HOUSEHOLD SOLID WASTE GENERATION ,CHARACTERIZATION AND MANAGEMENT PRACTICES IN MELKA RAFU TOWN, KOMBOLCHA DISTRICT OF EAST HARARGHE ZONE, ETHIOPIA

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Household Solid Waste Generation , characterization and Management Practices in Melka Rafu Town, Kombolcha District of East Hararghe Zone, Ethiopia

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As Thesis research advisors, we hereby certify that we have read and evaluated this Thesis entitled: "Household Solid Waste Generation, characterization and Management Practices in Melka Rafu Town, Kombolcha District of East Hararghe Zone, and Ethiopia**"** prepared under our guidance, by Adem Mume Oumere. We recommend that it be submitted as fulfilling the Thesis requirement.

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Final approval and acceptance of the thesis is contingent upon the submission of its final copy to the council of post graduate studies (CPGS) through the candidate's department or school graduate committee (DGC or SGC).

DEDICATION

This Thesis manuscript is dedicated to my friend, Ahmed Adem, and my wife, Dehabo Amedin for their support during my MSc study and thesis preparation.

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STATEMENT OF THE AUTHOR

I declare that this thesis is my own work and that all sources of materials used for this thesis has been fully acknowledged. This Thesis has been submitted in partial fulfillment of the requirements for M.Sc. degree in Environmental Sciences and Management at Haramaya University and deposited at the University Library to be made available to borrowers under the rules of the library. I seriously declare that this Thesis has not been submitted to any other organization anywhere for the award of any academic degree, qualification or certificate. Brief quotations from this Thesis may be used without any special permission provided that accurate and complete acknowledgement of the source is made. Request for permission for extended quotation from, or reproduction of, this Thesis in whole or part may be granted by the Head of the School or Department when in his or her judgment the proposed use of the material is in the interest of scholarship. In all additional instances, however, agreement must be obtained from the author of the thesis.

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BIOGRAPHICAL SKETCH

The author, Adem Mume, was born on September 15, 1986 from his father Mister Mume Oumare and his mother Halima Umar in Metta Woreda, East Hararghe Zone, of Oromia Regional State, Ethiopia. He attended his primary education at Kulubi Primary School from 1992 to 1999 in Kulubi Town. He attended his secondary school at Chelenko Secondary School and completed in 2003 After Successful completion of high school education, he joined Chiro Agricultural College and graduated with Diploma in Natural Resource Management in 2006. Soon after graduation, he was employed by Kombolcha Woreda Agricultural Office of East Hararghe Zone. In 2014, he joined Jimma University and graduated with BSC degree in Natural Resource Management in 2018. Then, he was reinstated at the same office at Kombolcha Woreda of East Hararghe Zone. After a year professional experience, he joined the Postgraduate Program Directorate of Haramaya University to pursue his MSC study in Environmental Sciences and Managements in 2019.

ACRONYMS AND ABBREVIATIONS

CSA	Central Statistical Agency
EPA	Environmental Protection Authority
HHS	households
HW	Hazardous Waste
KDAO	Kombolcha district Agricultural Office
MC	Moisture Content
MOH	Ministry of Health
MRTSEP	Melka Rafu Town Socio Economic Profile
MSWM	Municipal Solid waste management
NGOS	Nongovernmental Organizations
NHSW	Nonhazardous Solid waste
OC	Organic carbon
OR	Oromia Region
PCPDSWGR	Per capita per Day solid waste Generation Rate
RSW	Residential Solid Waste
SB	Sanitation and Beautification
SBPDD	Sanitation, Beautification and Park Development Departments
SW	Solid Waste
SWM	Solid Waste Management
UNEP	United Nation Environmental Program
USAID	United States Agency for International Development
USW	Urban Solid Waste
USWM	Urban Solid Waste Management

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ABSTRACT

Household Solid Waste Generation, characterization and Management Practices in Melka Rafu Town, Kombolcha District of East Hararghe Zone, Ethiopia

The rapid increase in population together with expansion of urban centers is producing large volumes of wastes, which demand better infrastructure, institutional setup and community participation for its management. But, most of solid wastes that generated are remaining uncollected and simply dumped at open space. This study focused on identifying the types of solid wastes, Household Solid Waste Generation, characterization and Management Practices Data was collected form 132 participant households from two kebeles through questionnaire, key informant interviews and field observations. Household solid wastes were collected daily for one week and analyzed for the component composition and physicochemical properties. The results showed that the average per capita and household generation rate of solid waste in the town were 0.304 kg/person/day and 1.58kg/HH/day, respectively. The largest proportion of waste types was the yard waste which represented 69.13 kg/day (33.29%) followed by Food waste which accounted for 40kg/day (17.82). Manure 34kg/day (15.81) Ash 29kg/day, plastic waste 28.76kg/day, Metal 3.25kg/day. paper 3kg/day and glass 1.5kg/day Results revealed that the mean values of MC, OC, N, P, K, pH, EC, and C/N ratio of the waste composition were 55.7%, 35.83%, 1.35%, 0.46 %, 0.85%, 6.77, 5.99 mS/cm, and 26.54:1, respectively. Finally, it is concluded that the RSW generations of Melka Rafu town is increasing in line with growth in socio-economic parameters, which is significantly affected by household family size and monthly income. The waste generated in the town is mainly biodegradable organic consisting of mostly yard and food waste materials. As a result, the more compostable organic content of the waste materials with optimum ranges of physico-chemical composition indicates an opportunity to give priority to the recovery of the waste materials through composting and biogas energy production, required for the appropriate waste management technology option in the town to reduce the current and future trends of waste generation *while benefiting the local households.*

Keywords: Household solid waste, generation, Management Practices, physico-chemical composition

1. INTRODUCTION

In many developing countries like Ethiopia, the generation rate of solid waste is increasing due to rapid urbanization, increasing population growth and economic development, while possible disposal areas for solid waste are invariably reduced. As a result, cities and towns are facing the challenge of managing solid waste. According to Bulto (2017), the collection of solid waste system is unable to deal with the increasing volume of solid waste. Currently, municipal solid waste is increasing in both quantity and composition throughout the world (Dhuguma et al., 2018). Many of the world cities are generating an ever-increasing amount of waste, and the effectiveness of their solid waste collection and disposal systems is declining (Emeghshw, 2013).

According to Wegedie (2018), economic development in developing countries has led to the very large migration of people from rural areas to urban areas for the purpose of better life. As a result, more urban slums are created rapidly presenting challenge to city and town administrators, urban planners, government and non-governmental organizations. Not only the quantity of solid waste generated is increasing but also the composition is changing, which accompanied by low collection rates threaten the health of residents (Solomon, 2011).

Africa generates approximately 0.5kg per person per day, which is lower than global average (0.74 kg per person per day), but it is rapidly increasing due to increasing population and rapid economic development (Kaza et al., 2018). In low-income countries waste generation will continue to increase in the coming decades with waste generation expected to triple by 2050. Only a small fraction of waste generated in low-income countries is processed and disposed properly whereas significant proportion either dumped openly without recourse to management systems or left in public dumpsters with no one to properly dispose them (Pradhan, 2009).

