainable management since majority of households’ solid waste stream comes from manufactured products including kitchen wastes, papers and cardboards, plastics, and hazardous wastes like electronics.

c) Waste prevention and source reduction

Waste prevention and source reduction is a fundamental waste management approach. It is at the top of the waste management hierarchy because it is one of the most effective management options with highest environmental, economic, and social benefits. Waste prevention is a useful mechanism to prevent waste generation and improving sustainability (Zhang et al., 2019). Source reduction also reduces the need to collect, process and dispose materials by preventing their generation at the source. In this regard, waste prevention and source reduction are one of the fundamental priorities of the MSWM system.

d) Provision of professional collection and disposal service

The first phase in the MSWM sector is the provision of fully operational waste collection and disposal service. The functional element of the MSWM from collection to final disposal is costly for its transport, transfer, and human resource requirements.

The priority for sustainable MSWM service provision is therefore ensuring the full operation of solid waste collection, transport and transfer and final disposal. This issue is the primary strategic objective that should be addressed with short- to long-term plans at the national level.

e) Resource recovery centers

The global shift in the approach of MSWM leads to the concept of resource recovery since waste is no longer taken as something useless. Resource recovery is one of the approaches in the waste hierarchy and practiced recovering value from the waste stream. The management system should consider the construction of resource recovery centers not only for proper utilization of natural resources and protection of environmental pollution but also for job creation and green business and marketing development.

f) Recycling, waste valorization and organic waste management

Recycling is one of the most effective management systems to effective utilization of finite natural resources of the earth. Globally; plastic, metal and paper recycling are most commonly practiced

(Hossain et al., 2022). However, recycling is not well developed and practiced in developing countries like Ethiopia.

The global waste management approach introduces the concept of waste valorization – which extracts valuable products from the waste stream using different techniques and approaches. Recently, waste valorization is under research and development. The approach, however, starts to introduce some products, materials, and value-added chemicals to the global market. Valorization of organic wastes generate bio-energy, biomaterials like bioplastic polymers and value added organic chemicals to the global market (Tsang et al., 2019, Talan et al., 2022, Braghiroli and Passarini, 2020, Fushimi, 2021).

However, the practice of organic waste valorization is still underdeveloped in the developing countries. The best practice is still limited to the production of bioenergy and compost. Since the world is striving to replace the petroleum-based economy by biobased economy; waste valorization and organic waste management should be taken as one of the priorities of the national MSWM system and should be incorporated in the strategic objective of the national MSWM system.

g) Green Business, job creation, income generation and market development

Most of the developed countries shift their MSWM system to green business. The primary approach towards encouraging the market development for green businesses have been found effective not only for its environmental and social benefits but also for its economic benefit in terms of job creation and income generation (Carus and Damer, 2018, Eickhout, 2012). The concept of integrating the waste management sector with the ideal of green business, market development and economic benefit from income generation should be taken as one of the priorities of MSWM. It is therefore important to strategically address the issue in the national roadmap of the MSWM system.

h) Monitoring and Evaluation

Monitoring and evaluation is the key aspect of any management system (Das et al., 2019). Sustainable MSWM requires continuous monitoring and evaluation system to improve the implementation of key strategic objectives at the national level. In many of the developing countries including Ethiopia, the monitoring and evaluation system of the MSWM system is underdeveloped and neglected. National policy- and decision-makers should be promoted to consider the development of well-organized monitoring and evaluation methods and approaches to ensure a better management system.

7.4.2 Strategic Pillars Of The MSWM System

The existing MSW strategy primarily focused on linear management approach with an ultimate goal disposing collected wastes in open field dumping sites (Figure 7.2). It doesn't consider those stated in 7.4.1 a – h. In this regard, the overall management strategy requires a new wholistic approach to improve the management system in a more sustainable way.

