ADDIS ABABA INSTITUTE OF TECHNOLOGY
ADDIS ABABA UNIVERSITY

School of Chemical and Bio Engineering

Addis Ababa Institute of Technology
Addis Ababa University

Assessment of the Current Solid Waste Management Practice; Case Study of Bishoftu Town, East Shewa Zone of the Oromia Region, Ethiopia

A Thesis Submitted to the School of Chemical and Bio Engineering as a Partial Fulfillment of the Requirements for the Degree of Master of Science in Chemical Engineering (Environmental Engineering)

Name of the student: Mahelet Admassu

Name of the advisor: Dr. Birhanu Assefa

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A Thesis Submitted to the School of Graduate Studies of Addis Ababa University for the Partial fulfillment of the requirements of the Degree of Masters of Science in Chemical Engineering (Environmental Engineering Stream).

By: Mahelet Admassu

Approved by the Examining Board

Birhanu Assefa (Dr.-Ing)	____________________	____________________
Advisor Name	Signature	Date
____________________	____________________	____________________
Internal Examiner Name	Signature	Date
____________________	____________________	____________________
External Examiner Name	Signature	Date
____________________	____________________	____________________
Chairperson	Signature	Date

DECLARATION

I, hereby, declare that the study entitled "Assessment of the Current Solid Waste Management Practice; Case Study of Bishoftu Town, East Shewa Zone of the Oromia Region, Ethiopia" is my original work and has not been used by others for any other requirements in any other university and all sources of the materials used for this thesis have been properly acknowledged.

Name: Mahelet Admassu

(GSR/0922/13)

Signature _____________

Date of Submission _______________

This thesis has been approved for:

Dr. –Ing. Birhanu Assefa

Signature _____________

Date _______________

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Abstract

The success of waste management requires reliable data on waste generation and composition, which is critical for making decisions about the best waste management system. There is currently no data on Municipal Solid Waste (MSW) generation and composition collected in Bishoftu town. In order to provide baseline data for the establishment of a municipal solid waste management system, the primary goal of this study is to analyse the rate of generation and composition of municipal solid waste. The samples were collected from the household from 4 Keble's and from different commercial activities like hotels, resorts, restaurants and cafeterias, open market, super market and mini markets found in the town. The collected sample was sorted out in to various components. Subsequently, the weight of each component were measured and recorded. The daily generation of MSW works out to be 0.31 Kg /day/person with a density of 306 Kg/m3.The study results reveal that the MSW stream has the largest proportion of biodegradable waste (69 %) followed by other waste (18 %) containing ash material and different solid waste types. From the socio-economic analysis, middle socioeconomic group and lower socioeconomic group generate more waste due to more family members and energy type used for cooking while socioeconomic characteristics like education level, occupation, age, gender, and housing condition have no relationship with solid waste management practices. Understanding the movement of waste in an urban area is crucial for identifying the main problems and opportunities for improvement in the efficient handling of waste. Assessment instruments like material flow analysis (MFA), a technique that is widely used in waste management research, offer an organized and objective assessment procedure to best describe the waste management system, identify its strengths and weaknesses, and suggest feasible alternatives. In order to assess the current waste management strategy used by the City of Bishoftu, this study uses material flow analysis. Due to the waste's high organic content If waste management options such as composting and recycling are implemented in the future, there is a greater possibility of reducing the amount of waste stream that is disposed of in landfills as well as lowering greenhouse gas emissions, which is a current global issue. By composting 50 % of the waste designated to the disposal site 47.9 % of resource is managed which have an increment of 78.1 % than the current SWM practice and a total reduction of 35.35 % in GHG emission.

Key word: ***Solid waste management; Material flow analysis; composting.***

Table of Contents

List of Tables

List of Figures

Acronyms

AD	Anaerobic Digestion
DSWGR	Daily solid waste Generation rates
HHs	Households
GHG	Greenhouse Gas
GWP	Global warming potential
HSEG	Higher Socioeconomic group
LSEG	Lower Socioeconomic group
MFA	Material Flow Analysis
MSSEs	Micros and Small-Scale Enterprises
MSEG	Medium socioeconomic group
MSWM	Municipal Solid Waste Management
MSW	Municipal Solid Waste
SBPA	Sanitation and beautification park agency
SDG	Sustainable Development Goal
SPSS	Statistical package for social science
SWM	Solid Waste Management

1. Introduction

1.1. Background of the study

To meet its most basic needs, humanity is still creating and developing cutting-edge products. But in many regions of the world, the ensuing resource production and consumption lead to serious issues with the creation and handling of solid waste (Mamady, 2016). Unwanted materials created by commercial, industrial, or household operations are referred to as solid waste. (Shiun Ming et al, 2015).

The disposal of waste is a significant and expanding human concern. A World Bank research projects a 70 % rise in garbage creation worldwide by 2050. (Kaza *et al.*, 2018).

Most sub-Saharan African nations are seeing rapid economic growth, and these nations are also becoming more urbanized and experiencing periodic population increases. Ethiopia is currently the second-most populous country in Africa and one of the nations with the fastest rates of growth in sub-Saharan Africa. Furthermore, Ethiopia is among the low-income nations that must deal with the impact caused by inefficient solid waste management. (Lema *et al.*, 2019).

Every single person on planet earth is impacted by the issue of solid waste management, and Ethiopia is no exception. Only 2 % of Ethiopians receive services by solid waste management services (Tassie and Endalew, 2020). As result, different towns of Ethiopia are facing a challenge from the accumulation of solid due to fast urbanization and population growth.

Bishoftu (Debre Zeyit) is one of towns located in addis-adama corridor. It is one of the most expanding towns in the country. It is largely recreational and a tourist center. It hosts large numbers of resorts and hotels. It is home to several colleges and one national university. It also has a significant number of economic and military infrastructure. Residents, commercial activities, institutes and industries generate large volumes of solid wastes. The town has a population of more than 245,544 thousand (Bishoftu city administration, 2022).

Even though there is little publication on the overview of the waste management trend of the town, there is no direct measurement on the solid waste generation and clear explanation of the solid waste management practice of the town. Therefore, the present studies focus on the actual quantity and composition of solid waste generated by its residents and commercial activities.

Adequate knowledge and data regarding the properties of solid waste are needed for the successful and efficient management of solid waste generated in a given city. Precise information on the amounts, compositions, densities, moisture content, and calorific value of solid waste generated in a city is necessary to decide on the types of facilities needed for solid waste management, to identify recycle and reuse possibilities, the best disposal options, and to project future needs (Birhanu, 2015).

Thus, the primary objective of the present study is to assess solid waste management practices of Bishoftu town and intended to fill the current data gap in terms of solid waste generation, characterization, overall solid waste management practice, and recommending optional solid waste recovery system for the city.

1.2. Problem of statement

Around the world, managing solid waste has presented significant challenges to both industrialized and developing nations. Rapid population growth in Bishoftu Town is a result of both higher birth rate and migration from rural areas (Gedefaw, 2015).Bishoftu has experienced rapid and uncontrollably increasing population and geographical expansion, as like many other towns in developing nations. This has frequently resulted to significant harm to environmental sanitation. Solid trash production has increased as a result of the town's rapid expansion and rapid population growth. This in turn leads to increased demand for infrastructure, the establishment of institutions, and community involvement in its management (Gedefaw, 2015; Duguma *et al.*, 2019). Due to the town's topographical appeal and surrounding natural beauty, including its lovely lakes, it is one of the most popular tourist destinations. As a result, many recreational parks have emerged, increasing the amount of solid waste produced (City Development, 2015).

Solid waste can be a useful resource if used properly, but if it is not handled well, it can have detrimental effects on the environment and public health. As a result, solid waste management is essential to urban sanitation and one of the most significant and resource-intensive services municipalities should offer (Doda, 2014).

The generation of solid waste from residential, commercial, industrial activities, as well as the characterization and composition of related waste and waste management practices with regard to (collection, transportation, recycling, resource recovery, and disposal) have not been adequately studied in Bishoftu town. According to earlier research, an individual's daily waste production is estimated to be 0.48 kg, with organic garbage accounting for 79% of waste and ash and plastics making up the remaining 12% and 3%, respectively (Bediye, 2023). The waste generation rate of Addis Ababa is estimated 0.45 kg per capita/day (Adefris, Damene and Satyal, 2023) indicating that the waste generation for Bishoftu town need further study . In addition to the higher value of waste generation rate no accurate data collection system and methods was found on the studies. Molla and Abegaz, (2015) indicate in their study that the overall daily household solid wastes generation rate was 0.32 kg/person/day for 10 towns of Ethiopia. From this Ambo, Bishoftu and Injbara produce higher rate per capita. In this study no clear research methodology was set and discussed and for reason further study is needed for Bishoftu town.

Reducing the data and information gap related to solid management is required in order to create a suitable solid waste management system for the town. Studying Bishoftu town's solid waste generation, characteristics, and management techniques is therefore essential. Furthermore, the research ought to examine global best practices and offer suggestions to assist local or regional government authorities in formulating policies and management plans related to solid waste management. It might also serve as a starting point for additional studies conducted at the regional level, including material flow analyses and life cycle sustainability assessments of municipal solid waste management systems based on the Sustainable Development Goals.

1.3 Research objective

1.3.1. General objective

The overarching objective of this study is to assess the current status of waste management practice in Bishoftu Town, East Shewa zone of the Oromia region, Ethiopia.

1.3.2. Specific objectives

The study will have the following specific objectives:

- To identify significant sectoral activities in terms of solid waste generation and quantify the waste generation and composition of solid waste generated by selected sectoral activities among commercial, industrial or residential.
- To identify formal and informal waste management processes and examine the existing spatial coverage of solid waste management service in the town.
- To assess socio-economic impacts of the solid waste management system
- To perform a preliminary solid waste material flow analysis

1.4. Significance of the study

One of the main causes of improper waste management is a lack of knowledge about the rate of solid waste generation, its composition, collection, transportation, and disposal at the municipal level as well as the state of solid waste management practices at the moment. In this regard, baseline data on the physical composition, rate of solid waste generation, and general management methods of Bishoftu town will be provided by this study. Additionally, it might provide the basis for additional research, such as a material flow analysis and a life cycle sustainability assessment of a municipal solid waste management system based on the SDG.

1.5. Scope of the study

Geographically, the study is limited to Bishoftu Town in Ethiopia's Oromia Region's East Shewa Zone. This study's focus is on Bishoftu's general solid waste management techniques, including solid waste generation, physical composition, and socioeconomic status, despite the existence of other forms and sources of waste. The research field examined a variety of waste sources produced in the city, including commercial, industrial, institutional and residential waste.

2. Literature review

2.1. Overview of solid waste

The amount of energy and material used in a system is comparable to the amount of resources used in that system. The population growth and expansion of the economy will stimulate resource demand even more. Consumption leads to resource depletion, the formation of products, and the generation of trash, all of which put pressure on environmental sinks. The input resource and the transformation process involved determine the kind of waste and its physicochemical characteristics. There are three types of waste: gas, liquid, or solid. The latter produced by settlements Municipal Solid Waste (MSW) is the broad waste of interest in this study(Masebinu, 2017).

Waste is a serious global concern that has existed since the earliest days of humankind and continues to rise. Because of the lesser population in the early pre-industrial era, waste generation was not a problem. In order to increase soil fertility, waste was placed in the ground where it would eventually compost. The increasing volume and complexity of solid waste production is endangering the environment more (Gobena, 2020). Waste collection rates are still low and the quality of collection services is poor in many developing country cities. However, waste collection services are typically nonexistent in poorer regions, such slums (Modak P, Jiemian Y, Hongyuan Y, 2010). In general, the collected waste is thrown carelessly onto land where it may be burned. Such careless and insufficient disposal of waste harms human and animal health, degrades the environment, and results in significant financial and socioeconomic losses (Ho and Maksimovic, 2002). In the developing world, between one-third and two-thirds of the municipal solid waste produced is carelessly disposed of on streets or in drains, which contributes to flooding and creates breeding grounds for rodents and insects that spread disease (Zurbrügg and Schertenleib, 1998). Urban population expansion, high urbanization, economic growth rates, poverty, ineffective governmental institutions, poor execution of laws, and inadequate public budgets are all factors that might aggravate this situation (Gobena, 2020).

2.2. Classification of Waste and Types of Waste

Solid waste is broad, hence there is no one classification method that works perfectly. Solid waste is categorized according to its characteristics, origin, and level of risk. Food waste, rubbish, ashes, and residues, agricultural waste, municipal services, industrial process waste, and demolition and construction wastes are the several categories into which solid waste can be divided based on where it originates from. It also falls under the categories of biodegradable and non-biodegradable. Furthermore, it can be classified into hazardous and non-hazardous wastes based on its potential for risk (Centre For Enviroment and Development, 2003). According to (Daniel et,al.,1999), solid trash can come from a variety of sources, including residential, commercial, institutional, industrial, construction and demolition, and municipal services. All of the above mentioned should be classified as municipal solid waste.

Common Types of Solid Waste Based on Their Point of Source

- **Domestic /residential waste**

Solid wastes from single-family and multi-family homes fall under this type of waste. These types of wastes are produced by various household activities, including cooking, cleaning, repairs, hobbies, redecoration, empty containers, packaging, clothing, old books, writing utensils, old furnishings, and large, unusable appliances and furniture (Centre For Enviroment and Development, 2003).

- **Commercial Waste**

Paper, cardboard, plastics, wood, food wastes, glass, metals, special wastes, and hazardous wastes produced by retail stores, restaurants, wholesalers, hotels, markets, office buildings, warehouses, and other commercial establishments are among the wastes included in this category. Because this sector produces a significant volume of solid waste, commercial waste is an important waste stream (*What is the Waste Hierarchy*, 2021).

- **Industrial waste**

Wastes from this category is generated by light and heavy manufacturing, fabrication, construction sites, power plants, and chemical facilities. This waste includes ashes, packaging, food wastes, hazardous wastes, and wastes from construction and demolition (Haile, 2011).

- **Institutional waste**

Wastes generated by institutions including schools, colleges, hospitals, and research centers are referred to as institutional wastes since they resemble commercial wastes (Bhada-Tata, 2012).

- **Municipal Waste (MSW)**

Wastes originating from municipal operations and services are included in this class. Dead animals, waste from parks and beaches, tree and landscape trimmings, street sweepings, and general wastes(Bhada-Tata, 2012). Iyeke,(2011) defines MSW as non-air and sewage emissions produced inside and disposed of by a municipality, such as business and residential waste, dead animals, abandoned cars, and building and demolition debris.

2.3. Physical composition of solid waste

A waste stream's physical composition defines the amount of different material types in it. The physical composition of solid waste varies greatly due to many causes, similar to the rate at which waste is generated (Birhanu, 2015). This includes:

- Economic level difference: regions with lower incomes produce comparatively more organic waste; higher-income areas often produce more inorganic trash.

Table 1. Municipal solid waste characteristics for low, middle, and high-income countries (% by weight)

Composition	Low-income countries (%)	Middle income Countries (%)	High income Countries (%)
Paper	1-10	15-40	15-40
Plastics	1-5	2-6	2-10
Metals	1-5	1-5	3-13
Glass. Ceramics	1-10	1-10	4-12
Leather, Rubber	1-5	-	-
Wood, bones, straw	1-5	-	-
Textile	1-5	2-10	2-10
organic matter	40-85	20-65	20-50
Miscellaneous	1-40	1-30	1-20

Source : (Kibrekidusan, 2017)

- Demography (difference in amount of population for example, tourist places).
- Locations: includes sociocultural variables, natural resource types and quantity, and other elements that significantly influence the variety of waste in various locations.
- Season: In this regard, yard wastes like grass clippings and raked leaves contribute significantly to solid waste during specific seasons.

2.4. The concept of waste management

Waste management occurs at the interaction of the anthroposphere and the environment. Waste management's goals and definition changed over time and continue to do so. When people began to gather waste and remove it from their immediate living spaces, organized waste management began to take shape. This was a crucial hygienic measure that assisted in preventing epidemics. Over the ages, these procedures were improved. However, over the 20th century, there were significant changes in the amount and composition of wastes, which led to new challenges. First, groundwater was contaminated and greenhouse gases were produced by the emissions from disposal sites, or landfills. Second, in highly populated places, landfill space became rare. Even the idea of sanitary landfilling may not reduce these issues in the long run (Paul H et,al., 2005).As the world's population and consumption grow and produce more garbage, waste management concerns are becoming more and more prominent on the environmental agenda (Birhanu, 2015). The most popular idea is the waste hierarchy, which categorizes waste management techniques based on how desirable they are in terms of trash minimization and relates to the "3 Rs" of reduce, reuse, and recycle (Bacinschi et,al., 2010).