Improper handling and disposal of solid wastes contribute to high level of death and morbidity (Modak et al., 2010), because of town and municipalities cannot manage to cope up with the accelerated rate of waste production and composition in terms of technology, institutional arrangement and cost effectiveness of solid waste management (Biruk et al., 2020). As a result

of lack of proper waste management, it is common place to see waste strewn in open spaces, river banks and street sides, which create unsanitary conditions and health risks to residents. (Alam and Ahmade, 2013) Even though the overall objective of town solid waste management is to collect, treat and arranged of solid waste generated by all town dweller, 30%–60% of all the town solid wastes are uncollected, and less than 50% of the population is served (Monyoncho, 2013)

Unproductive municipal solid waste management system increases disease transmission, contaminate ground and surface water, create greenhouse gas emissions, damage ecosystem services, discourages tourism and other business activities (Chinasho, 2015; Fenta, 2017). According to Kassa (2010), solid waste management is becoming a most important public health and environmental concern in urban areas of Ethiopia that only 2% of the population established solid waste collection, transportation and landfill disposal services.

Melka Rafu town is one of the towns in East Hararghe zone where urban population is growing rapidly causing a rise in household solid waste generation rates in the town. Presently, wastes are scattered in every open space due to illegal dumping. The lack of proper handling and management practices remove the area of its aesthetic value and present health risk to population. No studies have dealt with generation rate and management options of household solid waste in the town. Since there are no studies on solid waste generation rates and physico-chemical characteristics as well as management practices,

This study is significant because it will give some basic information to policymakers, solid waste managers and environmental protection agencies about existing situation of solid waste management in Melka Rafu town. Moreover, the study may provide baseline information to the next work who will like to conduct detailed and comprehensive studies either in Melka Rafu or other study area. Thus, this study attempts to generate data and provide additional information regarding waste generation and management aspects in the town.

General objective

The general objective of this study was to assess generation rate, selected physic-chemical composition and management practices of household solid waste in Melka Rafu town, East Hararghe zone, Oromia Regional State, Ethiopia.

Specific objectives of the study are:

- To determine the generation rate of household solid waste in Melka Rafu town
- To determine the physico-chemical composition of solid waste in Melka Rafu town
- To assess solid waste management practices of solid waste in Melka Rafu town

2. LITERATURE REVIEW

2.1. Concept of Solid Waste

Waste is defined by Penido et al. (2009) as movable material that is supposed, often incorrectly, to be of no additional value. Once unnecessary, it may be no problem, or a nuisance or a hazard. Similarly, waste can be generally described as any item or material that is generated and disposed of or intended to be disposed of by a person that has keeping of it (Hajkowicz et al., 2006).

2.2. Sources of Solid Waste

Classifying wastes by their sources is a useful way of determining the relative contributions of the different sectors of society to the waste stream and how to plan for their collection and disposal (Baabereyir, 2009). The materials that are collected under the term solid waste include many different substances from a multitude of sources (Takele, 2004).

Therefore, several categories of municipal solid waste are distinguished based on the source of origin. A good example of the source classification was provided by the a study in Asia which identified the sources of waste as residential, commercial, industrial, municipal services, construction and demolition, processing and agricultural sources (Hoornweg and Laura, 1999). Tchobanoglous *et al*. (1993) categorize in to 8 general sources those which generate the MSW. These sources are residential, commercial, institutional, construction and demolition, municipal service, treatment plant sites, industrial and agricultural. The study showed that solid waste generated from households count for a large percentage of the municipal waste stream (Bobeck, 2010).

Household solid waste is therefore one of the constituents of municipal solid waste, which accounts for the waste in developing countries (Adewumi *et al*., 2005).

It is referred to as residential refuse or domestic waste comprises wastes that are the consequence of household activities. Typically, this includes food preparation, sweeping, cleaning, fuel burning and gardening wastes, old clothing, old furnishings, retired appliances, packaging and reading matter. Where diapers or bucket latrines are used, household wastes include faecal material (Cointreau, 1982 and Dereje, 2001). Tchobanoglous *et al*. (1993) also

stated that food wastes, paper, cardboard, plastics, textile, leather, yard wastes, wood, glass, tin cans, aluminum, other metals, ashes, steel leaves, special wastes (including bulky items, consumer electronics, white goods, yard wastes collected separately batteries, oil, and tires) and household hazardous are types of residential solid wastes.

Residential source are among the highest generator of municipal solid waste which generate large volume of waste. In Uganda for example, the residential wastes takes a portion of 52 - 80% of the weight of wastes produced, followed by markets, commercial sectors, industrial sectors and others. This also happens at other African countries like Kenya. A case study of 4 towns in Kenya; Nairobi, Nakuru, Mombasa and Kisumu shows that around 61% of the wastes produced there are residential wastes, followed by industrial and others such as hospitals and markets (Mwesigye *et al.,* 2009); in Makurdi, Nigeria this waste stream contributes about 82% of the total waste (Sha'Ato *et al*., 2006). Similarly, in Addis Ababa household waste constitutes 76% of total solid waste generated (Tadesse, 2004; SBPDA, 2005).

There are various sources of SW and it can be deduced that every sectors which are generators of MSW are considered as sources of SW, however as far as solid wastes produced from residents are concerned, it is common to manage the waste separately from other SW given that responsible parties will be in charge of proper management (Daniel and Perinaz, 2012).

Industrial wastes are wastes arising from industrial activities. Industrial process wastes include a very wide range of materials and the actual composition of industrial wastes in a country will depend on the nature of the industrial base. Composition of industrial waste depends on the kind of industries involved. Examples of the wastes which may be found under this category are general factory rubbish ashes, organic wastes from food processing, packaging materials, plastics, papers, acids, and alkalis, metallic sludge's, demolition and construction waste, hazardous waste and tarry residues (Dereje, 2001). It is therefore a norm for industrial sector to produce a huge amount of wastes which can be from automobile, fabric, manufacturing industries, construction sites or power plants (Bello *et al*., 2016).

Commercial waste or refuse category consists of wastes from shops, offices, hotels, stores offices, fuel service stations, warehouses, restaurants, etc and typically consisting packaging

materials, office supplies and food wastes. In developing countries, markets may contribute the major portion of these waste categories refuse. Institutional sources of solid waste include waste from schools, hospitals, clinics, and government offices, police, barracks, religious buildings, military bases etc, and comprise hospital and clinical wastes including potentially infectious and hazardous materials. Construction and demolition wastes are produced from construction wastes and its composition depends on type of construction materials used, but it typically includes soil, brick, stone, concrete, ceramic materials, wood, packaging materials and the like (Dereje, 2001).

Solid wastes from agricultural sector due to agricultural activities generated from Crops, orchards, vineyards, dairies, feedlots, farms etc. This includes spoiled food wastes, agricultural wastes, hazardous wastes (e.g. pesticides) (Tchobanoglous *et al*., 1993). Agricultural Wastes - include garden wastes, field wastes, leaves, branches, and weeds. In many cases, they also include dirt and manures in the more rural areas where households keep animals or raise vegetable or flower gardens adjacent to the house (MUDC, 2012)

2.3. Solid Waste Management

Solid waste management may be defined as "the discipline associated with the control of generation, storage, collection, transfer and transport, processing and disposal of solid wastes in a manner that is in accord with the best principles of public health, economics, engineering, conservation, aesthetics, and other environmental considerations, and that is also responsive to public attitudes" (Tchobanoglous *et al.*, 1993)

Solid waste management is one of the basic services attracting widespread attention on the urban agenda of a number of SSA countries (Kaseva and Mbuligwe, 2005). Municipal solid waste management is the most important service a city provides; in low-income countries as well as many middle-income countries, which is the largest single budget item for cities and one of the largest employers (Hoornweg and Bhada-Tata, 2012).