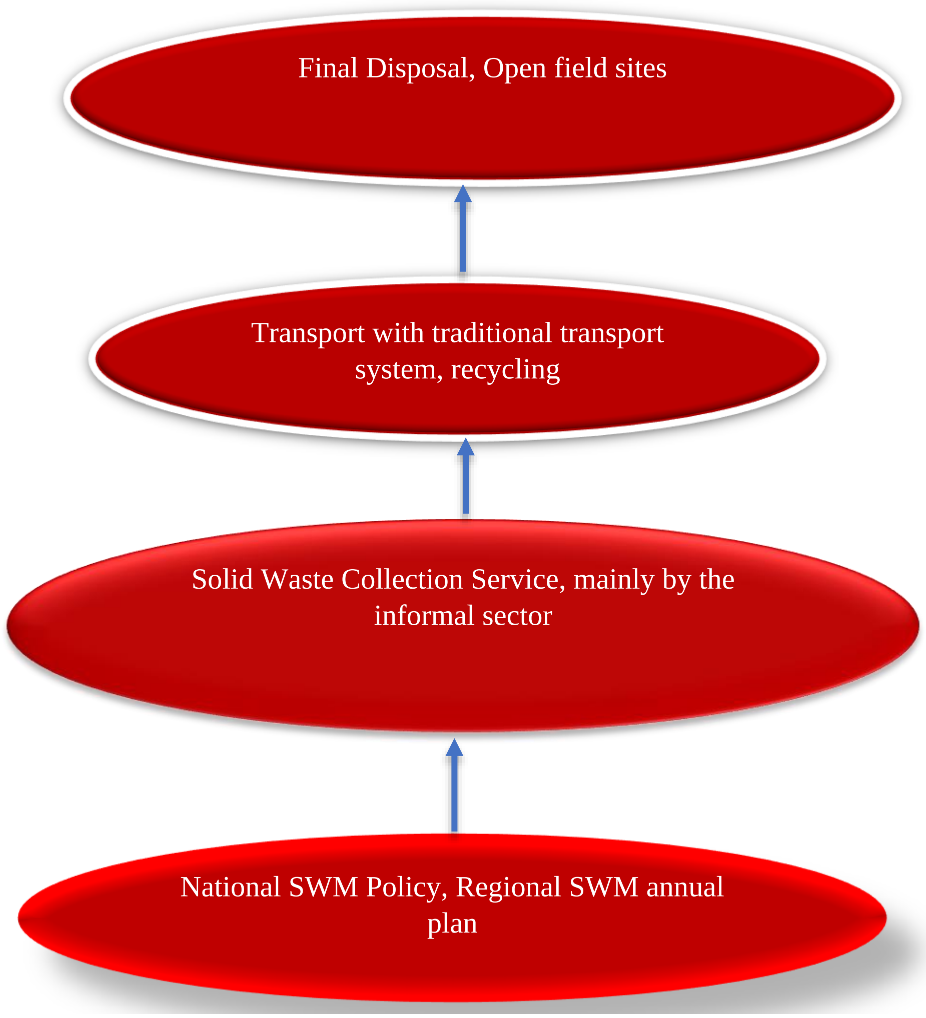

Figure 7.2: The existing MSWM approach in Ethiopia.

The following six major strategic pillars are globally accepted and used to ensure sustainable MSWM system at national level (Hossain et al., 2022).

1. **Leadership and Governance**

Strategic objective 1: Develop the government – federal to local level – core competences in integrated municipal solid waste management.

This objective shall be achieved through strengthening and enhancing the capacity and regulatory functions of federal government bodies to ensure development of effective environmental, social and economic balance in the MSWM sector.

Key stakeholders at regional, zonal, woreda and city/town level shall also develop their leadership capacity, cascading national policies and strategies and enhance good governance to ensure better MSWM service provision. Local authorities shall also develop guidelines to address service performance specifications, service performance monitoring as well as legal frameworks for full functioning of the system.

Strategic objective 2: Improve sectoral collaboration among key stakeholders of the MSWM sector.

This objective shall address sectoral collaboration among stakeholders – federal to local level – for planning, implementing, monitoring, and evaluating the overall MSWM system. The strategic objective shall also define roles and responsibilities of each stakeholder and define accountability.

2. **Service Delivery**

Strategic objective 3: Progressive public awareness creation towards waste prevention, reduction at the source and on-site handling

This objective shall address one of the critical gaps in the implementation of sustainable MSWM. The objective shall be used to promote and create awareness on waste prevention, source reduction, on-site handling including sorting, reuse and resource recovery and proper removal of solid waste.

Strategic objective 4: Improve provision of full and professional collection and disposal service.

This strategy shall be applied to make progressive and continuous improvement in the MSW collection service that should be provided via different methods including house-to-house collection, collection from common large disposal containers and collection from common transfer sites.

The implementation shall be the responsibility of local authorities including facilitating transport and disposal systems with mid-term plan of providing fully operational service provision.

Strategic objective 5: Construct and operationalize fully equipped transfer and treatment sites.

This strategic objective requires special attention since the existing transferring and treatment service provision is nearly nil at the national level.

Providing support from land provision and designing facilities to construct transfer and treatment sites and allocating all the required finance shall be taken as one of the national priorities and it shall be considered with mid-term plans of national to local authorities who is responsible in the provision of MSWM service.

Strategic objective 6: Enhance waste recycling.

This strategic objective shall encourage the practice of waste recycling from the waste stream. It shall support the private sector to be engaged in the waste recycling and remanufacturing industries. The federal government shall consider tax reduction, loan provision, subsidy and other supporting mechanisms at the national policy and strategy to encourage the private sector to invest in the waste recycling business. The objective shall also encourage integration of waste recycling with the circular economy and shall be supported with national policies.

Strategic objective 7: Increase organic waste valorization.

Organic waste is the highest waste fraction generated from households and the primary waste stream in terms of creating nuisance and environmental pollution.