According to Regional Centre for Urban and Environmental Studies (2014), SWM is the process of gathering, storing, moving, processing, and getting rid of leftover solid waste in a sanitary landfill that has been specially designed for that purpose. This integrated process includes multiple methods of collection, storage, different types of transportation equipment, recyclable material from recovery mechanisms, and approaches like composting, waste-to-power (thermal treatment technologies) and disposal in an engineered sanitary landfill to reduce waste quantity and volume (Ngatata, 2016).

2.4.1. Functional Elements of Solid Waste Management System

In every society, solid waste management is a necessary service. The waste management system consists of six functional parts (LeBlanc, 2020).

- **Waste Generation**

Solid waste is generated as a result of human, animal, and natural activity. Planning, creating, and running a solid waste management system all require an understanding of how solid waste is generated. The two dimensions of generation are the quantity and quality of solid waste, respectively. While quantity reflects the rates of generation and the overall amounts and volumes of waste generated, quality refers to the sources, types, and typical composition of solid waste along with its characteristics (Haseeb Jamal, 2020).

- **Waste Handling and Separation, Storage, and Processing at the Source**

The solid waste management system contains six functional elements, the second of which is waste handling, sorting, storage, and processing at the source. The processes involved in managing wastes up until they are put in storage containers for collection are referred to as waste handling and sorting. Transporting filled containers to the location of collection is also included in handling. An essential first step in managing and storing solid waste at the source is sorting the various components of the waste. An essential first step in managing and storing solid waste at the source is the separation of waste components. The other activity is on-site storage, which is very important because solid wastes need to be taken into account, along with the kind of container to be used, where to store it, public health and aesthetics, and the best collection technique (Tchobanoglous, 2012).

- **Waste Collection**

The process of collecting trash from collection spots, loading them into a car, and driving them to processing facilities, transfer stations, or disposal sites is known as waste collection. An essential part of waste management processes is waste collecting. In most municipal solid waste management systems, collection costs constitute a considerable fraction of the entire cost (M.Massod, 2017).

- **Separation, Processing, and Recovery**

The fourth functional element involves the sorting, processing, and transformation of solid waste materials. This functional part includes the recovery of sorted components, processing of solid waste, and transformation of solid waste that mostly takes place in sites away from the source of waste generation.

- **Transfer and Transport**

The functional part of transfer and transport consists of two steps: (i) transferring wastes from the smaller collection vehicle to the larger transport equipment, and (ii) transporting the wastes to a processing or disposal facility, typically over significant distances. Typically, the transfer happens at a transfer station (Tchobanoglous, 2012).

- **Disposal**

The final option for treating solid waste is to dispose of waste in landfills. This is due to the fact that waste that is dumped in landfills eventually loses its usefulness and negatively impacts the ecosystem. There are three different kinds of disposal in landfills. These are surface impoundments, hazardous waste landfills, and landfills for MSW (Shiun Ming et al, 2015).

2.4.2. Methods of Waste Management

An essential component of environmental preservation is waste management. Its goal is to provide a clean, effective, and cost-effective method of collecting, transporting, treating, and disposing of solid waste without contaminating the environment, the land, or the water system (Iyeke, 2011). According to Seo (2004) there are four common ways to manage solid waste: land filing, burning, composting, and anaerobic digestion. Another aspect that goes into solid waste management is the 5Rs (Ghahramani, 1998) .

Land Filling

Landfills raise environmental concerns since they have the potential to harm groundwater. If the waste's toxins are permitted to enter the groundwater, they may result in health issues as well as other environmental issues (Ghahramani, 1998). The waste sector's main greenhouse gas (GHG) emission, CH_4, originates from landfills and is released for several decades after wastes get disposed (IPCC, 2007a).

Incineration

Incineration is a controlled combustion process that converts combustible waste into gases before reducing it to a residue of noncombustible materials. Moisture in the solid waste evaporates during incineration, and the combustible fraction oxidizes and evaporates as well. After incineration, $C0_2$, water vapor, ash, and non-combustible residue are produced (Centre For Enviroment and Development, 2003). Suitable for getting rid of waste that contains more flammable materials, like food scraps and packaging, paper, cloth, plastic, etc. It can be an excellent resource utilization to use waste to obtain energy because of its high degree of volume reduction, amount reduction, and less harmlessness. As stated by Lu (2018) , this process has more sophisticated operational procedures, a larger initial investment cost, and an operating coast.

Composting

Microorganisms are used in the composting process to break down the organic material in the waste stream. The process of aerobic composting is faster and produces a homogenous, stable humus similar to compost from the heterogeneous organic waste materials (Centre For Enviroment and Development, 2003). Although they produce relatively little greenhouse gas, composting and other biological treatments were included in the 2006 IPCC Guidelines for completeness (IPCC, 2007a). In low-income nations, composting is a particularly significant solid waste management technique, especially in densely populated urban areas with limited waste processing facilities (Nsimbe *et al.*, 2018).

Anaerobic digestion (AD)

In AD, biomass (separated from MSW) is converted by microorganisms into biogas, which is a carbon dioxide and methane combination. Three physiological groups of bacteria are involved: methanogenic archaea, anaerobic oxidizing bacteria (syntrophic-acidogenic), and primary fermenting bacteria (hydrolytic-acidogenic). After the waste's organic component is separated, a difficult process of degradation results in the generation of biogas, which can be used to produce energy. According to Roy *et al* (2022) ,the decomposed materials can be recycled as compost or biofertilizer, allowing for the recycling of nutrients like phosphate and nitrogen.

The 5R's

Refuse: is the initial stage of the 5R method. It is the guiding principle that encourages us to deny everything we do not truly need. The best approach to reduce waste is to refuse to use single-use plastics or wasteful, non-recyclable items (Com *et al.*, 2022).

Reduce: is the second R, which determines if refusing is impossible and then reduces. It's about obtaining what is absolutely necessary or cannot be minimized (Ekmekcioglu, 2020).

Reuse: is using the item once more. Being creative is key to reusing a waste. Because the consumer selects the product's next path. Which purpose it is utilized for is up to the users (Ekmekcioglu, 2020).

Repurpose: is the 5R process's fourth stage. Repurposing is the concept of using objects that were intended for one use but have several uses. It is crucial to remember that repurposing comes before recycling, thus we should try to repurpose things whenever we can (Com *et al.*, 2022).

Recycling: waste recycling is the act of converting waste into products and resources that can be used again. Recycling waste is a common and effective way to manage municipal solid waste. Plastic material recycling has advantages for the environment and the economy because it reduces pollution and allows for the reuse of recycled goods (Roy *et al.*, 2022).

2.4.3. Solid Waste Management practice in developing countries

In developing countries, municipal solid waste management is not given much attention by the government, which results in very little funding being provided to this sector. This issue is particularly severe at the local government level, where there is a weak financial foundation for public services, including MSWM, and an improperly designed local revenue collecting system. Many local governments in developing nations lack sound financial planning and administration in addition to having low funding. Inadequate financial planning and management, especially in the area of cost accounting, leads the sector's limited resources to be used up even faster and results in the suspension of solid waste management services for a while, which reduces trust among consumers (M.Massod, 2017).

The widespread and uncontrolled disposal of waste in water bodies and unmanaged dumpsites, which are the result of poor waste management strategies, worsen the issue of low sanitation standards throughout the African continent. In Africa's rural areas, waste management infrastructure is mostly nonexistent (United Nation, 2009). A door-to-door collection approach is used in the majority of developed nations. However, due to administrative and financial limitations, towns in less developed nations may only offer this service to a small portion of the general population. Unplanned waste dumps or communal waste bin placements could harm water resources, particularly water sources such as rivers and streams. Other groundwater sources, such as manually dug wells and boreholes, will eventually be affected as well. Due to a lack of access to effective municipal waste disposal and sewerage systems, a large number of urban dwellers in developing nations significantly damage their surroundings (Teshome.; et al, 2022). Municipal solid waste management issues, such as increased solid waste generation, open burning, and dumping, are occurring at an alarming rate in Sub-Saharan African countries. Due to Ethiopia's rapidly expanding economy, increasing urbanization, and industrial development in its main cities, MSWM is a significant problem (Hirpe and Yeom, 2021).

Studies show that a sizable amount of Ethiopia's solid waste is disposed of without collection, ending up in open spaces and sewers. The effects of this phenomenon threaten both human life and the ecosystem (Teshome.; et al, 2022). The Federal Democratic Republic of Ethiopia has accepted a number of international agreements that significantly affect the nation's solid waste management practices. The proclamation on solid waste management emphasizes how crucial community involvement is to minimizing the negative consequences and maximizing the positive effects of solid wastes. Most Ethiopian cities, like those in other developing nations, are suffering from the negative impacts of incorrect solid waste disposal, such as plastic materials, due to a lack of waste management information and execution of the proclamation (Wondimu, 2020) . Even though municipalities in Ethiopia are responsible for MSWM under a decentralization policy, the majority are unable to handle their waste concerns. As a result, the primary goals of MSWM in Ethiopia have been collecting waste at the source and transportation to disposal facilities. According to Hirpe and Yeom(2021), the main causes of this include insufficient institutional capacity, funding, knowledge, and awareness; a lack of baseline data on solid waste; a lack of cooperation among stakeholders; a lack of political commitment and prioritizing; and ineffective planning and implementation.

2.4.4. Challenges of solid waste management in Ethiopia

- **Absence of waste segregation**

In Ethiopia, segregation occurs only on a limited scale, with recyclable waste items separated for informal recycling (Biruk, 2017). A small minority of individuals segregate exchangeable and saleable waste for personal gain, and the majority of waste is not segregated by households due to lack of knowledge and sometimes negligence (Teshome, 2021) .

- **Constraints in waste collection and transportation**

The door-to-door solid waste collection method is primarily used by Micro and small-scale enterprise (MSSE), private waste collectors, as well as municipality collection trucks to collect solid waste from residential areas; however, very few households actually receive MSSE services (Doda, 2014). Not every home is serviced by the waste collection system (does not cover poor communities). Only 50 % of the waste generators have complete coverage. The coverage is even less than half in some towns (Teshome, 2021) .

According to Hagos (2013), less than 50 % of solid waste is collected in Mekelle City due to severely insufficient collection coverage. The collection service is irregular; at worst, it may not even occur once a week. At times, it occurs once, twice, or more than once. The absence of trucks to empty the central collection containers and move the waste to disposal locations is the transportation issue (Teshome, 2021).

According to a study, municipal solid waste management has helped Kebridehar City (Somali regional state, Ethiopia) in the past, but due to the city's rapid urbanization and population increase, the problem has not been resolved. In the city, water and other liquid packaging materials are disposed of extensively. According to the report, the majority of respondents (60.6 %) had access to door-to-door solid waste collection services. However, due to labor and transportation issues, the municipalities were unable to cover the entire town (Teshome , et al, 2022).

- **Problems in the waste disposal and Management**

The disposal sites are set up without a thorough impact evaluation or research. Household waste is disposed of in one large pile without any kind of separation. To prevent health issues and environmental contamination, the dumpsites are not fenced off or covered in soil. Open burning of waste is done by HHs and in some locations by the city municipality (Teshome, 2021) . The same issue is noticed in Bishoftu town and open burning of wastes is done by households to get rid of the waste created around.

- **Financial constraints**

The waste management sector's low priority is the single root cause of Ethiopia's budgetary constraints in the waste sector. In addition to having little funding, there is also inadequate planning and management of financial resources, which leads to the halt of services and the disintegration of waste management (Teshome, 2021).

Urban governments and municipalities in developing nations have faced difficulties managing urban waste, partly because of inadequate institutional capacity, bureaucratic incompetence, and inadequate infrastructure. Municipalities all around Ethiopia are not free from these issues, as they have been dealing with serious problems related to landfill management and the collection of solid waste (Birhanu, 2015).

A review of the literature indicates that institutional, financial, logistical, and public participation issues were the main obstacles to the implementation of efficient solid waste management methods in the towns of Wolidiya, Mekelle, and Dessie (Cheru, 2011; Hagos, 2013; Abegaz et al., 2021).

In Ethiopia, municipalities were primarily responsible for providing solid waste management services, which led to insufficient service delivery. Thus, the government is currently considering integrating Micro and Small-Scale Enterprises (MSSEs). MSSEs began taking part in SWM in Addis Ababa in 2003/04. However, there are a number of obstacles that affect how well MSEs are integrated for SWM in Ethiopian cities, including a lack of funding and support, community attitude and knowledge, poor training, an unstructured fee collection method, and low revenue (Damtew et al., 2015).

2.5. Material flow analysis

The systematic evaluation of the flows and stocks of materials inside a system that is characterized in both space and time is known as material flow analysis (MFA). It establishes a connection between the material's sources, pathways, intermediate, and final sinks. Because to the conservation of matter law, an MFA's outcomes may be managed with a straightforward material balance that compares all of a process's inputs, stocks, and outputs. This method can serve as a decision-support tool in resource management, waste management, and environmental management due to its distinctive characteristics. A full and consistent set of data regarding all flows and stocks of a certain material inside a system is provided by an MFA. The flow of wastes and environmental loadings become visible and their sources can be found by balancing inputs and outputs (Paul H et al., 2005)**.**

Material flow analysis is a system assessment tool that provides an approach for energy and material flow connections in to and out of a defined system within a time frame. It can be applied in evaluating the entire waste management structure or a single waste stream towards identifying the sources of MSW generation, sources for reducing waste, internal flows of materials, potential possibilities for reuse, recycling, and accounting for hidden flows and sinks that may be unexplainable (Masebinu, 2017) .

In order to improve knowledge of marine litter and its effects on the accumulation of solid waste for small island developing states (SIDS), Owens (2011) applied the MFA tool to household solid waste and marine litter gathered from Kayangel Island. MFA was used to assess the system's components and MSW flows in order to find flows with unused potential, the existence and volume of mismanaged flows, and flows that are currently being disregarded by Maputo City, Mozambique's decision-makers, whether intentionally or unintentionally (Sarmento et al., 2016).

As it has been showed, MFA is a widely used evaluation instrument for finding essential data for discussions on sustainable resource management. The knowledge obtained has been used for efficient product design and waste minimization. In depth understanding of MSW flows within the town of Bishoftu is needed to identify process routes, factors, locations, inefficiencies, problems and opportunities within existing waste management approach. Despite being a data-driven analytical method, MFA has a great deal of potential to supply the information required for more in-depth research during the decision-making process. This study uses material flow analysis (MFA) to assess material flows within the Bishoftu town's current waste management framework. It also provides an environmental assessment of the waste management system, considering resource management, waste collection performance, and greenhouse gas emissions/ global warming potential (GWP). The study also discussed the function of informal recyclers in the management of waste.

Few researches have been conducted regarding the town's compositional analysis and waste generation. The available studies by Molla *et al* (2015) and Duguma *et al* (2019) only identify the town's solid waste management trend; their investigation focused on general awareness, knowledge, and attitude toward waste management. Other researcher Alemayehu (2022) study focused on the opportunities and challenges that logistics provide for solid waste management practices. Direct measurement on waste generation determination and compositional analysis was not found in previous studies up to my knowledge. Therefore, the present study aims to address some of these gaps; particularly the research focused on the determination of waste generation and compositional analysis by identifying major sectorial activities in terms of solid waste generation of Bishoftu town. The research also included performing a preliminary solid waste material flow analysis.

2.6. Description of the study area

Bishoftu town is one of the so-called railway towns of Ethiopia established following the construction of Ethio-Djibouti railway in 1917. The altitude of the city ranges from 1900-1995 M above sea level. The geographical/astronomical/ location of Bishoftu town is at 8º 43"-8º 45" North Latitude & 38º 56"-39º 01" East Longitude and covers about 20,574 hectares of area. It is located in the Oromia Region, North Shewa zone of Ada‘a Wereda and divided in to 14 kebel’s (administrative units) with 9 urban and 5 rural Kebel’s. Bishoftu town is found at about 47 km to the south east of Addis Ababa and situated between Dukem and Mojo towns along the Addis Ababa-Djibouti road (City Development, 2015). The town population growth is rapidly increasing by more than 4 % annually. Based on house hold survey conducted on 2021(2012 e.c) by city administration the population size of the city is projected to be 245,544 (Bishoftu city administration, 2022). Based on the above data the population of the city is predicted to be 256,593 for the year 2022 (2014 e.c) with a growth rate of 4.5 percent annually and 70,495 households (HHs). The two main factors for the increment of this population is rural urban migration and fertility. In the city, migration (rural to urban) / urban to urban/ has predominant role in changing the population characteristics and reflects the urbanization rate. Much of the population growth has been the result of internal migration and expansion of different pulling factors. There are **seven** crater lakes in and around the city namely: HoraArsadi, Babogaya, Bishoftu, Kuriftu, Cheleleka, Kilole, and Green Lake. Most of them are well developed with lodges, resorts and spas all are becoming tourist attraction.