However, it has been one of the most crucial issues facing authorities in the fast-growing cities in developing countries (Ogwueleka 2009) since it has become a pressing problem and is now frequently called for by many urban masses. This has placed a heavy burden on many municipalities in developing countries to manage the waste effectively (Imam *et al.*, 2008) and

city authorities lack the financial and technical resources keep pace with the challenges associated with huge amounts of solid waste (Ogwueleka, 2009).

Most of the waste generated in the urban areas is not collected (Imam *et al.,* 2008), rather it is disposed in open dumping areas of solid waste which is the cause for environmental and health hazards (Jin *et al*., 2006). Consequently, heaps of solid wastes are not uncommon sights in these areas Poorly managed waste has an enormous impact on health, local and global environment, and economy (Hoornweg and Bhada-Tata, 2012). Improper management of solid waste in most cities of developing countries leads to problems that impair human and animal health and ultimately result in economic, environmental and biological losses (Sharholy *et al*., 2007; 2008).

The open landfills disposal method for solid waste with no environmental control have reached their capacities and in most cases the environmental conditions are very poor (Remigios, 2010). This has caused considerable land degradation and contamination of underground water sources through leachate pollution (Parrot *et al*., 2009). Open dumps undergo biological and chemical processes that produce leachates which later pollute the underground water sources (Jin et al., 2006).

Residents are also intended to resort to burying or burning the waste, they generate, in open spaces (Zurbrugg, 2003). Similarly, the waste picker causes intentional fires at the dumpsites and temporary collection points when they burn waste to sort out metals or even reduce the volume of the waste dumped (Jin *et al.,* 2006). Air pollution is common on many of these landfills when burning waste (Parrot *et al*., 2009).

For instance, methane from the anaerobic decomposition of waste causes fires and contributes to global warming, since the accumulation of greenhouse gases in the atmosphere, particularly carbon dioxide and methane, is believed to be responsible for global warming (Jin *et al*., 2006). Furthermore, uncollected waste degrades urban environments, leading to unattractive aesthetic conditions (Kinobe, 2015).

Improper of waste management systems can expose the urban residents, especially poor housing, living in the slums to health risks (Zurbrugg, 2002). In Africa for instance, solid waste is regarded as the second most important environmental health concern apart from water

quality as per the WHO (Zerbock, 2003). The problems caused by solid waste in urban Africa is largely due to the explosive growth rates, particularly in sub-Saharan Africa, which eventually translates into generation of copious amounts of solid waste (UN-HABITAT, 2010; Taiwo 2011).

At the dumpsites, garbage (Zurbrugg, 2003) and food leftovers attract animal rodents and insect vectors transmit diseases to the people leaving nearby (Jin *et al.,* 2006). Flies and mosquitoes breed in the blocked drains and these are vectors that spread diseases such as malaria (Kinobe, 2015). Emission of bad smell is major other problems they encountered in addition to its health problem Getachew and Habtamu (2015).

There are also other social constraints in the context of the improper handling of wastes. This can be evident from the indiscriminate waste disposal, for instance in drainage channels and along the side of streets. As a result, the minimum amount of the waste generated is collected and transported to the landfill (Zurbrugg, 2003) and the rest is left on vacant plots, along streets, in drainage channels, in open sewer lines and on railway lines. The nature and set-up of most of the waste collection points are such that they are located next to drainage channels. These prevail more in slum areas with narrow, unpaved streets and roads, leading to more problems when it rains and all the waste and soil find their way into the drainage channels. This then leads to blockage and subsequently flooding (Kinobe *et al.,* 2015).

Solid Waste Management Options

To make waste management practices as environmentally sound as possible, the US Environmental Protection Agency (EPA) proposed an integrated waste management strategy. These integrated waste management strategies include source reduction (reuse of products and backyard composting of year trimming), recycling of materials (including composting) and disposal (including waste combustion, preferably with energy recovery and land filling).

This integrated strategy is considered as a useful policy tool for conserving resources, dealing with landfill shortages, minimizing air and water pollution and protecting public health. According to EPA, source reduction including reuse of products is the most preferred option, followed by recycling and composting. Land filling is the last option in the ladder of waste management strategies. Some of the options are defined as follow.

Recycling**:** Municipal solid waste recycling refers to the separation and collection of wastes and their subsequent transformation in to usable or marketable products. The materials that can be recycled include plastics, wood, metals, glass, textiles, paper, cardboard, rubber, ceramics and leather. Organic solid waste can also be recycled into fertilizer for agricultural purposes. Recycling reduces the amount of household solid waste to be collected, transported and disposed of promoting cleaner environment and economic competitiveness.

Composting**:** It is a biological process of decomposing the organic fraction of municipal solid waste. The end products of this process can be used as agricultural fertilizers or fuel for motor vehicles. However, open composting is not friendly because it produces carbon dioxide (which is a greenhouse gas) and also spreads harmful airborne spores and bacteria.

Land filling: in many respects, land filling is seen as the bottom of the hierarchy of municipal waste disposal options. It is the main option for the disposal of municipal solid waste in developing countries due to cost constraints.

2.4. Solid Waste Management Challenges

The inadequate collection, recycling or treatment and uncontrolled disposal of solid waste are particularly frequent in low and middle-income countries and lead to severe health risks and environmental pollution. In such countries often more than 50% of the total municipal solid waste is organic (Christian Zurbrügg, 2017). Postconsumer waste, through its production and management, affect air quality, water quality, and public health, and it contributes to climate change (Bogner *et al.*, 2007).

Improperly managed waste can affect the environment at different scales. Open dumping of wastes contaminates nearby water bodies with organic and inorganic pollutants. It also threatens public health by attracting disease vectors and exposing people living near the waste to the harmful products within (McDougall et *al.*, 2001).

2.5. Goals and Principles of SWM

The first goal of SWM is to protect the health of the urban population, particularly that of low-income groups who suffer most from poor waste management. Secondly, MSWM aims to promote environmental conditions by controlling pollution (including water, air, soil and cross

media pollution) and ensuring the sustainability of ecosystems in the urban region. Thirdly, SWM supports urban economic development by providing demanded waste management services and ensuring the efficient use and conservation of valuable materials and resources. Fourthly, SWM aims to generate employment and incomes in the sector itself. To achieve the above goals, it is necessary to establish sustainable systems of solid waste management which meet the needs of the entire urban population, including the poor.

The essential condition of sustainability implies that waste management systems must be absorbed and carried by the society and its local communities. These systems must, in other words, be appropriate to the particular circumstances and problems of the city and locality, employing and developing the capacities of all stakeholders, including the households and communities requiring service, private sector enterprises and workers (both formal and informal), and government agencies at the local, regional and national levels.

2.5.1. Solid waste management in developing countries

Developing countries have peculiar solid waste management problems different than those observed in the industrialized countries. Although low-income countries solid waste generation rates average only 0.4 to 0.6 kg/person/day as opposed to 0.7 to 1.8 kg/person/day in the industrialized countries, indeed, the very composition of their waste is different than that of developed nations (Rouse, 2008).