This strategic objective shall be used to reduce the disposal of organic waste and to recover resources from the waste stream. The aim shall be implemented by supporting value-addition practices including bioenergy, biomaterial and biochemical production using organic waste valorization techniques. The implementation shall also be enhanced by financing research and development activities as well as by supporting facilities for large scale production of bioproducts. The objective shall also encourage integration of waste recycling with the circular economy and shall be supported with national policies.

3. Human Resource

Strategic objective 8: Improve capacity of the working manpower and leaders of the sector operating at all level.

This strategic objective shall address the need to develop skilled professionals in the MSWM sector as well as to enhance the leadership capability of the administrative staff at all levels – national to local level. The objective shall be implemented by providing short-term training which should be planned at the annual bases to long-term education that should be part of long-term plan of authorities working at all levels.

4. Equipment and Technologies

Strategic objective 9: Construct/maintain transfer and treatment sites, recycling and resource recovery centers and standard landfill sites.

This strategic objective shall be considered in the national long-term plan of sustainable MSWM and supported with facilitating land provision, technical and financial support. It shall also support introduction of the state-of-art technologies for waste recycling, treatment and construction of sanitary landfill sites.

5. Financing

Strategic objective 10: Increase job opportunity and income generation

The MSWM sector has a great opportunity in terms of job creation and income generation. This strategic objective shall be used to integrate development of MSEs to provide basic solid waste management service to increase the national job creation opportunity of the sector and to improve income of those engaged in the sector. It should also consider the engagement of private sectors in waste recycling and resource recovery works to increase the job creation opportunity of the sector.

Strategic objective 11: Improve national budget allocation.

This strategic objective shall be used to improve the allocation of budget at the federal level. The budget allocation shall consider the benefit of sustainable MSWM from its environmental, natural resource and public health perspectives.

Strategic objective 12: Enhance revenue generation of the sector.

The MSWM sector shall be supported with policies and strategies to improve its self-provision of finance and improve its revenue generation.

6. Information System

Strategic objective 13: Developing automated information and communication technology at all level.

One of the main gaps of the MSWM sector is lack of well-organized data and lack of automated information system that will be used by policy- and decision-makers. This strategic objective shall address the development of automated information and communication system at the federal, regional, and local levels.

The six major strategic pillars and their thirteen strategic objectives are used to present the corporate strategic map in order to imply their major interrelations that will be used during planning, implementation, monitoring and evaluation of the achievement of the road map from the ultimate result which is defined as Ensuring Sustainable MSWM System

The research findings show that each city needs to have their own road map for SSWM based on the waste generation, physical composition, and climate condition of specific locality. Addis Ababa needs to have a modern sanitary land fill at a city level and additionally needs to develop Sustainable Resource Management Framework, Waste Management System and facilities in each local sub city.

This is a sample proposal for Bahir Dar city.