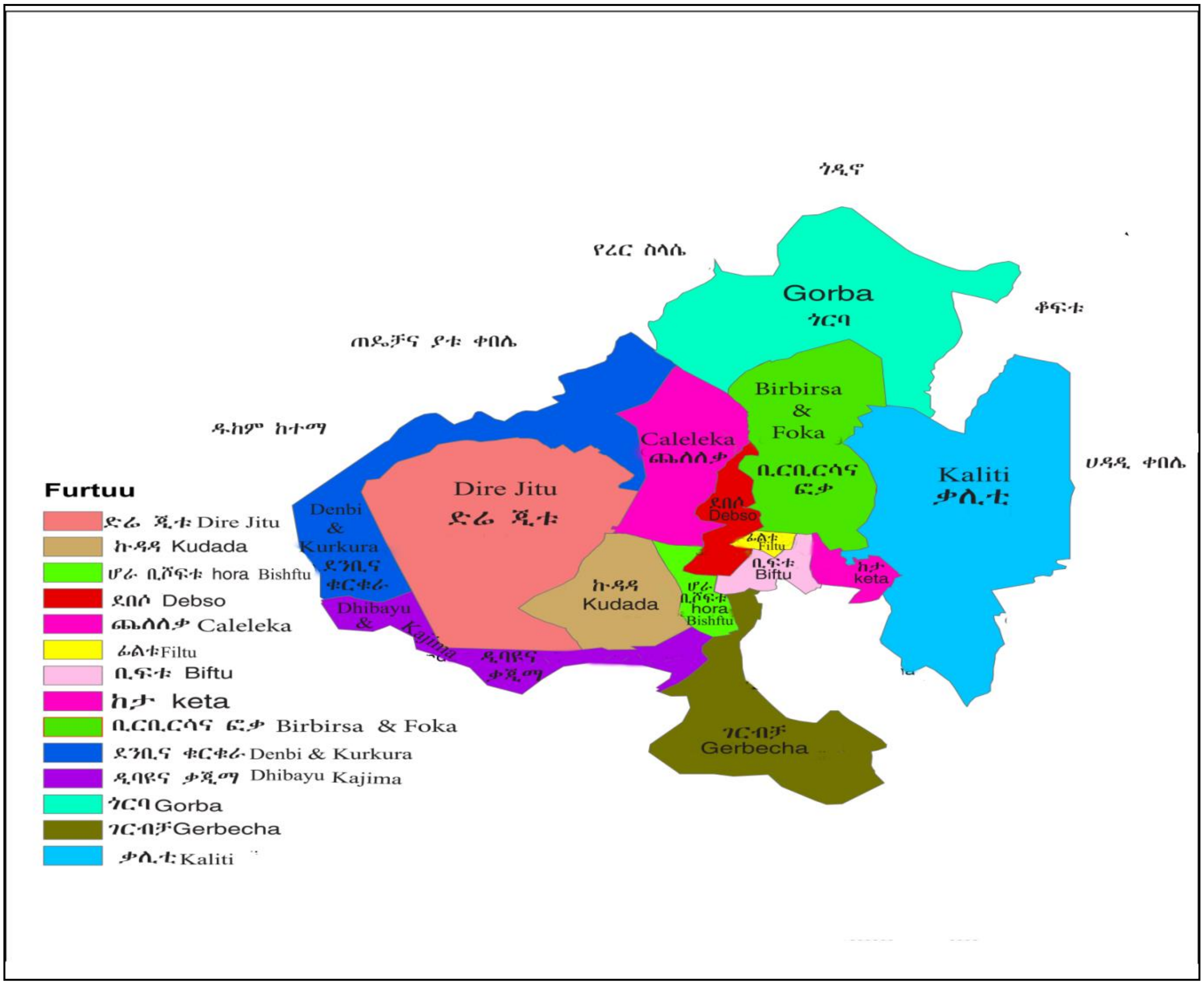

Figure 1.Map of Bishoftu city(Bishoftu city administration, 2022)

Industrial Activities of the City

Its close proximity to the capital city, Addis Ababa, and its position on the road to Djibouti, makes it a hub for industrial development. Currently around 149 industries are in operation (Bishoftu city administration investment office, 2022). Table below shows numbers of industries based on their investment capital and manufacturing sub sectors.

Table 2.Industrial Activities of the City

Investment capital / Sub sector	Small	Medium	Large	Total
Agro processing	8	20	12	40
Wood processing	12	5	2	19
Steel	7	13	6	26
Garment	10	6	3	19
Plastic	4	9	10	23
Construction material	10	6	6	22
Total	51	59	39	149

Source: (Bishoftu city administration investment office, 2022)

3. Material and Methods

3.1. Study design, sampling procedure and sample size determination

The study area was selected purposively. Cross-sectional descriptive survey design and both qualitative and quantitative methods were used in this study. The quantitative study method was used to collect data on the solid waste generation rate and physical characterization and composition from household, industrial, as well as commercial activities. According to Gleen D.Israel,(1992) ,the Simplified formula to calculate sample sizes is :

$$n = \frac{N}{1+(N*e^2)} \quad \text{..........} \quad (3.1)$$

Where n=the total sample size

N=population size (number of household to be 70,495 (Bishoftu city administration, 2022))

e=the level of statistical significance (allowable error)

$$n = \frac{70{,}495}{1 + (70{,}495 * (0.05)^2)} = 398$$

It may be unfeasible and costy to collect waste samples from 398 households for 7 days for a city, therefore sample from 90 households (10 households from 3 survey areas from high, middle and low income groups) was taken for average cities according to UN procedure (UN Habitat, 2021).

The primary phase of the investigation is the sampling phase. A multistage sampling method like cluster sampling to group the 14 kebel's in to 4 group based on their location and simple random sampling to select one representative sample from the group was used. Housing types was used to stratify the household based on their income.

There are 2,706 small shops (Bishoftu city administration trade office, 2022) found in the city but they were not studied separately because around 2,585 of the small shops are found in the 2 open market due to this reason their waste generation rate was calculated in bulk. The reaming

220 small shops were not included in the research. For the commercial activities, 16 samples were analyzed randomly from 678 commercial center.

Table 3.Commercial Activities of the town

commercial activities of the town	Total No	No of sample selected
Super markets	37	2
Mini markets	170	4
Open market	2	1
Hotels, lodges, resorts	71	3
Restaurants	98	4
Cafeteria	300	2
Total	678	16

Source: (Bishoftu city administration trade office, 2022)

3.2. Measurement and field observation

3.2.1. Average Daily Generation per Capita and composition analyzation

At household level, a measurement was carried out to examine households' solid waste generation rate and physical composition and separation by distributing plastic bags to 90 selected households each of 7days. The components of the waste were separated in to major components, weighted and recorded. Daily Solid waste generation rates (DSWGR) of the town at household level were calculated according to Waste Wise Cities Tool (WaCT) guides (UN Habitat, 2021) .

$$\text{DSWGR} = \frac{\text{Total solid waste generated for consecutively 7 days}}{\text{Consecutively 7 days} * \text{total family size household}} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3.2)$$

Based on the estimated population of Bishoftu town, the daily solid waste generation rate was calculated from multiplication of DSWGR and estimated total population of the town. Monthly solid waste generation rate of household was calculated by summing up the daily generation rate for the 30 days (Gobena, 2020).

Similarly, annual solid waste generation rate of household was determined from daily solid waste generation rate of household and multiplying by the number of days in the year (365 days). Furthermore, determination of the solid waste generation and characterization from different commercial units was performed based on representative sampling from each commercial unit's category, such as Retail Trade shops, Wholesale Trade shops, super markets and mini markets, Hotels, resorts Bar, Restaurants, cafeterias and Repair services.

3.2.2. Analysis of bulk density

Field measurement of wastes was carried out in order to determine the bulk weight of solid waste. In order to accomplish this task, 20 L circular plastic bucket were used to determine the weight of sample volume of solid waste. First, a waste sample was poured into known volume equipment of $0.02m^3$ (20L) and then, the density in (kg/m^3) was calculated by dividing the net weight of the solid waste sample in the container by the container's volume for each three category of solid waste sources (HH, open market and hotels, resort and restaurant). According to the waste wise city tool guide quartering techniques was used to take our sample from the different source of waste streams. Firstly 200-300 kg of MSW was accumulated to derive a representative sample of 50-70 kg for the analysis. The sample was mixed thoroughly by using a shovel and divided in to four layer (ABCD). From the four section the two opposing side (B and D) was discarded and the reaming two quarter was mixed. The quartering process was repeated once more to derive a sample which is approximately one quarter of the size of the original sample around 50-70 kg (UN Habitat, 2021).

3.2.3. Formal waste management processes and examination of the existing spatial coverage of solid waste management service in the town

Field observations were employed to determine spatial distribution of households' solid waste handling practices, solid waste collection, separation, and disposal site. The overall effectiveness and efficiency of solid waste management practice in terms of overall collection, transportation and disposal mechanism of the town was investigated qualitatively from key informant interview.

The purposive sampling technique were used to select municipal officers, scavengers (waste pickers), all of the waste collectors and cleaners in Bishoftu town.

3.3. Socio-economic analysis

A municipal solid waste management system's life cycle consequences on the environment, society, and economy can be better understood by conducting an SDG-based life cycle sustainability assessment. The assessment results can help decision-makers optimize the system's sustainability. To assess a system's sustainability consequences as a whole, information on material and energy flows, as well as socioeconomic data, must be collected for each phase of the system's life cycle. According to (Mansaray-Pearce, 2019) Socioeconomic variables (particularly wealth) may influence attitudes such as perceived ability or inclination to recycle municipal solid waste, although these attitudes can be positively influenced by awareness-raising campaigns and educational initiatives. The required data is determined by the indicator set used, which must be appropriate for the local context. Based on the work done by Wang et al (2018) the socio-economic data similar to that listed in the following could be collected and assessed within case studies in Bishoftu town, Ethiopia: income of actors below international poverty line, expenditure/cost of living of actors, collection rate of household waste, number of trainings/campaigns offered, participation rate in trainings/campaigns, number of health incidences/accidents, energy consumption, rate of female workers. These data were collected based on appropriate questionnaires, observation, and data collection from different city administration offices.

3.4. Data collection tools

In this study, both primary and secondary data sources were used. For gathering primary data, direct solid waste measurement, physical characterization, questionnaires and filed observations were employed according to the standard procedure of Waste Wise City Tool by the UN-Habitat project. Regarding to the questionnaires, there were two types of questionnaires (both close ended and open - ended interview questions) which were prepared in order to look at the general SWM practices and socio-economic impact.

On the other hand, secondary data were extracted from different sources including published and unpublished materials from different part of the municipality administrative office, Sanitation Beautification and Parks development Department (SBPDD).

3.5. Data analysis

3.5.1. Qualitative and Quantitative data analysis

The qualitative data was collected through questionnaires, personal observation and secondary data review was discussed. The quantitative data was analyzed with the help of Package for Social Science (SPSS version 20).

3.5.2. Prediction of future waste generation

Sustainable and effective MSW management depends on a precise estimation of the MSW generation rate. Forecasting is a decision-making technique that captures the trend of past and present data to be used in future projections. A number of stakeholders, including academics, legislators, governmental agencies, and municipalities, have used it to create efficient and sustainable MSW management. Having access to reliable historical data will be helpful in projecting the amount of MSW that will be produced in the future and in putting the circular economy into practice to repurpose waste materials. This will support improving the national economy, preventing the overuse of finite natural resources, increasing employment, and reducing adverse environmental effects (Elshaboury *et al.*, 2021). A simple calculation was used for predicting the amount of waste generated in Bishoftu town for the next ten years: multiplying the waste generation rate by the town's annual population. A population growth rate of 4.5% was assumed.

3.5.3. Material Flow Analysis

The study use MFA to identify the waste material chain from source to final disposal in the area using the STAN program (version 2.7). STAN is a freeware for MFA that was developed by the Vienna University of Technology (Institute for Water Quality, Resources, and Waste Management) in collaboration with INKA software in 2006 (Cencic and Rechberger, 2008). MFA is an analytical approach for determining the flows and stocks of materials or chemicals in a well-defined system. This is based on the law of mass conservation and is the most commonly used methodology for waste material flow analysis in research. According to mass conservation, any mass that enters a system must either depart or accumulate within the system. The mass balance of a system can be expressed mathematically as follows (Hemali *et al*., 2022);

$\sum inputs = \sum outputs + change\ in\ stock$ ………………………………………………………. (3.3)

In order to assess the potential increment of resource management and GHG emission reduction of solid waste management alternatives for Bishoftu city, some reasonable waste management scenarios were assumed with the priority given to the continuing use of existing solid waste management system.

Table 4.scenarios

Scenarios	Portion of solid waste for composting
S I	10%
S II	30%
S III	50%

The GHG emissions from MSW in this research are based on two main gases, which include Carbon dioxide (CO_2) and Methane (CH_4). In addition to the two main gases, Black carbon emission was calculated as it is formed primarily in flame during open burning (Bond *et al.*, 2013). The Intergovernmental Panel on Climate Change (IPCC) guidelines is adopted to estimate the GHG emissions from landfills, open burning, composting, and recycling. IPCC guidelines are also adopted by the United Nations for the Framework and Convention on Climate Change (UNFCCC) (Umar, 2019). It is used by all the member countries to report their national GHG emissions. This research, therefore, uses the IPCC (2006) to determine the GHG emissions from open burning, landfills, composting and recycling. It, however, needs to be noted that as a result of the uncertainties, the calculations are only approximate but still useful as a guide to the likely scale of impacts.

$$CH_4 = MSW(LandFill) * MCF * DOC * DOCF * F * \left(\left(\frac{16}{12}\right) - R\right) * (1 - OX) \quad \ldots\ldots\ldots\ldots(3.4)$$

Where, CH_4 = Methane Emission

MSW (Land Fill) = total amount of MSW in the landfill R = the recovered methane

DOC = the fraction of degradable organic carbon in MSW MCF = methane correction factor

DOCf = the fraction of DOC that can decompose (fraction) OX = the oxidation factor

F = the fraction of methane in generated landfill gas

16/12 is the molecular weight ratio CH4/C

The estimation of CH_4 from the composting in this research is made adopting equation 3.5.

$$EM = [M * EF] * 10^{-3} - R \quad \ldots\ldots (3.5)$$

Where; EM = GHG emissions from composting

M = amount of MSW composted

EF = an emission factor

R = amount of methane recovery– (valued used = 0)

Emission from open burning in this research is made adopting equation 3.6.

$$EM_{OB} = EM_i\ (CO_2) + EM_i\ (CH_4) + EM_i\ (BC) \quad \ldots\ldots (3.6)$$

Where; EM_{OB} = emission from open burning

EM_i (CO_2) = Carbon dioxide emissions

EM_i (CH_4) = Methane emission

EM_i(BC)=Black Carbon emission

Emission from Recycling in this research is made adopting equation 3.7.

$$ER = MSW\ (Recycled) * EF_i \quad \ldots\ldots (3.7)$$

Where; ER= Emissions from Recycling

MSW (Recycled) =Total amount of MSW recycled

EF_i=Emission factor

4. Results and Discussion

4.1. Solid Waste Generation and Compositional Analysis

The per capita waste generation is calculated by dividing the total waste generated with the number of people living in that house- hold that day (UN Habitat, 2021) . According to results, 0.31 kg/person/day is calculated for the entire study area in Bishoftu town. The generation rate calculated for the city is in the range as reported for low income country on the fourth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC, 2007a) . This result is in the range set for sub sub-Saharan country with waste generation rate 0.09 – 3 kg/person/day by Bhada-Tata (2012) in his global review of solid waste management.

Waste Composition

The waste composition gives information that helps to improve the sustainability of waste management, as the quantity and ways of diverting solid waste from landfills are mostly determined by waste composition. Furthermore, this helps in identifying recycling possibilities to explain the necessity for recyclable trash collection services and determining a charge strategy for mixed waste to promote waste recycling programs (Noufal *et al.*, 2020).