Increasing population levels, booming economy, rapid urbanization and the rise in community living standards have greatly accelerated the municipal solid waste generation rate in developing countries Othman, 2002). It is clear that most of the generated SW constituencies in most developing countries are decomposable and recyclable. If properly managed, such MSW would provide high opportunities for the development of the socio economy of the countries.

However, the fact is unfortunately the opposite as the SW remains a socio-economic that faces many problems. There are diversities of management options of MSW in the different developing countries. In Egypt, which is an African Middle East Arab country 75 percent of the MSW is generated in urban areas. Total estimated MSW for 2025 is expected to reach 33

million tons for a growth rate of 3.2percent based on 2001 records. Collection services cover less that 30percent of urban and rural areas and the rest are disadvantaged. A portion of 8 percent of the total collected MSW is sent to compost plant but the rest is sent to dump sites scattered in the country open spaces posing high risk to public health and the environment.

In most cities of developing countries, waste management is inadequate: a significant portion of the population does not have access to a waste collection service and only a fraction of the generated waste is actually collected. Systems for transfer, recycling and/or disposal of solid waste are unsatisfactory from the environmental, economic and financial points of view.

In relation to solid waste management in Africa, as different literatures show, the rapid and unprecedented population growth in Africa urban areas remained a serious problem to municipalities.

According to African Development Bank (2002) most major cities in Africa have an established municipal waste collection system. Collection is carried out by human- and animal-drawn carts, pushcarts, open-back trucks, compactor trucks, and trailers. Collection rates across the continent range from 20 to 80percent. Common feature of the municipalities is that they are ineffective, underequipped and poorly maintained, inadequately funded and poorly staffed. Often collection services are limited to high visibility areas, the wealthy, and businesses willing to pay for this service.

In most cities in developing countries, scavenging occurs on dump sites. Most of the workers concern themselves with the extraction of a single material, in order to collect salable quantities**.** The purchasers of the materials are wholesale dealers. It is not unusual for the traders not only to control the prices offered to the scavengers but also to act as controllers and masters of the dump.

2.5.2. Solid waste management in Ethiopia

Most attempts to improve solid waste management in cities in developing countries, like Ethiopia, have focused on the technical aspects of different means of collection and disposal of solid waste. This arrangement to solve the problem of solid waste in urban areas of the country, in general and in Addis Ababa in particular have not been achieving the desired goal.

This resulted in searching for another alternative that better minimizes the problem of urban solid waste. It was this trend that pushed / forced the Ethiopian government to form an agency that assumed the full responsibility of administering the management of municipal solid waste since 2003. Since then, there is an inclination towards the inclusion of the demand side aspects of solid waste management in addressing the problem of municipal solid waste management (AACASWMP, 2002). Thus, it is important to find efficient ways to treat solid waste.

In Ethiopia, as in all the other countries of the south, city councils and municipalities have insufficient means to solve the problems of solid waste management. The major source of these problems is the lack of resources in terms of manpower and particularly finances. There is no clear cost recovery structure related to solid waste management in Ethiopia, hence, there is an extremely low level of returns for efforts put into dealing with solid waste. The solid waste management institutions not only lack funds, but their capacity to work in partnership with the local communities is also limited (Edwards, 2010).

In large number of urban areas of the country, solid waste management services are either absent or insufficient. Solid Waste Management in Ethiopia is generally in a poor state. For example, the collection services are often inefficient and don't cover all areas. In general, the unauthorized and most of the authorized dump sites are poorly managed causing significant environmental impacts.

Over the last few years, many micro and small enterprises have been set up to carry out waste pre-collection service, receiving payment either from the respective beneficiaries or municipalities to collect waste and transport to the municipal waste containers, and helps to fill the created gaps in collecting and transporting wastes.

These enterprises represent a good starting point for building private sector participation and realizing the associated benefits. There are some positive aspects of the existing system in Addis Ababa, such as informal recycling, composting initiatives and in particular the introduction and expansion of private sector enterprises that carry out pre-collection service from households. These enterprises play an important role in improving waste collection and reducing unemployment at local and regional level (MUDCUPSBB, 2012).

Ethiopia is also becoming a challenge for municipalities. For instance, the municipal solid waste management practices of 15 regional cities of Ethiopia, a controlled solid waste disposal system were practiced in only two of them. That means small proportions of the urban dwellers are served and a large quantity of solid waste left uncollected. In addition, a study conducted reveled percentage of solid wastes which are left uncollected and disposed anywhere without due attention regarding their consequences in different towns of Ethiopia (WB, 2004).

2.6. Characteristics of Solid Waste

Waste characteristically refers to the quantity, composition and types of solid wastes. For effective and economic management of solid wastes produced in a particular city, a considerable knowledge and data about the characteristics of the solid wastes of the respective city is a necessity. In order to decide or determine the types and quantities of facilities required for solid waste management and the best disposal options needed in a particular city, needs precise information about the quantities (generation rate) and the nature of the constituents (Composition) of the solid wastes produced in the city. Even to plan for future provision of facilities, projected increases in quantities of each waste stream (source) should be estimated (Rush brook, 1999).

2.7. Composition of Solid Waste

The composition and characteristics of SW was deeply influenced by the financial status, living standards, food habits, rituals, literacy rate, type of energy source, climatic and topographical conditions (.Jin *et al*,.2006).The economic status of a country is reflected in MSW composition produced that means In high income countries the fraction of organic waste is comparatively low as compare to the low income countries (e.g. In Georgia organic waste accounts 39 % of the total MSW which is 62 % in Indonesia (Hoornweg and Bhada-Tada, 2013).

Typically, components of most residential solid wastes are Food wastes, paper, cardboard, plastics, textiles, leather, yard wastes, wood, glass, tin cans, aluminum, other metal, ashes, street leaves, special wastes (including bulky items, consumer electronics, white goods, yard wastes Collected separately, batteries, oil, and tires), and household HW. The percentage of

RSW components vary with location, season, economic condition and many other factors (Tchobanoglous and Kreith, 2002).

Composition of Solid Wastes plays a major role in determining compaction, decomposition and incineration process. Apart from that in low- and middle-income country the waste generated has high moisture content and density. In Europe, MSW composition is different from Asia, comprising household and commercial waste as well as waste generated from public building areas (Eurostat, 2003).

2.8. Generation rate of Solid Wastes

Solid waste generation rate is the amount of waste join to waste stream from human activities and the amount of solid waste generated from households. In order to design the waste management system, one of the important factors is waste generation rate. Determining the total amount of MSW helps to design the collection routs, material recovery and disposal facilities. All the activities which cause to throw away the useless and unwanted material during the process, manufacturing, distribution and consumption are defined as waste generation (Rousta, 2008).