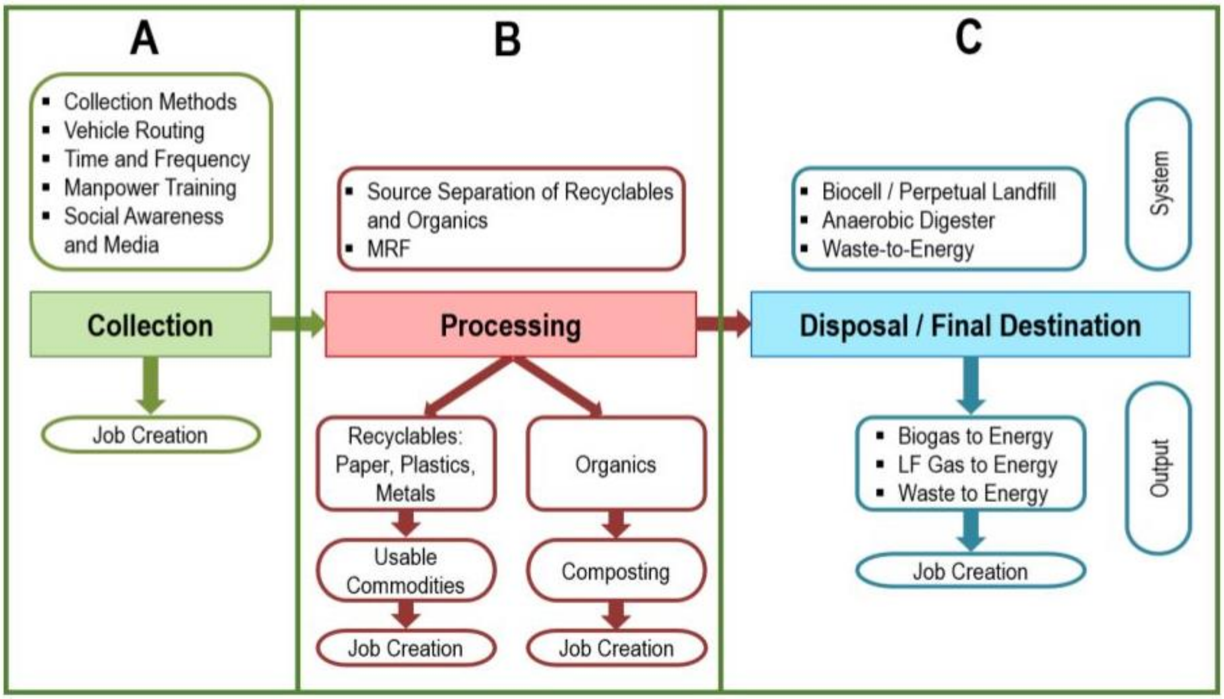

Figure 7.3 :Roadmap to Sustainable Resource Management Framework (Hossain et al. 2022)

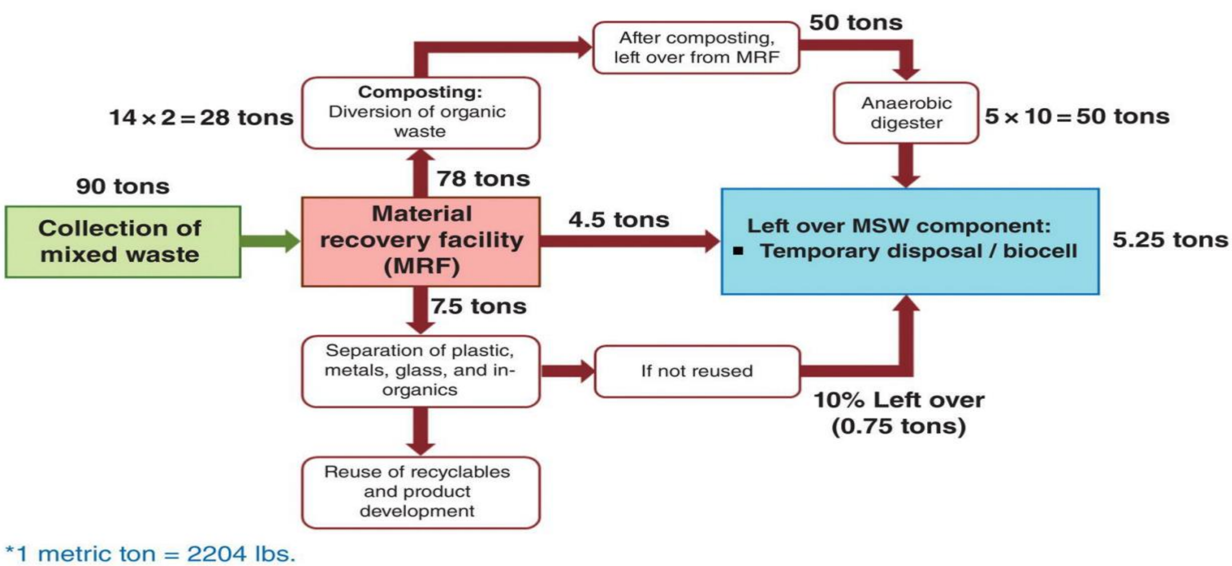

Figure 7.4 :Roadmap to Proposed Waste Management System (Hossain et al. 2022)

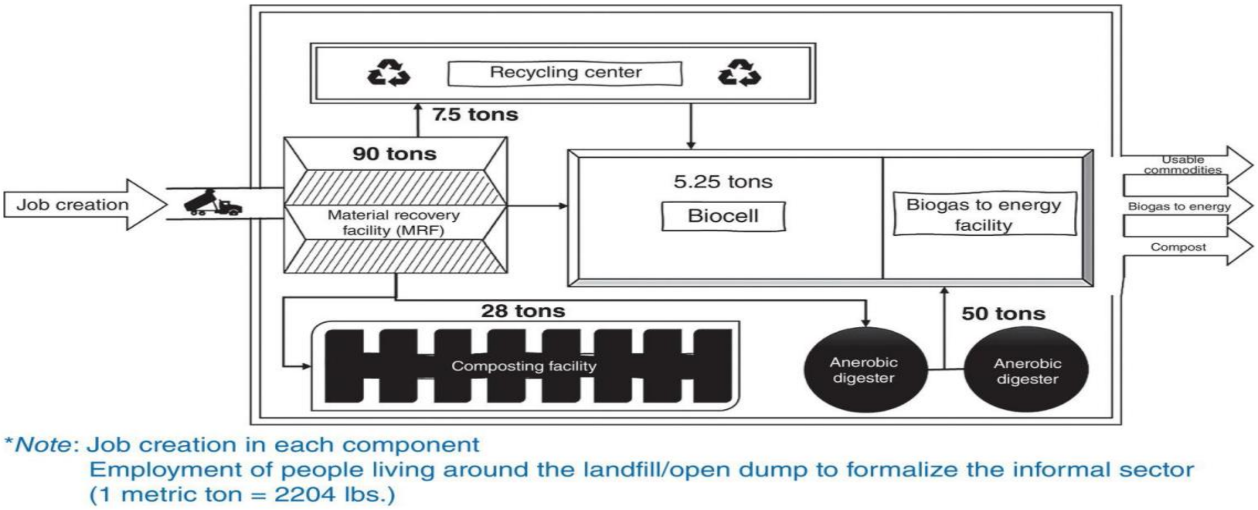

Figure 7.5 :Roadmap to SMART Facility for Bahir Dar City (Hossain et al. 2022)