The main typical compositional categories of Bishoftu municipal solid waste are organic waste (food, garden waste), other waste (containing ash in large portion), plastic-film, paper, dense plastics, glass, textiles, and metal. The results clearly indicate that the composition of organic waste is dominated by food waste (mixed). Previous studies have reported that large portion of solid waste in developing countries is food waste(Wakjira, 2007; Palanivel et al., 2014). From the results, it is clear that in Bishoftu huge quantities of food waste is generated from household and commercial establishments like restaurants and hotels. Next to organic waste, other waste accounts 18 %, which contains ash in large amount, soil and dust from house and garden sweeping. Inert materials, such as sand, ash, dust, and stones are major constituents of solid waste in developing countries (world Bank, 2008). Figure 2 show the percent distribution of the different categories of waste generated in the town.

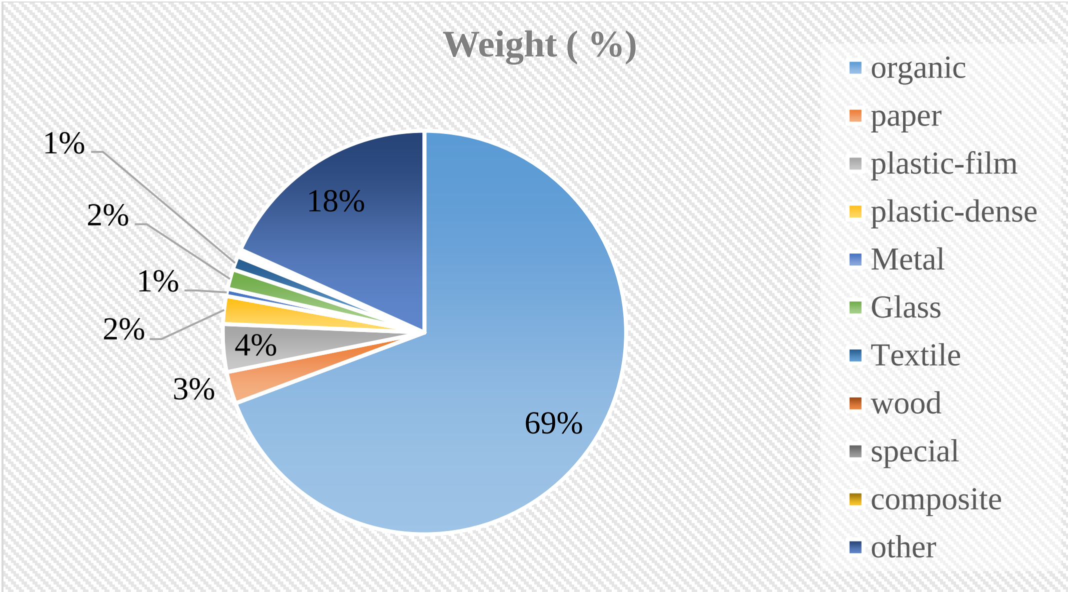

Figure 2.Percent (wt. %) distribution of MSW composition generated

4.2. Analysis of bulk density

Waste density is a significant factor when planning, scheduling, and developing MSWM infrastructure. The density of MSW varies with location, season, humidity, and so on. The density of the waste is calculated by using a known volume of 20-liter bucket. Table 5 shows some typical municipal solid waste densities of Bishoftu city.

Table 5.Calculated Bulk Density

Source	Density kg/L
HH	0.22
Open market	0.18
Hotels and restaurant	0.518
Average	0.306

These relatively high densities are mostly due to the high moisture content of the MSW, which is not allowed to open air to precipitation before collection (Adiloğlu *et al.*, 2016). According to World Bank study in many developing countries, domestic waste contains a large proportion of inert materials, such as sand, ash, dust, and stones, and has high moisture levels because of the high usage of fresh fruit and vegetables. These factors make the waste very dense (high weight per unit volume) (world Bank, 2008).

4.3. Waste generation multipliers (kg/day) for different commercial sectors

The solid waste generation for an open market is calculated in bulk for this reason we use the calculated bulk density of refuse for the estimation of waste generation for the open market.

Table 6.Calculated waste generation multipliers (kg/day) for different commercial sectors

Commercial sectors	Unit (kg/day)
Hotels	146.43
Restaurant	69..93
Café	6.74
Super markets	4.66
Mini-market	0.926
Open market (kg/shop)	1.4

4.3.1. Total Waste generated from the different activities of the city

Based on the per capita per day generation, the daily, weekly, monthly, and annual generation amount of Bishoftu town was calculated. From the table below the annual solid waste generated is 37,509 ton/year from major solid waste generators (Household & commercial activities).

Table 7.Total waste generation calculated from different activities of the city

activities	waste generated kg/day	kg/week	kg/Month	kg/year	ton/year
House Hold	79,543.80	556,806.6	2,386,314	29,033,487	29,033.49
Hotels	10,396	72,772	311,880	3,794,540	3,794.54
restaurant	6,853	47,971	205,590	2,501,345	2,501.345
Café	2,023	14,161	60,690	738,395	738.395
super market	172.42	1,206.94	5,172.6	62,933.3	62.9333
Min-market	157.42	1,101.94	4,722.6	57,458.3	57.4583
open market	3,619	25,333	108,570	1,320,935	1,320.935
Total	102,764.64	719,352.5	3,082,939	37,509,094	37,509.09

4.4. Demographic and socio-economic characteristics of the sample population

Demographic and socio-economic variables such as occupation, education, number of household members, and income affect waste generation. A study done in Malaka Regency showed that age, gender of the family head, income, occupation, last education, and the number of family members had a significant influence on waste generation in the study area (Leonarda Sofiani Rame et al, 2022). Socio- economic factors have a greater effect on the waste produced and choice of disposal methods (Geetha *et al.*, 2020).

- Sex, age, family size and housing condition

Table 8.Sex, age, family size, and housing condition of the respondent

Characteristics of dummy variables	Description	Frequency	Percent
Sex	Female	64	71.1
	Male	26	28.9
age of the respondent	<30	15	16.7
	30-60	57	63.3
	>60	18	20
Family size	1-3	17	18.9
	3-7	57	63.3
	>7	16	17.8
Housing Conditions (House ownership)	Private	60	66.7
	Rented	14	15.6
	Kebele	16	17.8

Source: computed from survey data, 2022

According to the profiles of respondents, 71.1 percent were female and 28.9 % were male indicating female heads dominate the survey population. The above Table 8 further shows that highest concentration (over half) of the respondents is found in the age group 30-60 years. The next highest concentration of the respondents is > 60 years age group while the remaining respondent were <30 years. About 63.3 % percent of the respondents have 3-7 household members as shown in table 8 and about 18.9 percent have less than 1-3 household sizes and 17.8

percent > 7 household members. Information extracted from Table 8 shows 66.7 percent of the respondent live in private house while 17.8 percent lives in kebele/government house and the reaming 15.6 percent in rented house.

- Educational status, profession of the households and family income

Table 9.Educational status, profession of the household and family income

Characteristics of dummy variables	Description	Frequency	Percent
Educational Status of the household head	Illiterate	3	3.3
	Primary	13	14.4
	Secondary	33	36.7
	higher education	41	45.6
Profession of the head of the HH	government employ	9	10
	private employ	14	15.5
	Business	28	31.1
	Student	6	6.7
	Housewife	17	18.9
	Retired	16	17.8
family income	< 8,000	30	33.3
	8,000-15,000	41	45.6
	>15,000	19	21.1

Source: computed from survey data, 2022

As per data collected from the respondents, the level of their education varies from illiterate to higher education. From this 45.6 %, 36.7 %, 14.4 %, 3.3 % as shown in Table 9 is the percent of the respondent which is higher educated, secondary, primary and illiterate respectively**.**

When we see the employment status of the respondents, as indicated in table 9, out of the total 90 sample household's 31.1 percent are engaged in business activities and constitute the highest percent of sample respondents, 18.9 percent are house wife ,17.8 percent retired, 15.6 percent are private employee. Whereas, government employee constitutes 10 percent of sample respondents. The remaining 6.7 percent of the respondents is student.

Finally, Income is another socioeconomic factor that leads the increasing volume of solid wastes as well as the increasing problem of municipal solid waste management. From the socioeconomic conditions amount of annual income of the household has an impact on municipal solid waste management. The income level of participated households also illustrated in Table 9. Households were categorized in to three groups based on their monthly household income. Thus, dominant 45.6 percent of sample households' average income is grouped in the second category who earns between 8000-15000 birr per month. 33.3 percent of households are fall under the least category, which earns less than 8,000 birr per month, and the remaining 21.1 percent are in the third category, which earns greater than 15,000 birr per month.

- **Energy availability**

The researcher found out that, out of the conducted households 46.7 percent of the total respondents use charcoal and electricity as an energy source for cooking and making their day-to-day food. 26.7 percent households out of 90 respondents use kerosene, charcoal and electricity as an energy source where as 24.4 percent of the total respondents use firewood, charcoal, kerosene and electricity. In the study area 1.1 percent of the respondent use Firewood, cow dung, charcoal and the remaining 1.1 percent use firewood and cow dung. According to literature even if electricity accessibility is vast in urban areas, most of application is run by traditional biomass energy input. Half of the urban households rely on traditional biomass for cooking (Hailu *et al.*, 2020) which relates to the survey data that even though the HHs have an access to electricity they still use traditional energy source for cooking and other activities .

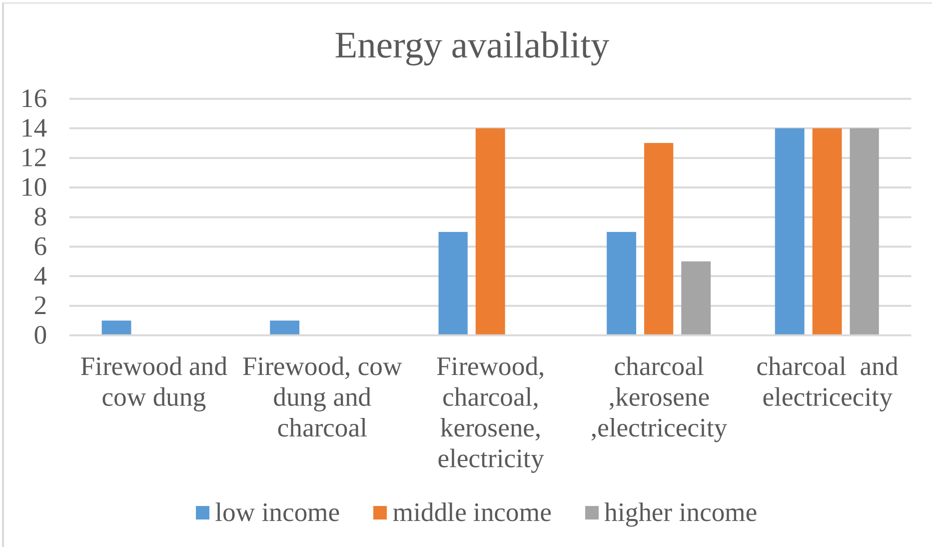

Figure 3.Energy availability of the study area (computed from sample survey, 2022)

Table 10.Correlation of Demographic characteristics of the sample population with solid waste management practice

Correlations					
		Do you separate your kitchen waste from other household waste	Do you reuse household wastes	Do you compost wastes	Do you burn household wastes
sex of the respondent	Pearson Correlation	-0.17	0.013	-0.121	.225*
	Sig. (2-tailed)	0.109	0.902	0.255	0.033
Family size	Pearson Correlation	-0.138	-0.090	0.095	0.026
	Sig. (2-tailed)	0.195	0.397	0.373	0.808
age of the respondent	Pearson Correlation	-0.136	0.011	-0.078	-0.025
	Sig. (2-tailed)	0.203	0.917	0.465	0.818
Educational Status of the household head	Pearson Correlation	-0.033	0.015	-0.163	0.157
	Sig. (2-tailed)	0.755	0.892	0.125	0.138
Profession of the head of the HH	Pearson Correlation	-0.085	.268*	0.112	-0.113
	Sig. (2-tailed)	0.426	0.011	0.292	0.29
Housing Conditions House ownership	Pearson Correlation	-0.045	-0.204	-0.05	0.013
	Sig. (2-tailed)	0.676	0.054	0.637	0.905
**. Correlation is significant at the 0.01 level (2-tailed).					
*. Correlation is significant at the 0.05 level (2-tailed).					

Table 11.Correlations of family size with waste generation

Correlations			
		Family size	waste generation per day
Family size	Pearson Correlation	1	.52**
	Sig. (2-tailed)		0.000
	N	90	90
**. Correlation is significant at the 0.01 level (2-tailed).			

In this study, education level, occupation, age, gender, and housing condition have no relationship or weak relationship with solid waste management practices like waste separation, reusing, composting and burning practice. The present study is consistent with a study conducted in different town of Ethiopia(Abegaz *et al*., 2021; Teferi, 2022) . According to the SPSS manual family size have large correlation with solid waste generation with person correlation value r= 0.52 (PALLANT, 2005) . Even though in the study area family size have positive relationship with the waste generation with Pearson correlation value r=0.52 it have insignificant relationship with solid waste management practice like sorting and composting. Insignificant result of family size as a factor that determines the understanding of waste sorting and composting is consistent with a previous study done in Surabaya city, Indonesia (Setiawan, 2020) .

When we see Socioeconomic group wise total waste generation rate of the study area middle socioeconomic group (MSEG) and lower socioeconomic group (LSEG) generated more wastes compared to higher socioeconomic group (HSEG) due to more members in a family as shown in Table 12.

Table 12.Generation rate based on income Level

Income groups	No of sample HHs	Family size	kg/day/HH	Generation rate kg/day/person
Lower	30	146	42.66	0.3
Middle	41	247	83.63	0.34
Higher	19	93	24.806	0.27
Total	90	486	151.096	0.31

The non-biodegradable wastes of middle and lower socioeconomic group consist of mainly inert materials as they use the solid fuels (fire wood, charcoal and dung cakes) usually in their kitchen as shown in Figure 3 above which have significant effect on the waste generation. It has been observed that most of the families in HSEG use electricity mainly and charcoal and kerosene often when there a disconnection in electricity. The results of the present study corroborated the finding of (D. Khan et al., 2016) that reported medium and lower socioeconomic group generates the maximum wastes due to more members in a family and the non-biodegradable wastes of lower socioeconomic group consists mainly of inert materials as they use the solid fuels.

4.5. Solid waste handling, disposal and collection practice in the study area

Storing the waste at household level before transferring to the transfer station is one of the management options(Mekonnen, 2012) . Table 13 shows how the respondents collect and keep the solid waste before disposal in temporarily storage tank at their home. Majority of the household 88.9% use sack as a temporary solid waste storage and 6.7 % of the respondent use plastic bag while the remaining respondent (4.4 %) use plastic dustbin for temporary waste storage in their house. From the survey, 86 household (95.6 %) of the respondent waste is collected once a week by the MSSEs and four household (4.4 %) have no regular collection schedule. From Table 13 92.2 % of the respondent prefer their waste to be collected once a week while 7.8 % of the respondent prefer once every three day. 55.5 % of the respondent dispose their waste in morning and 36.7 % dispose their waste in the afternoon while the remaining 7.8 % of the respondent have no definite time of disposal. The entire respondent (100 %) prefers disposing their waste in the morning. Door to door, solid waste collection system is used for all of the 90 household in the research area. 65.6% of the respondent pay 40-50 birr/month for the service and 18.9 % pay greater than 50 birr/month. As shown in Table below 12.2 % of the respondent pays 20-30 birr /month. Due to budget constraint and other factors, 3.3 % of the respondents do not pay for the service. According to study done in Hara city, factors like budget constraint, not believing in the waste management program and waste management must be government responsibility are some reason of the respondent for not being willing to pay for waste management service. The authors report 11 % of the HH were unwilling to pay for the improvement of solid waste management program (Haileyesus et al, 2022).

Table 13.Solid waste handling, disposal, and collection practice of the study area

Characteristics of dummy variables		Frequency	Percent
what is your temporary container type	Plastic Dust Bin	4	4.4
	Sack	80	88.9
	plastic bag	6	6.7
how often is your waste collected	once a week	86	95.6
	Irregular	4	4.4
How often you prefer if your waste is collected directly from your house:	Once every three days	7	7.8
	once a week	83	92.2
Generally, when do you dispose of your waste?	No definite time	7	7.8
	Morning	50	55.5
	Afternoon	33	36.7
When do you prefer for your waste to be collected?	Morning	90	100
Which system do you use for removal of your household waste	A collector will collect the waste from the house	90	100
How much are you currently spending for waste disposal per month	20-30	11	12.2
	40-50	59	65.6
	>50	17	18.9
	I didn't pay	3	3.3

Source: computed from sample survey, 2022

When we come to satisfaction level by the current waste removal system as shown in Table 14 64.5% of the respondents are highly satisfied with the current solid waste collection system and 33.3% of the respondent rating it as a good satisfaction level while the remaining 2.2% of the respondent are medium satisfied with current solid waste collection service. Comparing to studies done in other cities of Ethiopia like Jimma and Gondar the satisfaction level regarding to the solid waste management system is high (Batu, Admasu and Tolosa, 2016)(Tenaw, 2022). According to this finding as shown in Table 14, the entire respondent agrees that community participation is inevitable for local waste collection system and improvement of the environment. Currently solid waste management is given the lowest priority by the respondent (1.1%) followed by sanitation (17.8 %). 50% of the respondent need clear water supply currently and 31.1% of the respondent have a high problem in drainage system as shown in Table 14.