Solid waste quantities should always be expressed in terms of weight not volume, since the latter varies with compaction. The estimated quantity of Municipal Solid Waste (MSW) generated worldwide is 1.7–1.9 billion metric tons per year making cities a threat to the environment (UNEP, 2013). It is also expected to increase to approximately 2.2 billion tonnes per year by 2025 according to current trends in population growth as determined by country income level. This represents a significant increase in per capita waste generation rates, from 1.2 to 1.42 kg per person per day in the next fifteen years. However, global averages are broad estimates only as rates vary considerably by region, country, city, and even within cities. Waste generation in sub-Saharan Africa is approximately 62 16 million tons per year. Per capita waste generation is generally low in this region, but spans a wide range, from 0.09 to 3.0 kg per person per day, with an average of 0.65 kg/capita/day (Karak et al., 2012; Hoornweg and Bhada-Tata, 2012; UNEP, 2013). Despite this accelerated pace of solid waste production waste collection rates are lower than 70% in developing countries (Edward, 2010). Therefore, the technological options should be carefully investigated for an efficient waste management system.

2.9. Physicochemical Properties of Solid Wastes

Physical property of solid wastes includes identification of the individual components that make up municipal/domestic solid wastes, analysis of particle size, moisture contents and density of Solid wastes. In addition to analyzing for quantity and composition, it is recommended that the sampling program include provision for determining moisture content, bulk density, and Particle size distribution (Cunningham, 2008). The most important parameters of physical properties of solid wastes are specific weight (density), moisture content, particle size and distribution, field capacity and permeability of compacted Waste. "From the physical parameters are directly done specific weights, moisture contents bulk density".

2.10. Existing Solid Waste Management System in Melka Rafu

One of the most major problems of Melka Rafu town was the municipal solid waste management problems. The heart problem is the pollution of the environment, especially roads and ditches blocked solid wastes. Also, the pollution increases the health risks of the population and reduces the value of the environment. Municipality has only limited data on the rate of generation and composition. The types of solid wastes produced in the residential areas consist of mainly organic which consists of materials such as food waste, paper of all types, card board, wood and yard wastes. While the inorganic fraction consists of items such as glass, metals of different types etc. The disposal site that is currently in use for the total of Melka Rafu town is open field located in the town. This is an agricultural area where no extra preparation done to make it proper disposal site.

2.11. Solid Waste Management Hierarchy

The generally waste management hierarchy can be defined as a concept that promotes waste avoidance ahead of recycling and disposal. The essential components of this plan are Reduction and Reuse, Waste Collection, Recycling, Composting, Energy recovery, and Disposal. Way of waste reduction, waste reuse and recycling are the prefer options when collection waste. There are a lot of environmental benefits that can be derived from the use of this method. They reduce or prevent greenhouse gas emissions, reduce the release of pollutants, conserve resources, save energy and reduce the demand for waste treatment

technology and landfill space. Therefore, it is suitable that these methods be adopted and incorporated as part of the waste management plan.

Figure 1. Solid Waste Management hierarchy

Urban solid wastes can be divided into two major components called biodegradable and non-biodegradable. The recyclable/biodegradable component of urban solid waste constitutes organic wastes such as food waste, garden waste, and agricultural waste which undergo biological degradation under controlled conditions and can be changed in to compost or organic fertilizer. While non-biodegradable wastes include inorganic materials, which can not be decomposed and degraded.

2.11.1. Recycling

Recycling is being strongly expectant in most developed countries. From an environmental outlook it was an extremely favorable option for Municipal Solid Waste, mainly due to its relatively low negative environmental impact, its role in preserve raw materials by reusing unnecessary ones, as well as the energy it saves by reducing extraction processes. In 2007, Americans generated about 254 million tons of trash and recycled and composted 85 million tons of this material, equivalent to a 33.4 percent recycling rate on average, we recycled and composted 1.5 pounds of our individual waste generation of 4.6 pounds per person per day (EPA, 2007).

In early times, the disposal of human and other wastes did not pose a significant problem, because the population was small and the amount of land available for the assimilation of

wastes was large. Although emphasis is currently being placed on recycling and fertilizer value of solid wastes, the farmer in ancient times probably made a bolder attempt at this. Indication of recycling may still be seen in the primitive, yet sensible agriculture practices in many of the developing nations where farmers recycle solid wastes for fuel or fertilizers values (Alemayehu, 2007).

2.11.2. Composting

The waste Composting is the controlled aerobic decomposition of organic matter by the action of microorganisms and small invertebrates. Today being used there are a number of composting techniques. These contains: in windrow composting, vessel composting, vermin composting and static pile composting. The process is forbidden by making the environmental conditions optimum for the waste decomposers to thrive. The rate of compost formation was managed by the composition and constituents of the materials i.e., the Carbon/Nitrogen (C/N) ratio, the temperature, the moisture content and the amount of air. With regard to composting, the households practicing composting are very few, while 95%of this refuse was largely plant origin /biodegradable/ organic waste. According to (Gardner, 2001), as cited in (Bezaye, 2008), composting is an ancient practice where more cities in the world nowadays are reclaim the benefits of reusing solid organic waste material. It was a natural way to prepare the waste for use.

2.11.3. Waste Reduction

It is now well known that sustainable development can only be achieved if community in general, and industry in particular, produces „more with less‟ i.e., more goods and services with less important of the world‟s resources (raw materials and energy) and a smaller amount pollution and waste. Production as well as product changes have been introduced in many countries, using internal recycling of materials or on-site energy recovery, as part of solid waste minimization schemes (EPA, 2007).

Waste reduction and reuse of products are both ways of waste prevention. They control the production of waste at the source of usual generation and reduce the demands for large scale treatment and disposal facilities. Methods of waste reduction contains manufacturing products with less packaging, initiative customers to bring their own reusable bags for packaging,

encouraging the public to choose reusable products such as cloth napkins and reusable plastic and glass containers, backyard composting and sharing and donating any unwanted items rather than discarding them.

All of the methods of waste prevention mentioned require community participation. In order to get the public on board, training and educational programmers need to be undertaken to educate the public about their role in the process Recycling is the process by which waste otherwise destined for disposal is collected, reprocessed or remanufactured and used to make a product, while reuse is the process by which waste otherwise destined for disposal is cleaned or repaired for use, for the purposes of prolonging the original product lifetime prior to treatment or reprocessing (EPA, 1996).

2.11.4. Collection of Solid Waste

The term collection of waste includes not only the gathering or picking up of solid wastes from the various sources, but also the hauling of these wastes to the location where the contents of the collection vehicles are emptied (Tchobanoglous, 1993). There are three basic types of collection equipments: Human powered, Animal powered, and Engine powered. According to (Nurconsult, 1982 and AAHB, 1997) they are described as follows.

Human-powered collection equipment: These include pushcarts, pedal tricycles, wheelbarrows, and two wheeled dollies with baskets. In general, these equipments require some sort of smooth surface on the lanes to be effective.

Animal-powered collection equipment: Animal powered collection equipment either takes the form of drawn carts or the animal may be directly backed with containers such as basket. This type of collection is applicable in the cities where there is no much traffic.

2.12. Waste Disposal and Alternative Waste Management Options

Solid waste disposal (the disposal of solid or semi-solid materials) resulting from human and animal activities that are useless, unwanted, or hazardous. Most of the municipal solid waste (MSW) in developing countries is dumped on land in a more or less uncontrolled manner. These dumps make very uneconomical use of the available space, allow free access to waste pickers, animals and flies and often produce unpleasant and hazardous smoke from slow

burning fires. The safe and reliable long-term disposal of solid waste residues is an important component of integrated waste management (Tchobanoglous *et al*., 1977).