CHAPTER 8

SUMMARY AND CONCLUSIONS

8.1 INTRODUCTION

Solid waste management is a universal issue affecting every single person in the world and it is a global environmental and public health concern. In Ethiopia, solid waste management is a persistent and very serious problem. The overall solid waste handling and management practices (from collection to disposal) are poor. The functional elements of solid waste management in most cities and towns of Ethiopia are not properly functional and ill solid waste management is clearly implying the failure of the sector.

The solid waste management system is challenged with critical factors like poor service provision, including limited collection services, poor recycling and resource recovery practices, uncontrolled landfills, poor public awareness, poor governance as well as short sighted management strategies and policy frameworks.

In this regard, the main aim of this study was to investigate the existing solid waste management system in selected cities of Ethiopia and to develop road map on sustainable solid waste management for decision makers.

8.2 FINAL THOUGHTS

In this study, household solid waste generation rate and physical composition by type were addressed to determine the per capita solid waste generation rate (Kg/capita/day) in the five cities. The trend of dumping sites and its impact in the urban environment; estimation of job creation from the solid waste management sector; major challenges of the municipal solid waste management system in the cities were addressed in order to investigate the existing solid waste management system as well as to identify major issues to be addressed for future improvement of the municipal solid waste management system. It is also summarized to develop a roadmap that will be used by decision makers to ensure sustainable solid waste management at the national level.

Therefore, based on the current study, the following conclusions are drawn:

a) The average daily MSW generation rate of the total household units was found to be 0.40 Kg/capita/day. In the five selected cities, the per capita MSW generation rate from residential households ranged from 0.36 – 0.59 Kg/day based on estimation made from the daily generation report. From the overall study, it was found that the national urban residential households average WS generation rate ranged from 0.20 – 0.55 with a mean value of 0.37 Kg/Capita/day.
b) The daily BD of MSW samples collected from Bole sub-city ranged from 0.26 – 0.42 Kg/L with an average BD of 0.36±0.06 Kg/L and that of Kirkos sub-city was 0.16 – 0.30 Kg/L with an average of 0.22±0.05 Kg/L. The average bulk density of the total MSW samples collected from the household units were found to be 0.29±0.04 Kg/L.
c) Income was found to be the main determinant factor that statistically significant effect on households' MSW generation rate.
d) The annual MSW generated in Adama city reported as 97,000 tons (67,900 tons from residential households), Bahir Dar 85,100 tons (51,060 tons from residential households), Hawassa 86,300 tons (56,095 tons from residential households), Jimma 90,000 tons (54,000 tons from residential households) and Addis Ababa 1,007,662.9 tons (789,509 tons from residential households).
e) In the study area, the average percentage weight of various waste types was 65.9% organic, 6.2% paper, 7.7% textiles, 1.0% metals, 95% plastics, 1.7% glasses, 3.9% ash and dust, 0.7% hazardous wastes and 3.4% other rubbish.
f) The trend of the annual municipal solid waste generation rate from residential areas in the five cities increased linearly between 2016 and 2021. The annual increase in municipal solid waste generation ranged between 3 – 7% with an average increase of 5%/year.
g) The future projection analyzed from 2021 and 2050 indicated that the solid waste generation in the five cities will be quadrupled by 2050. There is an increase in the solid waste collection service provision. The recent annual solid waste collection capacity in Adama, Bahir Dar and Jima cities reached 65%, while 68% in Hawassa and 84% in Addis Ababa.
h) None of the five cities have modern sanitary landfill sites. The existing final disposal sites are uncontrolled and open dumping sites. The cities practiced 16 – 35% uncontrolled and illegal solid waste dumping in roadsides, water bodies, sewerage lines and open spaces. Uncontrolled practices in open dumping sites were found to have an impact on surface- and groundwater

bodies, on settlement areas and the disposal lands, on the ecosystem and affect public health. Uncontrolled disposal of municipal solid waste contributes to the emission of greenhouse gases like CO_2 and CH_4. The leachates also contaminate the nearby surface water, aquifers, and settlements.

i) The municipal solid waste collection sector created 18,000 jobs for individuals organized in 206 legal MSEs in the five cities. The recycling and composting sector created 1,157 (6.1%) jobs in paper recycling sector, 1,226 (6.8%) jobs in plastic recycling and 1,660 (8.4%) job in compost preparation.