Table 14.satisfaction level, attitude towards community participation and current priority need of the study area

Characteristics of dummy variables		Frequency	Percent
Satisfaction level about the present municipal waste removal system:	very Good	58	64.5
	Good	30	33.3
	Medium	2	2.2
Community participation is inevitable for local waste collection system and improvement of the environment – do you agree?	Yes	90	100
Current priority need	Water supply	45	50
	Sanitation	16	17.8
	Solid waste management	1	1.1
	Drainage	28	31.1

Source: computed from sample survey, 2022

Table 15.Household separating kitchen waste, reuse, and compost

Characteristics of dummy variables		Frequency	Percent
Do you separate your kitchen waste from other household waste?	Yes	33	36.7
	No	57	63.3
Do you reuse household wastes	yes, I use plastic bottles	39	43.3
	No	51	56.7
Do you compost wastes?	yes, I use organic waste	30	33.3
	No	60	66.7

Source: computed from survey data, 2022

For proper management of solid waste, composting organic matters at household level is highly recommended. From Table 15 we can see that above half of the respondent (63.3 %) have no trend of separating kitchen waste from other household wastes which is a common problem in the other part of the country (M.Massod, 2017) . From 90 household only 30 household(33.3 %) have the trend of composting which is relatively high comparing to study done in Jimma and Hawassa town (Mekonnen, 2012; Doda, 2014). Households who segregated their waste were more likely to engage in composting. Waste segregation has been known to easy further treatment processes such as composting of wastes (Nsimbe *et al.*, 2018) , and therefore, it is not surprising that HH who segregated their waste were more likely to engage in composting. The city is widely known for plant seedling activities, which is the cause for relative high compost activities.

In this finding as shown in Table 15 only (43.3 %) of the respondent have the trend of reusing only plastic material for different purpose indicating that Bishoftu town share the same problem as other part of Ethiopia in which the practice of reusing waste is very low (Birhanu, 2015). The remaining (56.7 %) of the respondent have no trend of reusing waste. Reusing of waste is more encouraged and more efficient and better than recycling and composting methods because cleaning and reusing materials in their present form avoids the cost of energy for remaking them in to something else (Birhanu, 2015).

Table 16.Household using open burning as a waste reduction system and open dumping as a disposal method

Characteristics of dummy variables		Frequency	Percent
Do you burn (incinerate) household wastes	yes, I burn waste from compound cleaning	40	44.4
	NO	50	55.6
Do you use open dump as a disposal method	yes, I dispose garden trim & animal waste	4	4.4
	No	86	95.6

Source: computed from survey data, 2022

Table 16 shows 40 household (44.4 %) of the respondent has the trend of waste burning and while the remaining HHs have no the trend of waste burning. Waste burning is the most common household waste management methods identified in Africa and a significant local source of air pollution, constituting a health risk for nearby communities (IPCC, 2007b; Pr. Desta Mebratu and Dr. Andriannah Mbandi, 2022), which is also true for Bishoftu city. The majority of the respondents (95.6 %) do not use open dumping while (4.4 %) use open dumping as a disposal method for wastes like garden trim and animal waste as shown in Appendix G, Figure G 3.

From the collected solid wastes, plastics, cardboard, tins, scrap metals and glasses are sorted and sold to the informal collector commonly known as Korales which practiced in different part of the country (Mekonnen, 2012) for the purpose of recycling and reusing final products before throwing it as a wastes. This contributed that, the actual volume of recyclable waste to be disposed of outside the house would be decreased and this was reflected in the compositional analysis. The result of the questioners shows 56.7 % of the respondent sell waste for korales (informal collectors) and from this metal, plastic and bottles are sold by the respondent in first place consisting 35.6 % of the total respondent. From the survey 18.9 % of the respondent sell plastic and bottles and the remaining 2.2 % of the respondent sell papers, metal, and plastics for the informal collectors as shown in Table 17 while the remaining 43.3 % of the respondent have no trend of selling waste at all.

Table 17.Household having a trend of selling recyclable waste and type of waste they sell to informal collector

Characteristics of dummy variables		Frequency	Percent
Do you sell wastes?	Yes	51	56.7
	NO	39	43.3
what type of wastes do you commonly sell	plastic and bottles	17	18.9
	metal, plastic and bottle	32	35.6
	papers, metal and plastic	2	2.2
	I don't sell waste	39	43.3
For whom do you sell wastes	Korales	51	56.7
	I don't sell waste	39	43.3

Source: computed from survey data, 2022

4.6. Over view of the formal waste management system

The responsibility of solid waste collection and disposal is entrusted to the city sanitation, beautification, and parks agency. The agency is responsible for the overall solid waste management in the city and currently it has 5 staffs (4 male, 1 female). Table below shows educational status of the staffs.

Table 18.Educational status of the sanitation and beautification staff

Educational status	No
Postgraduate	2
Degree holder (BA)	3

Source: (Bishoftu city administration sanitation and beautification office)

There are private entrepreneurs involved in the collection service provision. Currently there are nine micro and small-scale enterprises each having collection truck and one municipality collection truck, which are engaged in the collection service provision. The city administration facilitated an access for a credit and the nine micro and small-scale enterprise have tractors for the collection of solid waste each with a collection capacity of $12m^3$. In general, there are 13 tractors, 2 skip loader and 8 horse carts for the collection and transportation of solid waste to the dumping site.

4.6.1. Spatial Coverage of Solid Waste Management Service in the City

Currently around 79,129 kg/day of waste is collected from different part of the city. Door to door, collection system is used to collect waste generated from household once a week and for commercial activities, waste is collected from hotels, restaurants, and resort. The waste generated from the open market is collected three times a week and two times a week from super markets and mini markets. The waste collected is transported to the landfill by the tractors with a 3-5 trip per day.

Previous studies in Ethiopia indicates only 40–50 % of the waste produced is collected as the collection system doesn’t include the poor communities (Kibrekidusan, 2017; Teshome, 2021). Moreover, the percentage of solid waste collection in three Ethiopian cities, Addis Ababa, Hawassa, and Bahir Dar, was 70 %, 80 %, and 57 %, respectively (Hirpe and Yeom, 2021). Comparing to the other cities of Ethiopia collection coverage in Bishoftu city seems to be better. Around 70 % of the daily generated waste is collected, but still there are areas like the rural kebeles in which the collection system is not effective because of the distance from the dumping site and financial problem of the community. The remaining uncollected waste are usually burned and thrown in open areas while food wastes are usually sold to pig farming from hotels and restaurant before transporting to the dumping site.

The collection fee for the household depends on their family size based on their agreement made between the collector and the household head. Same method is used for commercial services. However, sometimes this payment system is not the same for the rural areas due the distance from the collection area to the dumping site.

The collection coast of solid waste in Bishoftu city is 47.8 birr/M^3 or 156 birr/T. The annual solid waste collection and transportation cost of the city is estimated to be 4,461,429 birr/T

Table 19.Collection fee for solid waste from HH and commercial services

Family size	Birr/month	Commercial services	Birr/month
1-3	20-30	Small	50
3-7	40-50	Medium	70
>7	>50	Large	70-100

Source: (Bishoftu city administration sanitation and beautification office)

4.6.2. Overview of the current landfill site

The solid waste collected from Bishoftu town is disposed at the final landfill site found at Burda kebele 3km away from the city without further characterization i.e. the solid wastes that have been collected from different source in the Bishoftu town were disposed together. The landfill was constructed by tekilbrhan anbaye construction by the financial aid of UNDP.

The area selected for the land fill is mountain locked. The total area of the landfill is 11 hectare and the dumping area constructed with two cell each aimed to operate for 10 years. The first cell has been operating for the last 4 years starting from 2019 G.C. It is covered with geo-membrane and linearly lined with a leachate collection system. The leachate produced is collected in to the septic tank and allowed to be evaporated. Even though the dumping area have a leachate collection system the researcher observed that it is difficult to remove rain water during the summer time which results from improper construction of the storm drainage system. There are three transfer station which are not active at the moment. Daily waste entry to the landfill is controlled with three waste controllers and five guards to overlook illegal disposal and entry to the landfill.

Figure 4.current landfill of Bishoftu Town

4.6.3. Formal collection of recyclable and reusable wastes

The separation of recyclable and reusable wastes is segregated by 40 workers (31 female, 9 male) under three micro and small-scale enterprise at the dumping site and 1 micro and small-scale enterprise outside of the dumping Site. Some of the hazardous wastes are also disposed of with the municipal solid wastes. Around 167.12 kg/day of recyclable waste are collected by the micro and small enterprise. Due to the absence of recycling site in the city, the collected recyclable wastes are sold to recyclable waste processing industry outside the city. As shown in Table 20 we can see types of recyclable waste and their price.

Table 20.Types of recyclable waste and their price

Types of recyclable waste	Price (birr/kg)	Types of recyclable waste	Price (birr/kg)
Plastic water bottle (highland)	10	Metal	100
Plastics	55-60	Cardboard, papers	40-50
Sack	12	Bone, toil	50-60

Source: computed from survey data, 2022

4.6.4. Overview of the current Compost plant

Composting is the natural process of decomposition and recycling of organic material into a humus rich soil amendment known as compost. There is only 1 compost plant or hanger in the city managed by 3 micros and small-scale enterprise. It is located in the landfill site. The production capacity of the micros and small enterprise is 10 ton per two months. This means there is no daily compost production. Mixed waste is brought to the plant especially from the open market, which contains largely organic wastes and sorted for the process. Currently 100 kg of a composted is sold with 300 -400 birr. Around 69% of the city waste is organic but only 3,000 kg (30 quintals) are sold per month due to marketing problems.

Figure 5. Current compost plant of Bishoftu city

4.7. Informal collection of recyclable waste

There are informal recyclable waste collectors (scavenger) in the city engaged in the collection and recovery of reusable and recyclable waste from the source of waste generation (house hold, commercial sectors) the streets, bins, for a sale through intermediaries for recycling industries. There is no comprehensive estimate of informal waste pickers in the city.

4.8. socio-economic impact of solid waste management system

Socio-economic impact assessment of solid waste management practices was analysed in terms of health, body injuries and in terms of employment and revenue generation (benefits).

❖ Socio - economic Coast

Household income is the amount a household earns on monthly basis and the higher the income the more willing individual are to manage their waste through the payment fee system (Galgalo Dika, Aga Nemie, 2019). 3.3 % of the respondent in the survey area did not pay for the collection service as shown in table 8 because of insufficient household income. Household income is put as one reason for not being willingness to pay for a proper solid waste management system in different study area (Bhattarai, 2015; Derese Getachewa, 2018).

Because the city authorities do not provide separate waste collection facilities, many dangerous items such as broken glasses, razorblades, hypodermic needles and other healthcare wastes, potential explosive cans were observed to cause injuries to scavengers (workers in waste materials).

Turyahabwe *et al* (2022) indicates open dumping were associated with breeding of flies, rats and other vermin and reported to spread diseases such as dysentery, cholera, and plague. During the study, it was observed that flies and cockroaches increased that they were seen moving near these dumping areas.

There are settlements around the landfill site and odour released due to the decomposition products of organic wastes contains gaseous products like methane and carbon dioxide, which are toxic substance for human health. Prince O. Njoku (2019) reported 78% of participants living closer to the landfill site indicated serious contamination of air quality evident from bad odour linked to the landfill site. Illnesses such as flu, eye irritation and weakness of the body were frequently reported by participants living closer to the landfill than those living far from the Thohoyandou landfill in Limpopo Province, South Africa.

❖ Socio - economic Benefits

People are employed in waste management activities ranging from sweeping streets, collecting, transporting, and scavenging (sorting), and treatment of wastes at sites. A number of MSE engaged in the collection of garbage from households to dumping site each employing 3-5 workers and in the collection of recyclable materials. The jobs have earned people incomes that have enhanced their standards of living. It was indicated in Sierra Leone Mansaray-Pearce (

2019) solid waste generated activities provide necessary supplementary income even not being a primary economic occupation for the majority of the municipality's local people.

Different types of training are offered for selected community of the city. Annual Training offered by the sanitation and beautification office for the staff and the community is based on the budget allocation of the city administration. In 2022, no training was given due to limitation of budget but around four training /year may be given for the staffs based on their training level and for selected community participant (staffs, waste segregator, municipal road sweeper, and people working on plant seedling). The offered trainings are effective in creating environmentally aware community, which can help to reduce the environmental impacts of the waste management operations and improve environmental performance.

Table 21.Types of training offered by the sanitation and beautification office and number of participants

Year	Type of training offered	Total participant
2020	level 1 (cleaning)	30
	level 2 (solid waste handling)	30
2021	level 1 (cleaning)	40
	level 2 (solid waste handling)	37
	level 3 (transfer station and compost operation)	39

Source: (Bishoftu city administration sanitation and beautification office)

4.9. Prediction of Future Waste Generation

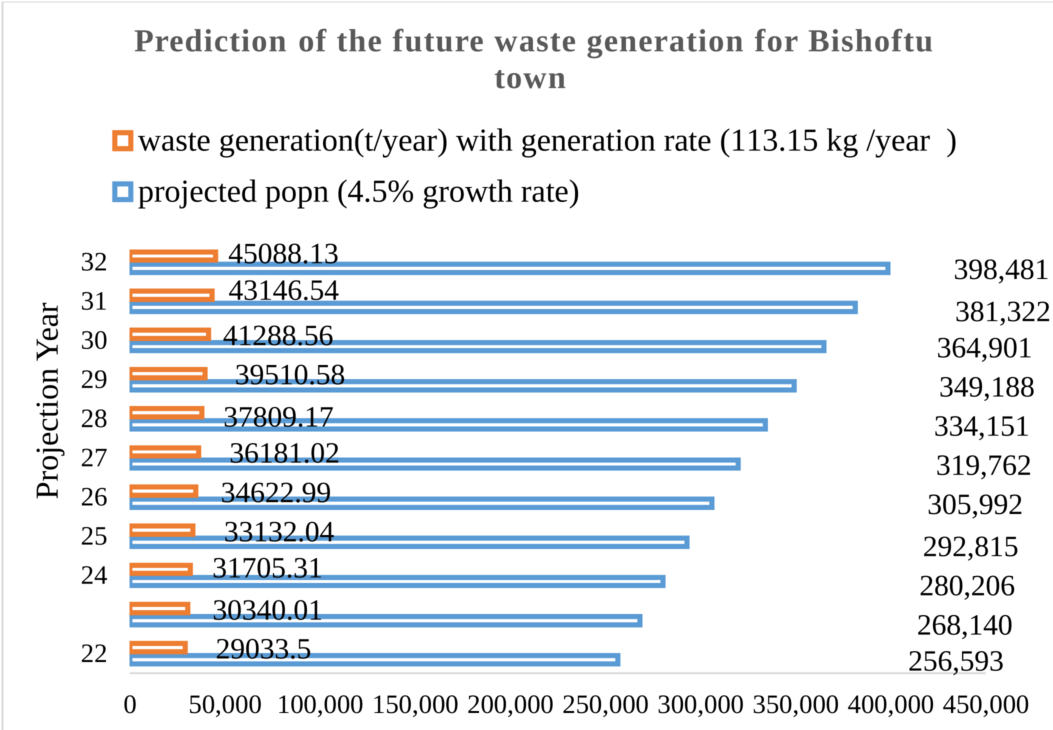

Figure 6.prediction of the future waste generation for Bishoftu town

4.10. Material flow analysis

Material flow analysis is a systematic assessment of the flows of materials within a defined space and a certain time which is based on the mass balance principle (Yeo *et al*, 2020). Using MFA, it is possible to evaluate an existing MSW management technology, identify the deficiency and assess the potential efficiency, improvement, approach and make a decision on the most preferred process for an integrated and sustainable waste management system (Sarmento, Tokai and Hanashima, 2016)**.**

The STAN software is used to show the current solid waste flow in the city as shown in Figure 7. All the activities required managing the waste from their point of collection and onsite sorting, transportation, treatment, and final disposal were assessed to evaluate the waste management system comprehensively. Annually 41,260 tons of waste is generated from major solid waste generator and only 70 % of the total generated waste is collected. The remaining 30% of the waste is treated at the source (compost, reuse and treatment at the source), disposed illegally (open burning, disposal on open filed and water body's and disposal on street and ditches) and the recyclable materials are collected by informal recyclable waste collected at the source. From the 30 % of the waste, which remain uncollected 17.4 % of the waste, is treated at the source by composting and reuse at household level. The wastes generated from different industries are also included in this category because industries follow different removal mechanism and treatment method at the source. Again, from the 30 % of the waste generated (which remain uncollected) 11 % of the waste is illegally disposed to the environment and from this 11% of waste around 48 % of the waste is burned in uncontrolled environment indicating that open burning is widely practiced. From the 11 % of the waste disposed illegally disposal on open filed and street account 26 % each. As we can see from the MFA diagram below from the 30 % of the waste that remain uncollected formally the informal collectors, (korales) collect 1.6 % of the waste. When we see the final waste flow of the town from figure 7 around 610.81 and 261 tons of waste is recycled in recycling facilities and converted to compost annually respectively which is very low. Finally, 28,435.65 tons of waste is transported to the landfill for final disposal. In this research waste generation measurement from industries and institution were not taken directly. Wastes from industries and institution were taken to be 6 % & 4 % of the waste generated by household and commercial activities respectively (N.TESHOME, 2023).