2.12.1. Transfer and Transport

These activities are associated with transfer of wastes from public storage facilities to collection vehicle and the subsequent transport of wastes to disposal site. Transfer refers to movement of waste or materials from primary collection vehicle to a secondary, larger and more efficient transport vehicle. When location of final disposal site is at a long distance from points of collection, transfer stations may be used.

There are two basic mode of operation: direct discharge and storage discharge. In storage discharge refuse is first emptied from collection trucks in to a storage pit or to a large platform. While in direct discharge station, each refuse truck empties directly in to larger transport vehicles" (Meenakshi, 2005). Transportation on the other hand covers all types of vehicles under operation to transport solid waste from its generation point to transfer station and then to treatment or disposal site.

2.12.2. Disposal

This is final functional element in solid waste management system. Disposal activities are connected with final dump of solid wastes directly to a landfill site. Today disposal of wastes by land filling or land spreading is the ultimate fate of all solid wastes whether they are residential wastes or residual materials from materials recovery facilities. "However, in most developed countries this method is formally banned allowing only sanitary landfill for final disposal. Because sanitary landfill is not a dump it is an engineered capacity used for disposing of solid wastes on land without creating nuisance or hazards to public health and environment" (Techobanglous et al., 1993).

3. RESEARCH METHODOLOGY

3.1. Description of the Study Area

This research was conducted at Melka Rafu town, which is found in Kombolcha district, East Hararghe Zone of Oromia Regional State. Geographically, Melka Rafu is located at latitude of 42°07‘0" and longitude of 90 25‘60". It is the administrative center of Kombolcha district and located at a distance of 542 km East of Addis Ababa and 16 km south of Harar town. The district is bordered by Jarso district to the east, Haramaya district to the west, Dire Dawa administration to the North and Harari national state to the South.

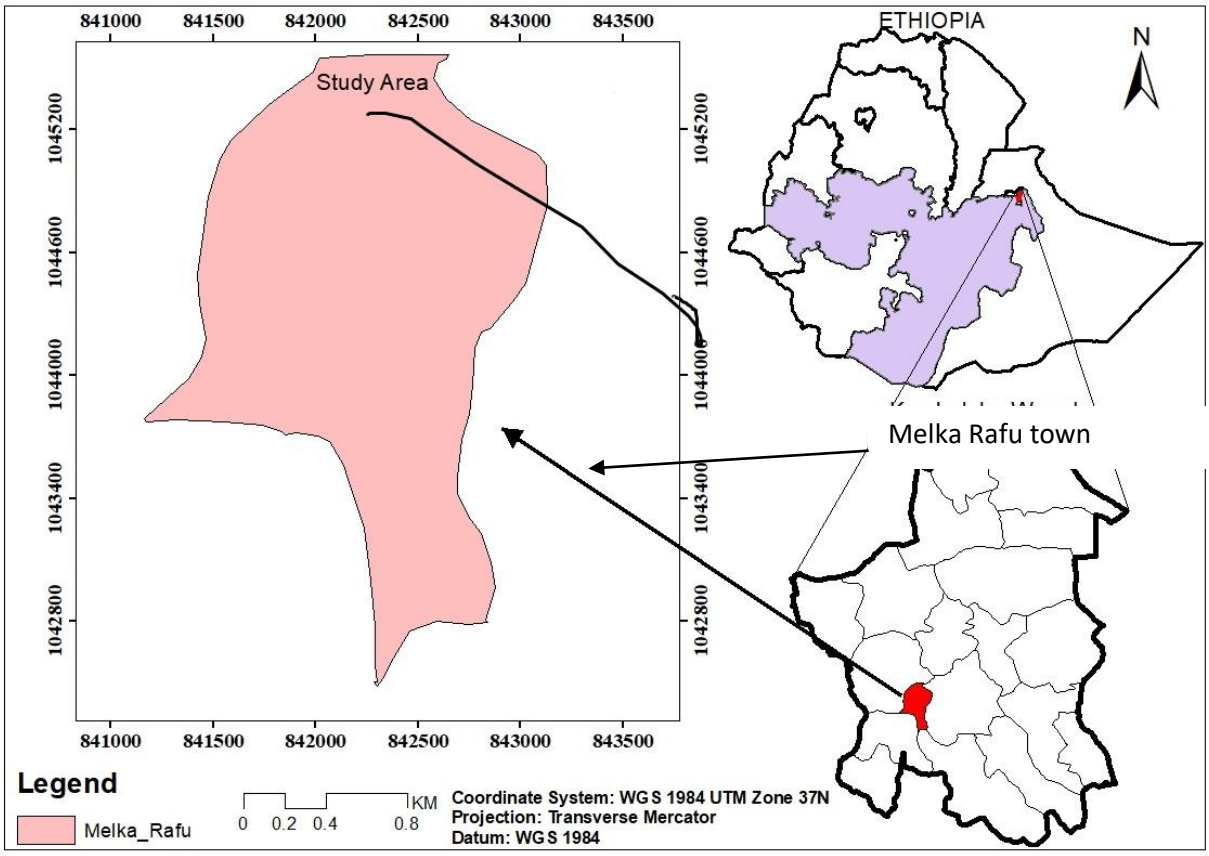

Figure 2. Map of the study area

According to central statistical agency (CSA) (2007), the total population of the Melka Rafu town is 15785. However, the recent enumeration conducted by Melka Rafu municipality

indicated that the town's population is increased to 37214, of which, 19624 male and 17590 female. The town has a total of 3059 households (Melka Rafu Town Municipality, 2020).

The mean annual rainfall ranges from 600 mm to 900 mm and the mean annual temperature ranges from 18˚C to 25˚C. The main rainy season, *kiremt* starts at the beginning of July and extends up to September while the short rainy season (*belg*) is from March up to April.

According to Kombolcha district Agricultural Office (KDAO, 2017), the topographical condition of Melka Rafu town can be classified into mountainous land (35%), undulating land (53%) and plain/ flat (12%), respectively. The altitude of the town ranges from 1200 to 2400 m.a.s.l. Climate of the area According to the information obtained from KDAO, the town is classified into *woina-dega* (74%) and kola (26%) agro-climatic zones. (KDAO, 2017).

Agriculture (mixed farming) is the major source of livelihood for residents of Kombolcha district. Malka rafu town residents engage in trading agricultural commodities such as chat, potatoes, cabbages, carrot, and onion. From the main economic earning of the area, chat ranks the first followed by vegetable, cereal and coffee. From cereal production maize constitutes 1st rank followed by sorghum and wheat and also out of the total areas covered by perennial crop 3480.66 ha and farmers commonly uses irrigation for vegetable and chat production. Intercropping cereals with chat is the common farming system in the study area (WAO, 2017).

3.2. Research Design

In this research, descriptive survey design with both qualitative and quantitative approach was implemented. The quantitative study method was used to collect data on Socioeconomic Characteristics of the study participants; on quantity of SW generated and on composition of SW generated. Depending on the nature of the data, simple descriptive statistical analysis such as percentage and frequency will be used to interpret result. Simple random and purposive sampling was employed to identify the study *kebeles* and participants (households, Key Informants and solid waste collection institutions). The data were collected from the respondents by distributing close-ended questionnaires and by weighting samples in each waste category. Qualitative data were collected through interview, open-ended questionnaires and observation. This method focuses on investigating the current status, practice and the

problem of MSWM of Melka Rafu town. Laboratory analysis was carried out to assess selected physico-chemical properties of solid waste samples collected from the study area.