j) The municipal solid waste sector can create a job opportunity for 52,000 – 260,002 job seekers by the year 2030 who can contribute to improve the municipal solid waste service provision of the five cities.

k) Informal waste recyclers largely contribute to the collection of recyclable materials, including paper, plastics and metals. The collection, recycling and composting sectors are contributing to the economic activity and the circular economy of the five cities. However, it requires special policy level attention to enhance the economic benefit of the sector.

l) It is concluded that poor public awareness, inadequate finance, shortage of budget, poor fund-raising activities, lack of infrastructures, poor enforcement of the national solid waste management proclamation and lack of adequate professionals were found the major challenges of the municipal solid waste management system of the five cities. The over solid waste management system of the cities was challenged with ill management of the collection service provision, insufficient recycling and resource recovery activities and open landfill. Illegal waste disposal was also found to be an important indicator of poor public awareness.

8.3 RECOMMENDATIONS FOR FUTURE STUDIES

- Further study needs to be conducted for finding the suitability of compost site, landfills, recycling for each city.
- Life cycle cost analysis (LCCA) needs to be conducted for the proposed roadmap.
- All concerned institutions, government, stakeholders, and policy maker should give due attention in terms of policy, resource and to maximize and enhance the economic benefit of the sector.
- The municipal solid waste sector should work on capacity building and technical expertise recruitment.

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The following recommendations are drawn from this study:

- The existing national MSWM policy and strategies should be revised to develop a more holistic approach to the future MSWM of Ethiopia.
- The current linear MSWM system should be geared to the principle of the circular economy and a new policy framework should be developed at the national level.
- Multisectoral collaboration should be entertained to improve the current MSWM system of the country as well as to sustainably solve the impact of solid waste in the public health and environment.
- An academic institute which excels in the MSWM sector should be opened at the national level to address the lack of professional and research gaps.

- The recycling and resource recovery sector should be developed to improve the economic benefit of the country from the MSWM sector.
- The road map developed in this study should be communicated from federal to local government level for its implementation.
- Further studies should be conducted to address the policy and implementation gaps in the sector.

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APPENDIX A

Quantitative Data Collection Tool

Household Survey Questionnaire

INTRODUCTION AND CONSENT

Hello. My name is ______________. I am here to collect data for a PhD study that will be conducted on "The Road Map on Waste Collection and Management for Decision Makers". The study will be done at the national level to improve the existing solid waste management by developing a national road map that will assist Decision Makers and other stakeholders. This interview should last no more than 45 minutes. All of the answers you give will be confidential and will not be shared with anyone other than members of the study team and used only for this study. You don't have to be in the interview, but we hope you will agree to answer the questions since your views are important. If I ask you any question you don't want to answer, just let me know and I will go on to the next question or you can stop the interview at any time.

Before we get started today, here are a few important things to know:

- We are here to learn from you. We are interested in your opinions. There are no right or wrong answers to the questions we are going to ask except some factual questions that need numeric answers.
- If there is any question you would rather not answer, for any reason, please just say "Pass," and we will move on to the next question.
- You can stop the interview at any time.
- We will keep the content of the discussion confidential, and it will be used only for research purpose.
- We will do our best to protect your privacy.
- Currently, do you have any questions about the study? (Note! If the respondent says YES, further discussion and clarification will be given for the raised questions and concerns.

May I begin the interview now? 1. [] Yes. 2. [] No

Signature of interviewer: ______________________

The interview was conducted on the date of ____/_____ /2022, from __________ to ________time (AM/PM).

English Version Household Interview on SWM
Region: _________
City/Town
HHID:
HHSWCID:
Interviewer code
GPS: Location (mandatory)

Dimensions	Variables	logical sequence	Q code	Question	Answers options	Q code
Socio-demographic characters	Gender	‘Questions in the first section help us learn about your household, you as a person and about your life so that we can use it to compare with other individuals and households.'	q0.1	What is your gender?	Male	1
					Female	2
					Other	3
					Prefers not to say	4
	Age		q0.2	How old are you?		18-99
	Marital status		q0.3	What is your marital status?	Married	1
					Divorced	2
					Separated	3
					Widowed	4
					In a relationship	5
					Single	6
					Other	7
	Family size		q0.4	What is the family size of HH?		
	Religion		q0.5	Do you practice religion? If No skip q0.6	Yes	1
					No	2
			q0.6	Which religion do you follow/practice?	Muslim	1
					Orthodox Christian	2
					Catholic Christina	3
					Wakefeta	4