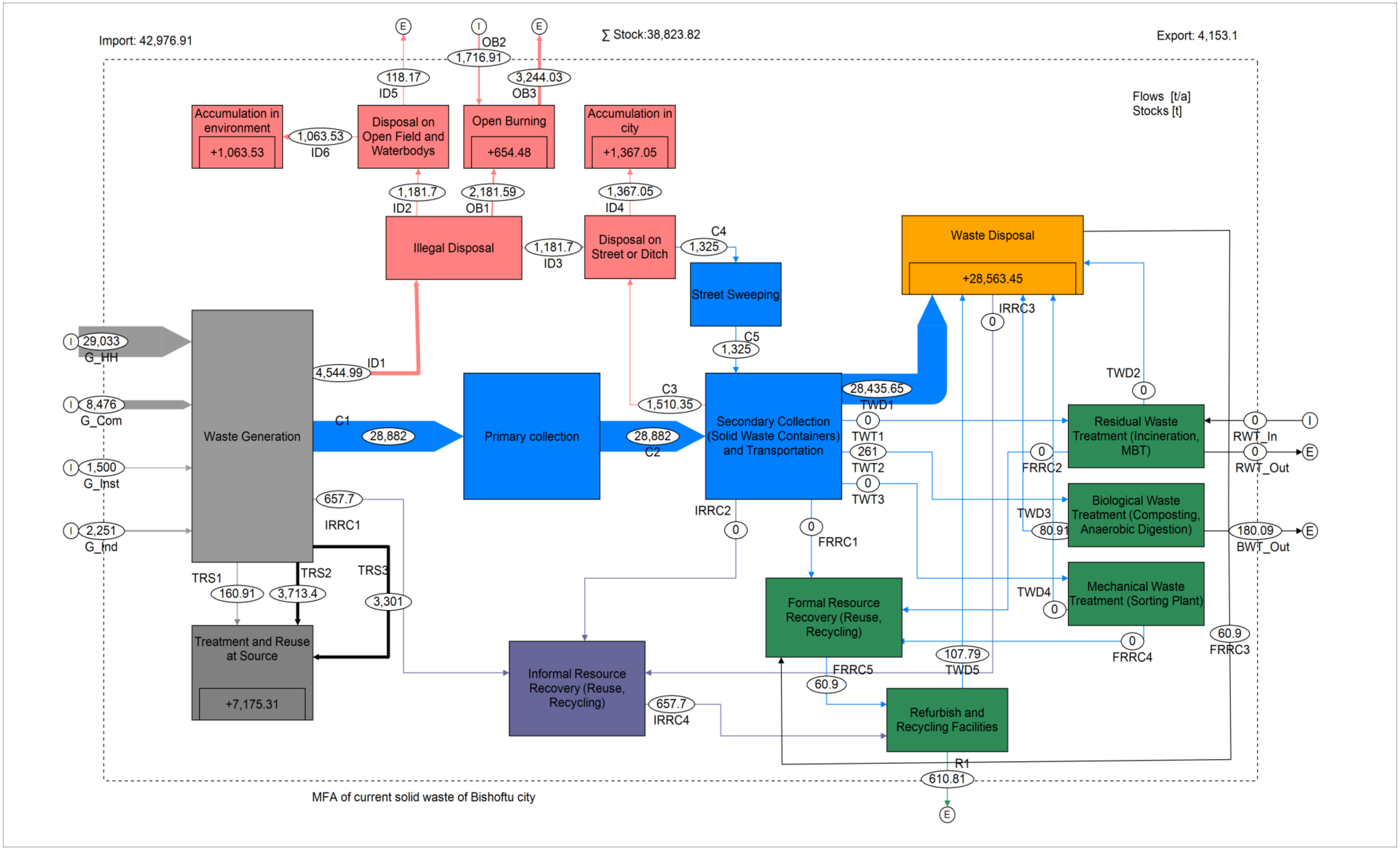

Figure 7.MFA of current solid waste of Bishoftu Town

4.11. Evaluation of different factors in the existing waste collection system

4.11.1. Waste collection performance

Table 22.Waste collection performance

Waste collection performance	
mass of waste formally collected [t/a]	28,882.00
mass of waste generated [t/a]	41,260
collection coverage [%]	70 %

4.11.2. Resource management

Currently only 10.0 % of the waste generated is recovered at different part of the city as shown in Table 23.

Table 23.Current resource managed in the solid waste management sector

Resource Management	
mass of waste material recovered [t/a]	4,333.72
mass of waste generated [t/a]	41,260
[%]	10.5%

4.11.3. Greenhouse gas emissions

Climate change is an urgent global environmental issue with increasing significance. Climate change has been recognized as one of the good representatives for the environmental impact of SWM (Indika Thushari, 2020).Costs and potentials for reducing GHG emissions from waste are usually based on landfill CH_4 as the baseline (IPCC, 2007a). The baseline emission is estimated to be 1.98 t co_2-eq / t waste as shown in Table 24 for Bishoftu town.

Table 24.Greenhouse gas emission

Greenhouse gas Emissions			
Illegal waste Disposal			
waste open burned		2,181.59	t / a
		5183.36	t co_2-eq / a
Waste uncontrolled disposal	waste quantity uncontrolled disposed	2,430.53	t / a
	GHG emissions waste uncontrolled disposal	6,076.33	t co_2-eq / a
Illegal waste Disposal GHG Emissions		11,259.69	t co_2-eq / a
Recycling			
Recycling	input waste	122.2	t / a
	GHG Emission	-1031.2	t co_2-eq / a
Waste Treatment			
bio-waste composting	input waste	261	t / a
	Net GHG emissions	-26.1	t co_2-eq / a
Waste Disposal			
mass of waste designated to disposal facility /site		28,563.50	t / a
Waste Disposal GHG Emissions		71408.75	t co_2-eq / a
Greenhouse Gas Emissions total		81621.58	t co_2-eq / a
		1.98	t co_2-eq / T waste

4.12. Scenarios

Due to the high organic content of the solid waste and the high agricultural activities of the rural kebeles composting will be the best option of solid waste treatment for Bishoftu town. (Hoang, Luong and Huong, 2013) certified the importance of available recycling practices, especially composting in order to avoid landfill organic waste. By composting, organic matter originating from multiple waste streams is going through a process which kills pathogens. It results in compost, which contains stable organic material that is useful for agricultural fields as a soil conditioner. Soil fertility, structure, water holding capacity, and buffering capacity are all improved by Composting (Luske, 2010).

Due to the high advantage of composting scenario development is made by composting 10 %, 30 % and 50 % of the waste designated to the disposal site resulting in 3,020.7 t/year, 9,062.1 t/year and 15,1003.5 t/year of waste to be composted respectively as shown in Table 25.

Table 25.Assumption taken for the scenarios.

Initial waste designated to disposal site (t/year)	Scenarios	Portion of waste composted (%)	Amount of waste composted (t/year)
30,207	S I	10	3,020.7
	S II	30	9,062.1
	S III	50	15,103.5

4.12.1. Evaluation of the waste management system after the development of the three scenarios

Scenario I

The first scenario is done by assuming 10 percent of the waste designated to disposal site to be composted. Figure B1 (Appendix B) shows 3,020.7 ton of waste is to be reused and resulting 2,084.28 tone of compost annually. Figure 8 shows that 17.4 % of the resource will be managed which show 39.6 % increment in resource management than the current solid waste management practice. The GHG emission is calculated to be 1.84 t co_2-eq /t waste (see Appendix E, table E 2) which result in reduction of 7.07 % in GHG emission as shown in Figure 9.

Scenario II

The second scenario is done by assuming 30 percent of the waste designated to disposal site to be composted. We can see that 9,062.1 ton of waste is to be reused and resulting 6,252.85 tone of compost annually (see Appendix B, Figure B1). Figure 8 shows that 32.4 % of the resource will be managed which show 67.59 % increment in resource management than the current solid waste management practice. The GHG emission is 1.56 t co_2-eq / t waste (see Appendix E, table E4) resulting in 21.1 % reduction in GHG emission, which can be seen in Figure 9.

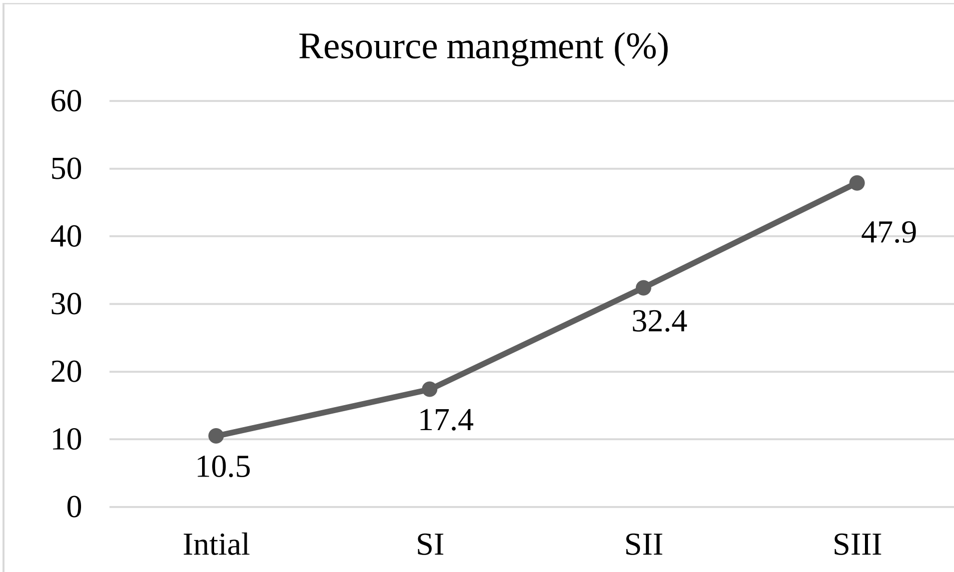

Figure 8.Resource management increment after the development of the scenarios

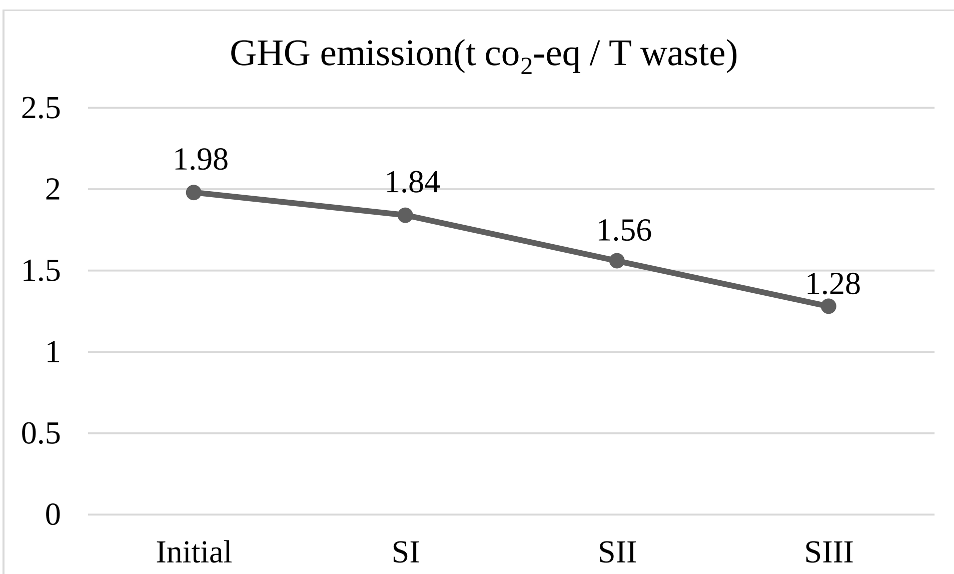

Figure 9.GHG reduction in the scenarios

Scenario III

In the third scenario 50 percent of the waste designated to disposal site is to be composted and 10,421.42 tone of compost will be generated by using 15,103.5 tons of waste as shown in Appendix B, Figure B3. In the third scenario 47.9 % of the resource is managed (Figure 8) and GHG emission of 1.28 t co_2-eq / t waste (see Appendix E, Table E 6). In general, comparing to the current solid waste management practices there will be 78.1 % of increment in resource management and 35.35 % reduction in GHG emission. Such emission reduction by composting facilities is comparable to results of study done in Tiassalé in Côte d'Ivoire indicating an emission reduction of 87 % can be achieved by Decentralized Composting if all the waste is to be composed (Yeo *et al.*, 2020) . Composting is acknowledged by the UNFCCC as one of the few emission reduction methodologies related to agriculture. A research in Egypt show that composting of organic waste and compost usage result in a significant reduction of greenhouse gas emissions compared with the baseline scenario due to avoiding of methane emissions from land fill or dumping the organic waste in the baseline scenario (Luske, 2010).

5. Conclusion and Recommendations

5.1. Conclusion

According to the finding, there is 70 % solid waste collection coverage in the city largely covered by the MSSE while the remaining waste either treated at the source or disposed illegally. In Bishoftu town, 69.23 % of the waste generated is dumped in the landfill and only 0.63 % and 0.14 % of the total waste generated is composted and recycled formally. In the study area, open burning of waste is widely used as waste removal method especially for waste coming from compound cleaning and plastic film contributing GHG to the environment.

Middle socioeconomic group and lower socioeconomic group generate more waste due to more family members and energy type used for cooking and in the study area education level, occupation, age, gender, and housing condition have no relationship with solid waste management practices.

Through door –door collection system for the majority of the study area waste is collected once a week which is preferable by the mass of the respondent at the current. On the other hand, the research findings observed that there is low waste separation activity around HHs and polyethylene sack is used as temporary storage.

One of the major observations of this study is that there is high satisfaction level with the current solid waste collection system. High willingness to co-operate with the solid waste management programme and high willingness to pay for proper services, especially for proper collection and management of waste is observed in the study area.

Referring to the current solid waste management practice of the city, the result from the scenarios indicates that when composting 50 % of the waste disposed in the land fill an increment of 78.1 % in resource management and 35.35 % reduction in GHG emission is achieved comparing to the current solid waste management practice.

5.2. Recommendations

- Solid waste reduction at the source is the preferable and crucial means to management system. Educating and creating awareness on segregation, recycling and reuse must be done in wider range through continuous training**.**
- The town administration should allow more budget for the solid waste management system to solve the current problem in equipment for the landfill compaction and other.
- A well-planned drainage system for storm water must be done in order to solve problems in summer season and increase the lifetime of the landfill.
- Due to Challenges in WTE Projects like Inefficient Waste Management, Unwanted Emissions, Occupational Hazard, High Capital and Operating Costs (Roy *et al.*, 2022) ,Observation of the failure in Reppie WTE plant in Addis Ababa and high agricultural activities in the rural kebeles of the study area composting is highly recommended for Bishoftu town which must be done in large scale .
- Introduction of worms (vermicomposting) and additives seems to increase plant available nutrient contents, while decreasing N leaching, heavy metal mobility and composting time which results in better resource management and reduction of GHG .
- Currently high problem in marketing for the produced compost is obseverd;by increasing the postive aweraness towards compost in the society and solving the misundestnding about what is compost , knowledge on how, how much and when to use compost , showing using compost can reduce the dependence on chemical fertilizers, help recover soil fertility, improve water retention and the delivery of nutrients to plants and how it reduce the impact on our plant .
- In addation of creating awarreness business must investe heavily in a skilled marketing team, involvement of different research institution for the arrangement with an agricultural company, which buys the compost and creating a good local market with demonstration project .
- A more centralized system shoud be estableshed for the collection of recyclable material. The formal and informal sectors need to work together, for the benefit of both.