3.2.1. Sampling Method and Sample Size

Sampling Method

The study working a multistage sampling method. Melka Rafu town was first selected based on the scale of the problem and knowledge to the area. Then after, two sample kebeles were randomly selected from Melka Rafu town. Accordingly, *kebele 01* and *kebele 02* respectively.

Therefore, random sampling technique was used to select "*village"* from. each *kebele* Based on this, 2 *'village*' from each *kebeles* with a total of 4 '*village*' were taken as a sample. To do this, the list of each '*village*' was use as a sampling frame. .The numbers of sample households were selected randomly from each *village*' using systematic random sampling.

Finally, probability proportional to size was applied to determine the number of the households from each *Kebele*. The respondent unit is the head of the house

Sample Size

The first sample size was designed to select Melka Rafu town for the study from the two towns in the Kombolcha woreda to achieve the objective of the study area. The town was selected because it is the largest of the towns in the woreda: Wara Mohammed and ijaa ginna. The town is also a center for running business more than others and an area where numbers of different activities are taking place. So that different levels of the residential population (individual groups) are living here. Subsequently, to determine sample size of households those who have been participated in the study, a sampling technique (formula), which was developed by Cochran (1977) In this case population variable (p) is house units variable, and is given as;

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

Where N= total number of housing unit, Q = 1-P (1-0.9), P= housing unit variable, d= allowable error (0.05), and Z= Standardized normal variable and valued that corresponds to 95% confidence interval equal to 1.96. According to the data concerning housing development of the town obtained from Melka Rafu Town Municipality (2020), there are3059 total legal housing units (N) in the two *kebele* of the town. Out of these, about 90% (P) are residential while the rest 10% (Q) is for commercial activities, offices and for others.

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

$$n = \frac{3059(1.96)^2(0.9)(0.1)}{(0.05)^2(3059-1)+(1.96)^2(0.9)(0.1)} = \frac{1053.63}{7.991} = 132$$

As a result of using Cochran Technique the Household Sample Size that Was Considered 132 Respondents It Was Selected by Systematic Random Sampling Procedure to Participate in The Study. About 132 Households Were Targeted and Were Possible to Reach 132 Household. But, The Household Sampling Method, Was Applied Systematic Simple Random sampling was applied to select the first respondent and the following ones were selected as per the nth term. In the proposed study the nth term was 23 that was 3059/132 = 23, therefore I had been used skip to select respondents based on the sample frame. This sampling was strictly done in the people who make the population of the study in the two *kebeles.*

Table1. Number of populations by kebeles of Melka Rafu Town (2021)

Name of kebele	Total population	Total Household head	Sample size	Percent	Method
Kebele (01)	16290	1330	57	43	probability proportional
Kebele (02)	20924	1729	75	57	probability proportional
Total	37214	3059	132	100	

Source; Melka Rafu Municipality (2021)

The interview was conducted with purposely selected key informants: 2 from municipality staff, 2 from the district health office expert and 2 from town health extension to collect qualitative data.

3.2.2. Identification of Households

To identify participant households within the study area, all households were stratified in to three income level groups; low, middle and high-income groups. According to CHFI (2011) cited in Fei-Bafoe *et al*. (2014), communities can be categorized into low income, middle and high income groups based on their life standards, income levels, housing structure and presence of basic social amenities. Households are categorized in to three groups depending on their monthly income. Income level and solid waste generation rates have direct relationship. Households that have better life standard use more consumption materials than low-income households do, through which they generate higher wastes (Wells, 1996)

Although there is currently no official standard that defines the different income groups in Ethiopia, a system of grouping was developed only for the purpose of this study. Therefore, the option used to stratify the households in the town was based on data regarding level groups of the trader and farmer households taken from the finance and economic bureau as well as

Land and Environmental Protection Office of Melka Rafu town. However, since there was lack of data on the other level group of the households, grouping was actually done with the help of personal observations and community knowledge (Melka Rafu town administration, kebele officials and some individuals who are expected to know residents in the neighborhood) whether individual household is rich, middle income or poor.

Households which were categorized under low income (the poor) were those who have poor social services and amenities. They mostly leave in the slump houses/buildings with congested living rooms made from wood with mud. The middle income groups were those residents who have some level of improved social amenities and services relative to low income groups. High income groups were households those which have relatively good social amenities and services such as well-planned and paved houses/buildings and other assets than the middle ones.

After grouping; households from three stage stratified income groups were selected to draw representative sample. The implication is that, a simple random sampling technique was then used to select respondents from each residential class grouping for the study. The number of samples within each stratum was determined based on respective proportional percentages of each stratum (348 high, income, 1135 middle income and 1576 low income group). By using the proportional allocation method it was decided to take household samples randomly from the town.

As a result, 68 households (52%) from low-income group, 49 households (37%) from middle income and 15 households (11%) from high-income groups were randomly selected

3.2.3. Data Sources

For the purpose of this study, data were collected from both primary and secondary sources. The primary data included the residential solid waste components, socio-economic characteristics and types of their energy sources from participating households and information on the currently existing condition of the residential areas regarding disposed solid waste which have been collected at the household level. These data were collected using survey of residential houses, personal observation in field and field measurement of collected waste in the study area. Secondary data was gathered from related published and unpublished materials, books, journals, manuals, website and report from the town's municipality.

3.2.4. Methods of Data Collection

To collect data on the existing socioeconomic characteristics of residents, questionnaires were distributed to the 132 randomly selected households in sample *kebeles*. Then data were collected with the help of field assistants. Personal observation in the field was carried out by a checklist which is designed to generate data about the existing condition of the residential area in the study site.

The collections of waste from the selected households were conducted for seven consecutive days in order to have average result of the whole days of a week. Wastes generated from these households were collected once a day every morning. For waste generation rate and solid waste management practices, each household was given a plastic bag identified by marker. Next day during collection, another bag with the same label was also given for the next day collection, and this process continued for seven days. The waste sample was collected by three trained individual collectors with three hand pull carts. Before the actual waste collection was started, collectors were trained in the working site in order to have general understanding on the waste collection.

Thus, trained collectors were assigned to the *kebele* every morning to bring the data to the working site using the carts. Finally, components of solid wastes were separated and weighed. The results were noted on data sheets prepared for recording of data according to the code assigned to households. Therefore, the average weekly generation rate of residential solid waste within seven days was determined using the following formula.

$$\text{Per capita per day waste generation} = \frac{\textbf{Total Solid waste generation with in 7days}}{(\textbf{Total family size of survey HHs})\times(\textbf{7days})}$$

The daily, weekly, monthly and annual overall generation rate of solid waste from total residential sources of the town were also estimated based on the result obtained from the average amount of per capita waste generated within 7 days.

3.2.4. Materials and Instruments

Data were collected from formal and informal survey. The formal survey was carried out by questionnaire, using schedule for interview with respondents of households from residences of Melka Rafu town where as the informal survey was undertaken through personal observation and field measurement of waste quantity in the study area. Thus, the three basic instruments/tools (questionnaire, field measurement and field observation) with the help of different materials and equipment including plastic bag, plastic sheets, 25 Kg weighing scale (spring balance) and safety equipment were used in the process of collecting and characterizing data for this study..