					Protestant	5
					Traditional	6
					Other	7
	Education		q0.7	What is the highest educational level of the head of the HH?	No formal education	1
					Primary school	2
					Secondary school	3
					TEVET certificate	4
					Diploma	1
					Bachelor's degree & above	2
	Profession		q0.8	What is the profession of head of the HH?	Government employee	1
					Private employee	2
					Business	3
					Farmer	4
					Student	5
					Housewife	6
					Not employed	7
					Other	8
	Income and spending		q0.9	How much is the monthly income of your HH?		
			q0.10	How much is the monthly expenditure of your HH?		
Households SW handling	**Household waste generation**	This section is to learn the households solid waste handling	q0.11	What are the most common solid wastes generated from the HH?	Kitchen wastes like vegetable and fruit piles, food remnants, decomposed food wastes	1

		practices and problems they face in managing			Paper, cardboard, and packaging	2
					Grass and wood	3
					Electronic materials and batteries	4
					Metals like tin can, iron, deodorant containers, insecticide containers	5
					Textile	6
					Glass/Ceramics	7
					Plastics	8
					Miscellaneous	9
	HH solid waste collection and storage		q0.12	Where is the HH waste collected and stored?	Kitchen	1
					At the backyard of the compound	2
					Anywhere in the compound	3
					Outside the compound	4
					Other	5
			q0.13	What type of material do you use to store your solid waste at the HH?	Plastic bags	1
					Garbage bin	2
					Bucket	3
					Sacks	4
					Others	5
	HH solid waste segregation		q0.14	Do you segregate the different types of solid waste generated in	Yes	1
					No	2

				your house using different storage containers?		
	Reuse and resource recovery at HH		q0.15	Do you reuse some of the solid waste generated in HH? If No skip to q0.17	Yes	1
					No	2
			q0.16	If you reuse it, which materials do you reuse?	Kitchen wastes like vegetable and fruit piles, food remnants, decomposed food wastes	1
					Paper, cardboard and packaging	2
					Grass and wood	3
					Electronic materials and batteries	4
					Metals like tin can, iron, deodorant containers, insecticide containers	5
					Textile	6
					Glass/Ceramics	7
					Plastics	8
					Miscellaneous	9
			q0.17	Do you use the organic waste from your	Yes	1
					No	2

				household to make compost or use it as a fertilizer in your compound?		
	HHs SW disposal		q0.18	Where do you dispose of your HHs solid waste?	Inside the compound	1
					Outside the compound	2
					By the side of the road	3
					In an empty space near the house	4
					In the nearby ditch/sewerage system	5
					In the nearby dustbin	6
					Collected and disposed in dumping site by waste collectors	7
					Burned outside the compound	8
					Others	9
			q0.19	How often do you dispose of your HH SW?	Everyday	1
					Once every two days	2
					Once every three days	3
					Once every week	4
					Other	5
			q0.20		Morning	1

				Generally, when do you dispose of your HH SW?	Noon	2
					Afternoon	3
					Evening	4
					No definite time	5
			q0.21	Who disposes your HH SW?	Servant	1
					Family member (mother)	2
					Family member (father)	3
					Family member (children)	4
					Other family members	5
					Wastes are collected by the town corporation from the house	6
					Wastes are collected by locally recruited person from the house	7
					Wastes are collected by private corporation from the house	8
					Other	9
			q0.22	What are the problems you are facing to	No dustbin in the area	1
					Dustbin is quite far away	2

				dispose your HH SW?	Dustbin is not in the right place	3
					Dustbin is not in the way of movement	4
					It is smelly near the dustbin	5
					No one is at home to dispose the waste	6
					Other	7
MSW collection service	**Service provider and delivery**	This section deals with the current MSW collection service in the town, gaps in the service, satisfaction with the current service and preference of the community regarding the service.	q0.23	Who collects HHs SW from your house and the neighborhood?	Town municipality	1
					Town corporation	2
					Private corporation	3
					Informal waste collectors	4
					Other	5
			q0.24	How often do they collect the SW?	Everyday	1
					Once in every two days	2
					Once in every there days	3
					Once in a week	4
					Irregularly	5
					I don’t know	6
			q0.25	What time do they collect the SW?	Moring	1
					Noon	2
					Afternoon	3
					Evening	4
					No definite time	5
			q0.26	Which system do	A collector will collect	1

				you prefer for removal of your household waste?	the waste from the house	
					The collector will come to a certain place at a certain time, you will give him the waste	2
					You yourself will dispose the waste in the dustbin	3
	HHs service provision preference				You will keep your waste container at a certain time by the roadside and the collector will collect it from there	4
					I prefer other option	5
			q0.27	If your waste is collected directly from your house, then it will be suitable if it is collected	Every day	1
					Once every two days	2
					Once every three days	3
					Once every week	4
					Any day the collector prefers	5
			q0.28	When do you prefer for your waste to be collected?	Morning	1
					Noon	2
					Afternoon	3
					Evening	4
			q0.29	Which service	Town municipality	1