6. References

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Appendixes

Appendix A: MFA system legend

Abbreviation Process	Name of Process	Abbreviation Process	Name of Process
FRR	Formal Resource Recovery (Reuse, Recycling)	RRF	Refurbish and Recycling Facilities
ID	Illegal Disposal	SC	Secondary Collection (Solid Waste Containers) and Transportation
ID_AC	Accumulation in city	SS	Street Sweeping
ID_SD	Disposal on Street or Ditch	TRS	Treatment and Reuse at Source
IRR	Informal Resource Recovery (Reuse, Recycling)	WD	Waste Disposal
OB	Open Burning	WG	Waste Generation
OFD	Disposal on Open Field and Water bodies	WT_1	Residual Waste Treatment (Incineration, MBT)
OFD_A	Accumulation in environment	WT_2	Biological Waste Treatment (Composting, Anaerobic Digestion)
PC	Primary collection	WT_3	Mechanical Waste Treatment (Sorting Plant)

Abbreviation Flow	Name / Description of Flow	source	Target
BWT_Out	Output materials Biological Waste Treatment	WT_2	Output
C1	mixed collected waste from primary collection	WG	PC
C2	mixed collected waste from primary collection transported to secondary collection points	PC	SC
C3	waste losses from primary and secondary collection	SC	ID_SD
C4	waste collected through street sweeping	ID_SD	SS

C5	waste collected through street sweeping	SS	SC
FRRC1	recyclable materials collected through formal primary collection	SC	FRR
FRRC2	recyclable materials from residual waste treatment	WT_1	FRR
FRRC3	recyclable materials from mechanical waste treatment	WT_3	FRR
FRRC4	total formally collected recyclable materials	FRR	RRF
G_Com	total waste generated by commerce	input	WG
G_HH	total waste generated by households	input	WG
G_Ind	total waste generated by industries	input	WG
G_Inst	total waste generated by institutions	input	WG
ID1	total waste illegally disposed	WG	ID
ID2	waste illegal disposed on open field and in water bodies	ID	OFD
ID3	waste illegal disposed in city area	ID	ID_SD
ID4	illegal disposed waste accumulated in city	ID_SD	ID_AC
ID5	waste discharged out of investigation area	OFD	Output
ID6	illegal disposed waste accumulated in close environment	OFD	OFD_A
IRRC1	recyclable material informally collected from waste generators	WG	IRR
IRRC2	recyclable material informally collected from municipal waste containers	SC	IRR
IRRC3	recyclable material informally collected from waste disposal sites	WD	IRR
IRRC4	total recyclable material informally collected	IRR	RRF
OB1	waste illegal disposed through open burning	ID	OB
OB2	ambient air for open burning	input	OB
OB3	combustion air for open burning	OB	output
R1	recycled material	RRF	output

RWT_In	Auxiliary and operating materials Residual Waste Treatment	input	WT_1
RWT_Out	Output materials Residual Waste Treatment	WT_1	output
TRS1	generated waste directly treated (reusing) at source	WG	TRS
TRS2	generated industrial waste treated at source	WG	TRS
TRS3	generated waste directly treated (home composting) at source	WG	TRS
TWD1	collected waste transported to disposal site	SC	WD
TWD2	residues from residual waste treatment to disposal site	WT_1	WD
TWD3	residues from biological waste treatment to disposal site	WT_2	WD
TWD4	residues from mechanical waste treatment to disposal site	WT_3	WD
TWD5	residues from recycling facilities to disposal site	RRF	WD
TWT1	collected waste transported to residual waste treatment facilities	SC	WT_1
TWT2	collected waste transported to biological waste treatment facilities	SC	WT_2
TWT3	collected waste transported to mechanical waste treatment facilities	SC	WT_3

Appendix B: MFA diagram of the three scenarios

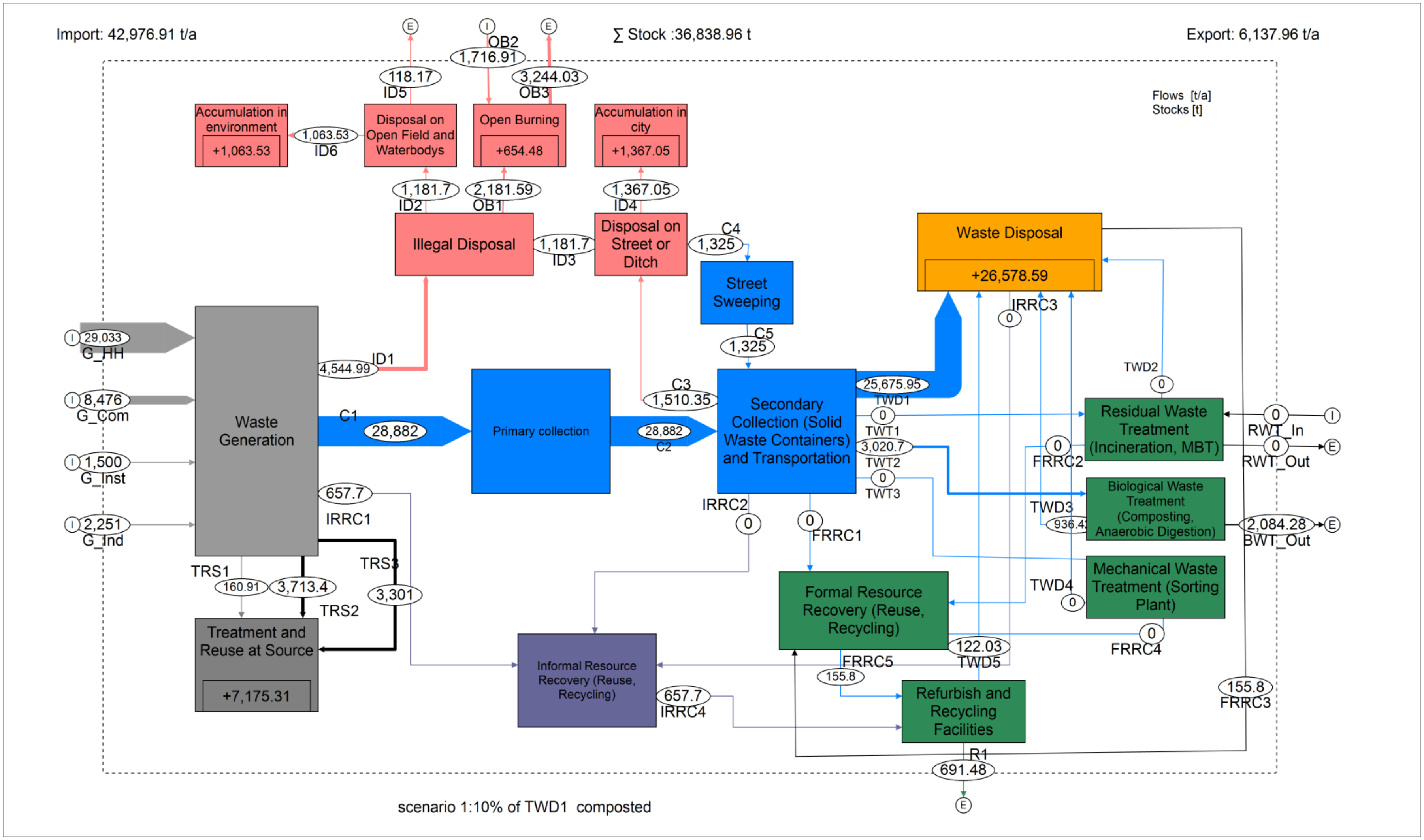

Figure B 1.MFA diagram for scenario 1

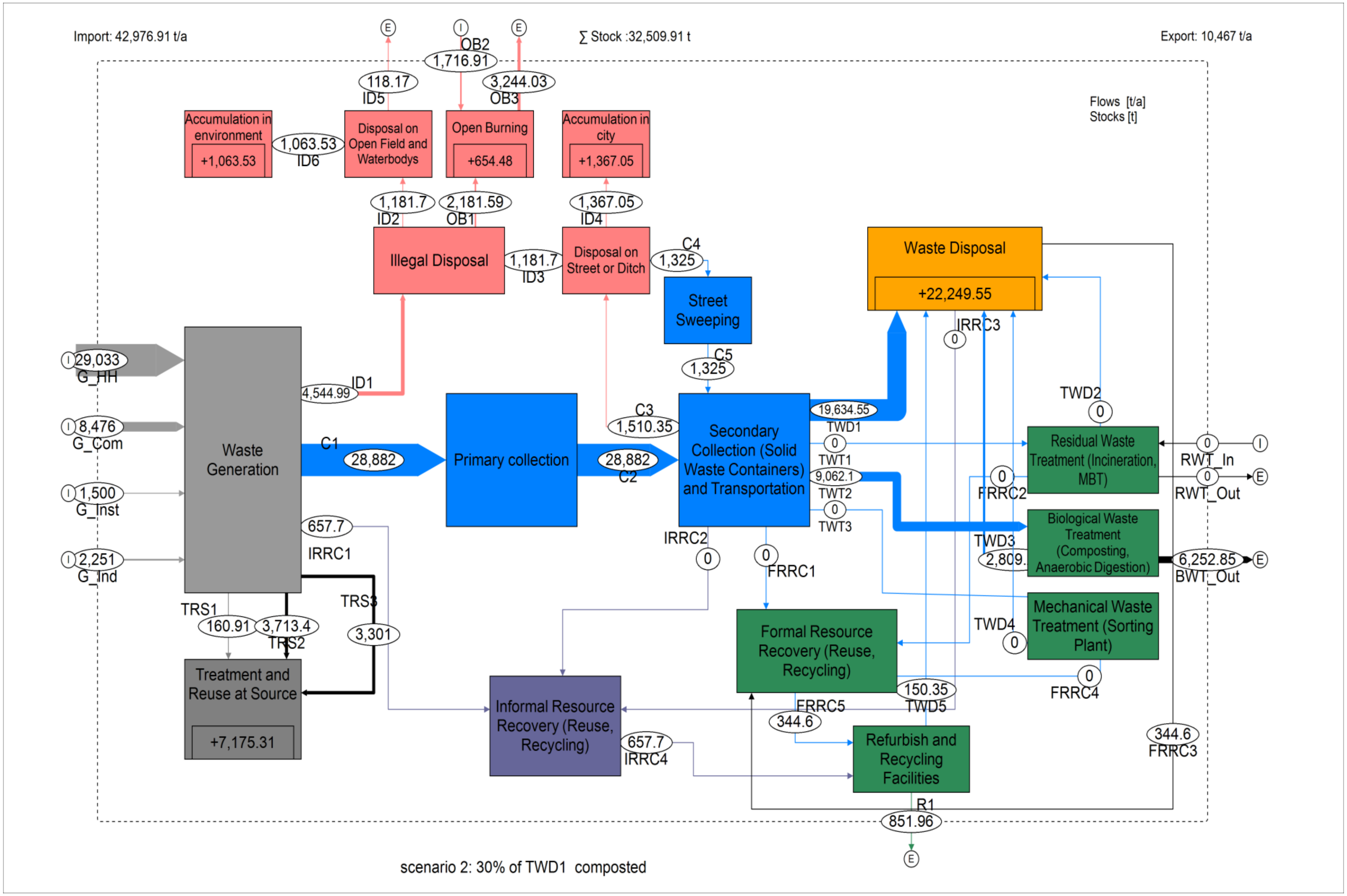

Figure B 2.MFA diagram for scenario 2

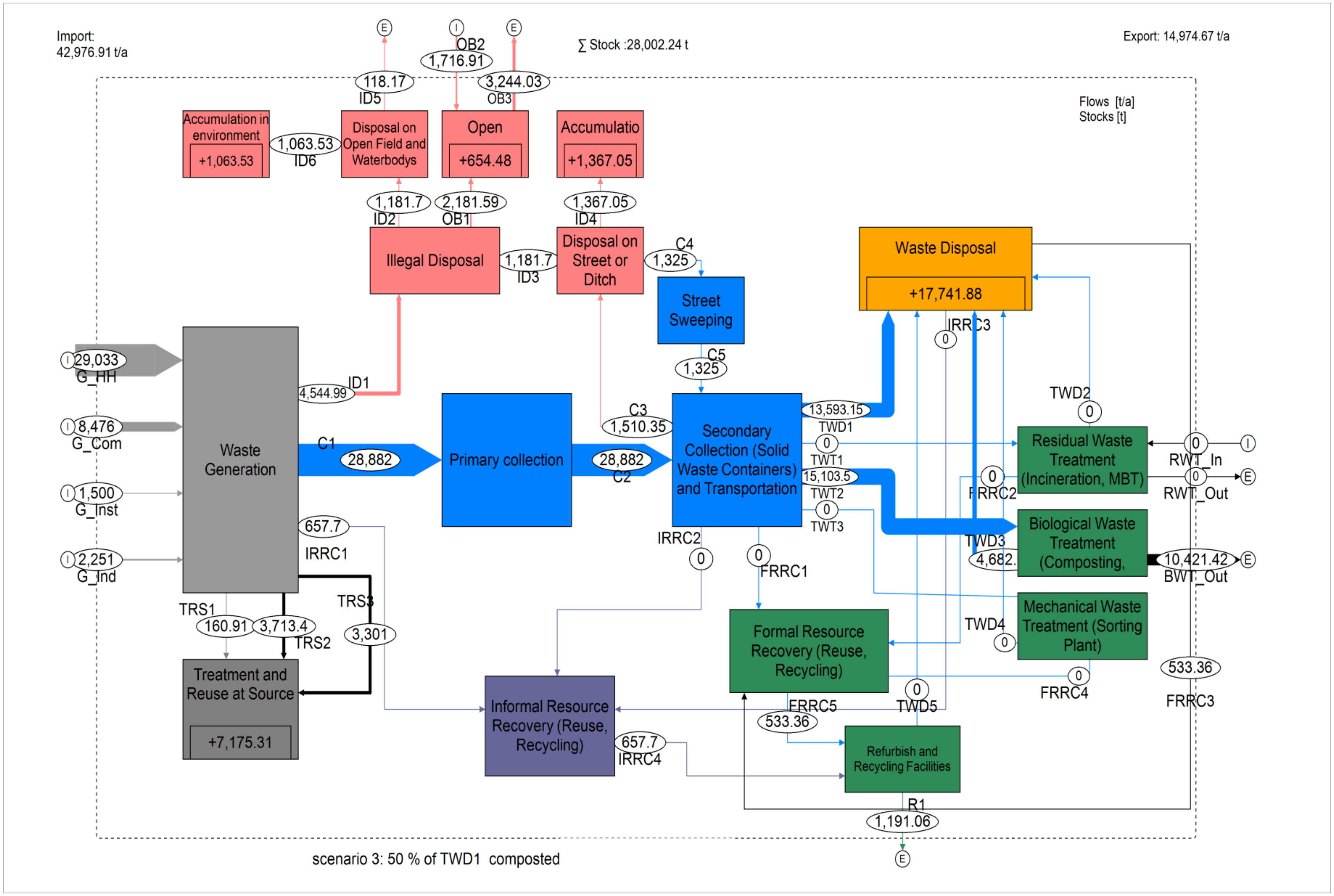

Figure B 3.MFA diagram for scenario 3

Appendix **C: Default values Greenhouse Gas Emission**

conversion factors CO_2-eq		
	GWP-100	source
Carbon Dioxide	1	(IPCC, 2007b)
Methane	25	
Nitrous oxide	298	
Black Carbon	910	(Bond *et al.*, 2013)

Emission factors composting			
GHG emission type	Emission factor	Unit	Source
Methane	4	g/kg	(Hoang et al. 2013)
N2O	0.3	g/kg	

Emission factors Open Burning			
GHG emission type	Emission factor	Unit	Source
Methane	3.7	g/kg	(Akagi *et al.* 2011)
Black Carbon	0.65	g/kg	

Emission Factor Incineration / Open Burning			
Incinerated Fraction	Emission factor	Unit	Source
Organic Waste	0.044	t co_2-eq / t (material input)	(ICF Consulting 2020)
Wood	0.044		
Paper and Cardboard	0.044		
Textiles	0.470		
Plastics	2.569		
Metal	0.000		
Glass	0.000		
Miscellaneous combustibles	0.470		
Inert	0.000		
Special / hazardous waste	0.470		
Fines	0.470		
Others	0.470		

Default Values Waste Disposal Emission Calculation		
MCF (methane correction factor to take account of the type of waste disposal site)		
1	managed landfill site – anaerobic	(IPCC, 2008)
0.8	unmanaged open dump – deep (> 5 m waste) and/or high water level	
0.4	unmanaged open dump – shallow (< 5 m waste)	
Oxidation Factor		
0	default value	(IPCC, 2008)
0.1	covered (e.g. soil, compost), well-managed landfilled site	

GHG Emission Calculation for Waste Disposal Facilities				
	managed landfill	unmanaged open dump – deep (> 5 m) and/or high water level	unmanaged open dump – shallow (< 5 m)	source
DOC in T C / T waste	0.3	0.3	0.3	Default value according to IPCC 2006
DOCf	0.5	0.5	0.5	
methane content of landfill gas in vol%	0.5	0.5	0.5	
MCF	1	0.8	0.4	
OX	0	0	0	
gas collection efficiency in %	0.5	0	0	own assumption

Net Emission Factor Recycling			
recycled Fraction	Emission factor	unit	Source
Mixed Papers	-3.91	t co_2-eq / t (material recovered)	(ICF Consulting 2020)
Mixed Plastics	-1.03		
Mixed Metals	-4.84		
Glass	-0.31		

Appendix **D: Calculation for the Evaluation of different factors in the existing waste collection system**

Table D 1.Waste collection performance of the existing waste collection system

Waste collection performance	
mass of waste formally collected [t/a]	28,882.00
mass of waste generated [t/a]	41,260
collection coverage [%]	70 %

Table D 2.Resource Management of the existing waste collection system

Resource Management	
mass of waste material recovered [t/a]	4,333.72
mass of waste generated [t/a]	41260
[%]	10.5 %

Table D 3.GHG Emission of the existing waste management system

Greenhouse gas Emissions			
Illegal waste Disposal			
waste open burned		2,181.59	t / a
		5183.36	t CO_2-eq / a
waste uncontrolled disposal	waste quantity uncontrolled disposed	2430.53	t / a
	DOC (degradable organic carbon in the deposited waste)	0.30	t CO_2 / t waste
	DOCf (fraction of DOC that is dissimilated over time)	0.50	default value according to IPCC 2006
	F (methane content of the landfill gas)	0.50	vol% (default value according to IPCC 2006)
	MCF (methane correction factor to take account of the type of waste disposal site)	1.00	default value according to IPCC 2006
	OX (oxidation factor)	0.00	default value according to IPCC 2006
	gas collection efficiency (RT)	0.00	
	GHG emissions waste uncontrolled disposal	6076.33	t CO_2-eq / a
Illegal waste Disposal GHG Emissions		11259.69	t CO_2-eq / a
Recycling			
Mixed Papers		122.2	t / a
		-477.6	t CO_2-eq / a
Mixed Plastics		366.5	t / a
		-377.5	t CO_2-eq / a
Mixed Metals		30.5	t / a
		-147.6	t CO_2-eq / a
Glass		91.6	t / a
		-28.4	t CO_2-eq / a

Recycling GHG Emissions		-1031.2	t co_2-eq / a
Waste Treatment			
Bio-waste Composting	input waste	157	t / a
	Net GHG emission factor	-0.10	t co_2-eq / t (material input)
	Net GHG emissions	-26.1	t co_2-eq / a
Waste Treatment GHG Emissions		-15.7	t co_2-eq / a
Waste Disposal			
mass of waste designated to disposal facility /site		28,563.50	t / a
share of managed landfill site – anaerobic		100%	% of waste designated to disposal site
share of unmanaged open dump – deep (> 5 m waste) and/or high-water level		0%	% of waste designated to disposal site
share of unmanaged open dump – shallow (< 5 m waste)		0%	% of waste designated to disposal site
managed landfill site – anaerobic		28,563.50	t / a
unmanaged open dump – deep (> 5 m waste) and/or high-water level		0.00	t / a
unmanaged open dump – shallow (< 5 m waste)		0.00	t / a
managed landfill site – anaerobic		71408.75	t co_2-eq / a
unmanaged open dump – deep (> 5 m waste) and/or high-water level		0.00	t co_2-eq / a
unmanaged open dump – shallow (< 5 m waste)		0.00	t co_2-eq / a
Waste Disposal GHG Emissions		71408.75	t co_2-eq / a
Greenhouse Gas Emissions total		81621.58	t co_2-eq / a
		1.98	t co_2-eq / t waste

Appendix **E: Calculation for the Evaluation of different factors after the development of the three scenarios**

Scenario I

Table E 1.Resource management for scenario 1

Resource Management	
mass of waste material recovered [t/a]	7,174.08
mass of waste generated [t/a]	41,260
[%]	17.4 %

Table E 2.Greenhouse gas emission for scenario I

Greenhouse gas Emissions			
Illegal waste Disposal			
waste open burned		2,181.59	t / a
		5183.36	t co_2-eq / a
waste uncontrolled disposal	waste quantity uncontrolled disposed	2430.53	t co_2 / t waste
	DOC (degradable organic carbon in the deposited waste)	0.30	default value according to IPCC 2006
	DOCf (fraction of DOC that is dissimilated over time)	0.50	vol% (default value according to IPCC 2006)
	F (methane content of the landfill gas)	0.50	default value according to IPCC 2006
	MCF (methane correction factor to take account of the type of waste disposal site)	1.00	default value according to IPCC 2006
	OX (oxidation factor)	0.00	

	gas collection efficiency (RT)	0.00	t co_2-eq / a
	GHG emissions waste uncontrolled disposal	6076.33	t co_2-eq / a
Illegal waste Disposal GHG Emissions		11259.69	t co_2-eq / a
Recycling			
Mixed Papers		138.1	t / a
		-540.0	t co_2-eq / a
Mixed Plastics		414.8	t / a
		-427.2	t co_2-eq / a
Mixed Metals		34.6	t / a
		-167.5	t co_2-eq / a
Glass		103.7	t / a
		-32.1	t co_2-eq / a
Recycling GHG Emissions		-1166.8	t co_2-eq / a
Waste Treatment			
Bio-waste Composting	input waste	3,020.70	t / a
	Net GHG emission factor	-0.10	t co_2-eq / t (material input)
	Net GHG emissions	-302.07	t co_2-eq / a
Waste Treatment GHG Emissions		-302.0700	t co_2-eq / a
Waste Disposal			
mass of waste designated to disposal facility /site		26,579.70	t / a
managed landfill site – anaerobic		26,579.70	t / a
unmanaged open dump – deep (> 5 m waste) and/or high water level		0	t / a
unmanaged open dump – shallow (< 5 m waste)		0	t / a
managed landfill site – anaerobic		66449.25	t co_2-eq / a
Greenhouse Gas Emissions total		76240.04	t co_2-eq / a
		1.84	t co_2-eq / t waste

Scenario II

Table E 3.Resource management for scenario II

Resource Management	
mass of waste material recovered [t/a]	13,375.96
mass of waste generated [t/a]	41,260
[%]	32.4 %

Table E 4.Greenhouse gas emission for scenario II

Indicator 6: Greenhouse gas Emissions			
Illegal waste Disposal			
waste open burned		2,181.59	t / a
		5183.36	t co_2-eq / a
waste uncontrolled disposal	waste quantity uncontrolled disposed	2430.53	t co_2 / t waste
	DOC (degradable organic carbon in the deposited waste)	0.30	default value according to ipcc 2006
	DOCf (fraction of DOC that is dissimilated over time)	0.50	vol% (default value according to IPCC 2006)
	F (methane content of the landfill gas)	0.50	default value according to IPCC 2006
	MCF (methane correction factor to take account of the type of waste disposal site)	1.00	default value according to IPCC 2006
	OX (oxidation factor)	0.00	
	gas collection efficiency (RT)	0.00	t co_2-eq / a
	GHG emissions waste uncontrolled disposal	6076.33	t co_2-eq / a

Illegal waste Disposal GHG Emissions		11259.69	t co_2-eq / a
Recycling			
Mixed Papers		170.4	t / a
		-666.3	t co_2-eq / a
Mixed Plastics		511.2	t / a
		-526.5	t co_2-eq / a
Mixed Metals		42.6	t / a
		-206.2	t co_2-eq / a
Glass		127.8	t / a
		-39.6	t co_2-eq / a
Recycling GHG Emissions		-1438.6	t co_2-eq / a
Waste Treatment			
Bio-waste Composting	input waste	9062.10	t / a
	Net GHG emission factor	-0.10	t co_2-eq / t (material input)
	Net GHG emissions	-906.21	t co_2-eq / a
Waste Treatment GHG Emissions		-906.21	t co_2-eq / a
Waste Disposal			
Waste Disposal		22,249.55	T / a
share of managed landfill site – anaerobic		1.00	% of waste designated to disposal site
managed landfill site – anaerobic		22,249.55	t / a
Waste Disposal GHG Emissions		55623.88	t co_2-eq / a
Greenhouse Gas Emissions total		64538.7	t co_2-eq / a
		1.56	t co_2-eq / t waste

Scenario III

Table E 5.Resource management for scenario III

Resource Management	
mass of waste material recovered [t/a]	19,756.46
mass of waste generated [t/a]	41,260
[%]	47.9 %

Table E 6.Greenhouse gas emission for scenario III

Greenhouse gas Emissions			
Illegal waste Disposal			
waste open burned		2,181.59	t / a
		5183.36	t co_2-eq / a
waste uncontrolled disposal	waste quantity uncontrolled disposed	2430.53	t co_2 / t waste
	DOC (degradable organic carbon in the deposited waste)	0.30	default value according to IPCC 2006
	DOCf (fraction of DOC that is dissimilated over time)	0.50	vol% (default value according to IPCC 2006)
	F (methane content of the landfill gas)	0.50	default value according to IPCC 2006
	MCF (methane correction factor to take account of the type of waste disposal site)	1.00	default value according to IPCC 2006
	OX (oxidation factor)	0.00	
	gas collection efficiency (RT)	0.00	t co_2-eq / a
	GHG emissions waste uncontrolled disposal	6076.33	t co_2-eq / a

Illegal waste Disposal GHG Emissions		11259.69	t co_2-eq / a
Recycling			
Mixed Papers		238.2	t / a
		-931.4	t co_2-eq / a
Mixed Plastics		714.6	t / a
		-736.0	t co_2-eq / a
Mixed Metals		59.5	t / a
		-288.1	t co_2-eq / a
Glass		178.6	t / a
		-55.4	t co_2-eq / a
Recycling GHG Emissions		-2010.9	t co_2-eq / a
Waste Treatment			
Bio-waste Composting	input waste	15103.50	t / a
	Net GHG emission factor	-0.10	t co_2-eq / t (material input)
	Net GHG emissions	-1510.35	t co_2-eq / a
Waste Treatment GHG Emissions		-1510.35	t co_2-eq / a
Waste Disposal			
Waste Disposal		17,741.88	t / a
share of managed landfill site – anaerobic		1.00	% of waste designated to disposal site
managed landfill site – anaerobic		17,741.88	t/ a
Waste Disposal GHG Emissions		44354.70	t co_2-eq / a
Greenhouse Gas Emissions total		52093.15	t co_2-eq / a
		1.28	t co_2-eq / t waste

Appendix **F: Survey Questionnaires**

1. Questionnaires on Socio-Economic Data

A. Demographic and social status

2. Kebele ______________ House No.___________

3. Age ______ Sex_________ Family size in number___________

4. Educational Status of the household head

a) Illiterate b) Primary c) Secondary d) Higher

5. Profession of the head of the HH…………………..

a) Government employee b) Private employee

c) Business d) Student

e) Housewife f) Retired

6. Family income /Month

a) < 8000 b) 8000-15,000 c) > 15000 Birr

7. Housing Conditions House ownership

a) Private b) Rented c) Kebele d) Other, specify____________

8. Energy availability

a) Firewood and cow dung b) Firewood, cow dung and charcoal

c) Firewood, charcoal, kerosene, electricity d) charcoal, kerosene, electricity

e) Charcoal and electricity f) if other please specify

B. On-site Solid Waste Handling practice

1. Do you have temporary storage container for generated refuse at home?

a) Yes
b) No

2. If yes, what is the container type?

a) Plastic Dust Bin
b) Sack
c) Plastic bag

Others, specify __________________

C. Solid Waste Disposal practices

1. You dispose your household waste in:

a) Plastic dust bine

b) Sack

c) plastic bag

2. How often does the city municipality collect the waste?

a) Everyday b) Once a week

c) Once in three days d) irregularly

3. How often you prefer if your waste is collected directly from your house:

a) Every day b) Once every three days c) Once a week

4. Generally, when do you dispose of your waste?

a) No definite time

b) Morning

c) Afternoon

5. When do you prefer for your waste to be collected?

a) Morning b) Noon

c) Afternoon d) Evening

6. Which system do you use for removal of your household waste?

a) A collector will collect the waste from the house.

b) The collector will come to a certain place at a certain time, you will give him the Waste.

c) You yourself will dispose the waste in the dustbin.

d) You will keep your waste container at a certain time by the roadside and the Collector will collect it from there.

7. What means do you use to transport wastes to containers?

a) By hands b) Hand pushed carts c) Horse drawn carts d) Others specify

8. Do you separate your kitchen waste from other household waste?

Y / N;

9. Do you reuse household wastes? Yes _________ No ___________

If Yes,
Type of reused wastes ____
Purpose of Reused wastes _____________________________________

10. Do you compost wastes? Yes ___________ No _____________

If yes,

What type of wastes? __________________________________

11. Do you burn (incinerate) household wastes? Yes _________ No _________

If yes what type of wastes? ___________________________________

12. Do you use open dump as a disposal method? Yes _______ No ______

13. Do you sell wastes? a) Yes b) No

14. If yes, what type of wastes do you commonly sell?

a) Plastics and bottles b) Metals, plastics and bottle c) Papers, metals and plastics

d) Leaves and grasses f) I don't sell waste

15. For whom do you sell wastes?

a) Korales b) Formal recycling centers c) Others Specify e) I don't sell waste

16. How much are you currently spending for waste disposal per month? (birr /month……….)

17. Satisfaction level about the present municipal waste removal system:

a) Very good b) Good

c) Ok/medium d) Not satisfactory

18.Community participation is inevitable for local waste collection system and

Improvement of the environment – do you agree?

Y / N

19. Current priority needs (1, 2, 3, 4):

Facilities	Priority No
Water supply	
Sanitation	
Solid waste management	
Drainage	

2. Examination of existing waste management and recycling systems

A. Formal collection system

1. How much waste is collected by the formal waste collection sector (per day)?

2. How many staff is employed for waste collection? (Male ----- Female --------)

3. Payment system for the waste collector

4. How many staff is employed in waste management in total?

5. What type of equipment is used?

6. How is waste transported?

7. How many trucks are used by the city for the collection of waste? Please mention the capacity of each truck, the number of trips made per day.

8. Are there any transfer stations?

9. Are there collection fees for households and businesses? If yes, please specify.

10. Are there special collection systems for hazardous waste and hospital waste?

11. Does the formal sector collect recyclable waste?

12. Approximately how much of the formal sector's income comes from selling

Recyclable wastes.

13. How are the recyclables disposed? Is there any recycling plant and what types of material is recycled?

B. Analysis of operations of a current landfill site

1. Do you have a sanitary landfill in the city?

2. If yes, how long has it been operational?

3. How far is the landfill from the city?

4. What is the total area of the landfill/crude dump/controlled landfill?

5. What is the amount of waste brought to the plant (tons/day)?

6. Please describe the landfill site:

  a. Unmanaged landfill site with no cover and compaction

  b. Managed landfill site with cover and compaction

  c. Landfill site with cover, compaction, liner, gas collection system and leachate Collection system

7. How is the leachate produced from the landfill is controlled?

C. Analysis of the Existing Compost Plants

1. How many compost plants are in the city?

2. What are their respective capacities? (Tons/day)

3. Where are the plants located?

4. Amount of waste brought to the plant (tons/day).

5. What percentage of the waste brought to the plant is organic?

6. Total waste composted per day (tons/day).

7. Do you bring mixed waste to your plant? If yes, do you sort it at the plant?

8. Daily/ monthly production of compost (kg/day).

9. What is the average price of compost (per ton)?

10. Do you sell compost in bulk or bag?

11. Do you have any problems with marketing of compost? If yes, please specify.

Appendix **G: Important Photo Shoot During Data Collection and Field Observation**

Figure G 1.waste collected from HHs ,waste sorting and measurement of waste

Figure G 2.Typical commercial waste in Bishoftu town

Figure G 3.waste disposed illegal in open filed, street and water bodies