				provider do you prefer best for SW collection service?	Town corporation	2
					Private corporation	3
					I don't know	4
			q0.30	Which kind of SW collection do you prefer at best?	Cheap but quality service	1
					Affordable quality service	2
					Quality service with high cost	3
					I don't know	4
			q0.31	How much do you currently spend for SW collection and removal service per month?		
			q0.32	If your waste is collected directly from your house to the maximum how much are you ready to pay monthly for the service?		
	Satisfaction with the MSW service		q0.33	Are you satisfied with your current waste disposal system?	Yes	1
					No	2

			q0.34	Satisfaction level about the present municipal waste removal system	Very good	1
					Good	2
					Ok/medium	3
					Not satisfactory	4
MSWM knowledge and attitude	**MSWM knowledge and attitude**	Questions included in this section will help us to learn about the respondent's knowledge and attitude regarding SWM system.	q0.35	Collecting solid waste with any material and storing it anywhere in the house or nearby has an effect on the environment and health of family members.	Yes	1
					No	2
			q0.36	Burning solid waste in the compound or nearby empty space is a good way of HH solid waste handling.	Yes	1
					No	2
			q0.37	The current waste disposal system is polluting the environment. Do you agree	Yes	1
					No	2
			q0.38	If yes, identify the reason/reasons:	As there is no dustbin nearby, wastes are disposed of here and there and	1

					create nuisance	
					Wastes are not collected regularly	2
					Wastes are left around the dustbin	3
					Wastes are left on the drain	4
					Wastes are left on the road	5
			q0.39	Do you think SW generated from your house can be valuable to others?	Yes	1
					No	2
			q0.40	Waste generated from your house is a resource. Do you agree?	Yes	1
					No	2
			q0.41	Do you know that from kitchen and vegetable wastes, an organic fertilizer can be made which is good for the environment , does not degrade the fertility of land like other	Yes	1
					No	2

				chemical fertilizers, and is very much useful for plants and lands?		
			q0.42	Would you like to use this organic fertilizer in your garden or in the plants' tub?	Yes	1
					No	2
			q0.43	Will you agree to separate your kitchen waste from other household waste?	Yes	1
					No	2
			q0.44	Community participation is inevitable for local waste collection systems and improvement of the environment – do you agree?	Yes	1
					No	2
			q0.45	Would you like to participate in the communities' local waste collection system like cleaning your neighborhood at a	Yes	1
					No	2
					I am not sure	3

				regular time?		
			q0.46	Taking care of HH SW is primarily the responsibility of women and girls. Do you agree?	Yes	1
					No	2
			q0.47	Well managed solid waste collection system can create a good job opportunity.	Yes	1
					No	2
			q0.48	If you have no job, are you willing to work as a waste collector?	Yes	1
					No	2
			q0.49	Working in SW collection and disposal corporate lowers one's dignity. Do you agree?	Yes	1

Daily Solid Waste Generation Recording Format

HHID	**Family size**	**Weigh of solid waste in kilogram generated/day**								**Total**
		Demo	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7	
1.										
2.										
3.										
4.										
5.										
…..										
100										
Total										

APPENDIX B

Some pictures showing the existing solid waste management practices in cities and towns of Ethiopia.

(a) Plastic disposal in open spaces

(b) Organic waste disposed in open markets.

(c) Solid waste disposal in ditches

(d) Solid waste dumping along river banks

(e) Open dumping site

(f) Recyclables collected by informal collectors and sold for wholesalers

BIOGRAPHY

Mr. Assegid Getachew Yimenu was born in Bedele Town, Illu Abbabor Province, Ethiopia. He completed his bachelor's degree in the field of Geography and Environmental studies from Addis Ababa University in 2002. He also completed his master's degree in organizational leadership from Azusa pacific university of California, USA He has also Professional diploma in modern business management from open university of the UK.

He worked as a senior government official at the regional and Federal government of Ethiopia in different leadership positions for more than ten years. He served as Head of the mayor's office &cabinet affairs of A.A city Administration, Deputy General manager of A.A city Administration, General manager of A.A city Administration water and sewerage authority, Deputy General manager of A.A city Administration, Bureau head of Oromia regional state and cabinet affairs.

Mr. Assegid Getachew joined the University of Texas at Arlington in Fall of 2019 to pursue Ph.D. in the Civil Engineering department specializing in the Solid Waste Institute for Sustainability (SWIS) program under the close supervision of Dr. MD Sahadat Hossain. Mr. Assegid Getachew achieved "Outstanding Civil Engineering Ph.D. Student Award" in 2020-21 at University of Texas at Arlington.

During his professional leadership period, Mr. Assegid has served as professional leaders in many sectors but not limited to urban sector, Water supply and development sector, Responsible for sewerage infrastructure constriction & treatment plant, Responsible for reengineering process of city administrations, responsible for overall the activities of municipal activities, housing project, urban transport, and land administration.

He aims to contribute and implement the Road map for sustainable solid waste management in African cities through reforming the increasing municipal solid waste challenges. Apart from this vision, Mr. Assegid Getachew loves to participate in activities of corporate social responsibilities.