Questionnaire

The questionnaire for household survey was first prepared in English; then translated and delivered in to Afan Oromo language with the help of enumerators. It was composed of closed nd open-ended questions and distributed to the respondents. The response formats for close ended items were multiple choices and ‘yes’ or ‘no' types and open-ended questions were also enabled the respondents to wrote variable and possible suggestions, which they thought, should be included.

Observation

It was employed to observe currently existing condition of the residential areas regarding solid waste disposed, at the household level in the town. This technique was carried out through personal observation in the field by preparing a checklist which was designed to generate data about the condition of the study area

Field measurements

The practice of field measurement method was applied in the working field to estimate the waste quantities for weight and component material analysis. This was used for quantification of solid waste generated by households and separation of waste into its typical categories. The quantification of waste was practiced directly at the working site in terms of weight. These direct quantifications were made by measuring the waste sample collected from selected households using a weighing scale.

3.2.6. Sorting of solid Waste and its Procedure

Sorting is an important component of solid waste management and best-done onsite which includes separation of bulky items and components of the waste. First waste was collected from selected households using labeled plastic bags and then brought to working site. After waste collection is completed, the collected waste was disposed onto the thick plastic sheet placed on the floor. Subsequently, the mixed sample waste was separated in to different sub-categories manually through hand picking.. Finally the separated wastes were weighed and the weights recorded in the prepared data sheet.

3.3. Solid Waste Sample Preparation and Procedures for Laboratory Analysis

The organic residential solid waste samples used in the present study for physico-chemical analysis were collected randomly from representative sample of the three stages stratified income groups of households in order to get representative result in the analysis. The waste samples obtained was then prepared for analysis. Generally, the sample preparation and procedures used for the laboratory work was discussed as follow

The method used to take the waste sample analysis was established based on the Mexican standard NMX-AA-015-1985 used by Medina *et al*. (2013). Accordingly, sampling was carried out during five successive days, taking a sample daily for a total number of five since one of the most significant characteristics of solid waste is its great heterogeneity. About 7.5 kg of RSW sample composed of five sub samples (1.5 kg each day) were obtained after collection and preparation. The sampled materials were transported to the central laboratory of Haramaya University using waterproof polyethylene plastic bags. The analyses of the samples were done within the maximum of three hours after collection in order to reduce the magnitude of error arising from the moisture change.

The RSW samples consisting of compostable organic components including food, yard, and animal manure waste were collected. On the basis of waste sample preparation for the laboratory analysis by Jimenez and Garcia (1992) and WHO (1978), the inert and contaminating materials such as glass, metal, stones, gravel, plastics, cardboard, textile, dusts etc. were excluded from the samples.

The samples were then chopped to be reduced to a maximum size of approximately 5cm using size reduction materials (knife and scissor) and mixed well for the analysis of moisture and organic matter (OM) contents. .

The dried materials were finely grounded with smashing machine in Haramaya University, until it can be sieved through a 0.5 mm sieve shaker in order to get a more homogeneous product of representative samples. Homogenized samples were then obtained after sequential fractionation.

The analysis and determinations of pH, EC and total nitrogen (TN), total phosphorous (TP) and total potassium (TK) content were performed in this final product. The analysis of each sample was performed in five replicates and the results were averaged for a total of these five repetitions for the purpose of data quality or accuracy in the results.

Figure 3. Sample Preparation for Laboratory Analysis

Source: Field Survey (2022)

3.4. Methodology Used for Analysis of Solid Waste Samples

Moisture content: It was determined by drying well mixed samples in an oven at 105 C for 24 hrs and expressed as a percentage of total weight according to the differential weight of fresh and dry waste (WHO, 1978). Thus, the moisture content is expressed as

$$\text{Moisture content} = \frac{\text{Fresh weight of sample} - \text{Oven dried weight of sample}}{\text{Fresh weight of sample}} \times 100$$

The total organic carbon (TOC): It was calculated from the simple determination of TOM by loss on ignition using factor of transformation method. The statistical study showed that a constancy exists in the TOC content of TOM is around 51 and 58% (average 54%) and the predictive equation deduced (TOM = 1.135 + 1.803 TOC or TOC = 1.703 + 0.520 TOM) may prove very useful in commercial composting plants. Moreover, the predictive equation can be considered valid only for city refuse composts of which the organic fraction of municipal solid wastes is the raw material for composting (Jimenez and Garcia, 1992). Similarly, Brinton (2003) also showed that organic matter (OM) represents combustible content or VS and is typically reported in terms of total weight loss on ignition as VS. Brinton found that TOC is estimated from TOM in solid waste and it comprises typically 54% of VS.

The pH and electrical conductivity (EC): These were measured in 1:2.5 and 1:5 suspension ratios of distilled water to raw composited by pH-meter and the electrical conductivity meter, respectively (WHO, 1978).

Total N content: It was determined by Kjeldahl digestion method and the result was reported with an accuracy of (+0.05). Carbon to nitrogen (C/N) ratio was calculated out of the ratio of total amount of organic carbon and nitrogen content (WHO, 1978).

Total P concentration: It was determined using a vanado-phospho-ammoniummolybdate (PO4 (NH4)3 VdO3 NH.16 MoO3) method (WHO, 1978). Total K concentration: It was measured using Flame photometer after samples were digested with nitric acid (HNO3) and perchloric acid (HClO4) (WHO, 1978).

3.5. Method of Data Analysis

All data collected from primary sources were entered into a Microsoft Excel worksheet and transferred to SPSS version 20 for analysis. The waste generation rate of the respondents was calculated by dividing the total solid waste collected to the numbers of days over which the waste had been collected and total number of family members.

The results were presented using descriptive statistics such as frequency, percentages, tables and figures. Thus, the Liner regression analysis were employed to know the influence of socioeconomic factors on waste generation rates and the relationship between the variables, with the proposition that socioeconomic factors can affect and associate with the daily quantity of solid waste generated by households. Therefore, six resident's parameters: monthly income, family size, education level, occupation level, age and sex were considered for the analysis.

4. RESULTS AND DISCUSSION

4.1. Socioeconomic Characteristics of the Respondents

The sex characteristic of HH respondents in the study area are presented in Table 2. Of the 132 respondents, 63 (47.73 %) were males while 69 (52.27 %) were females. Besides this, out of the total study population about 50.0 % of the respondents were in the age group 30-40 years.

In the present study, positive correlation (r=-0.3561, P=0.000) was found between household waste generation and the sex of the household head.

Women take greater responsibility of taking care of the home and the health of the family members and can be considered as waste managers (Bernache, 2003).

Socioeconomic data analysis showed that those respondents who were unable to read and write accounted for 30(23.5%) generated 14.49 kg/hh/week or 2.07kg/hh/day solid waste while respondents with elementary and junior education accounted for 52(39.4%) generated 12.31 kg/hh/week or 1.75kg/hh/day solid waste. Those respondents who had high school education and Diploma level education constituted 40(30.3%) %) generated 8.23 kg/hh/week or 1.17kg/hh/day solid waste and the remaining 9 (6.8%) generated 6.22 kg/hh/week or 0.88kg/hh/day solid waste respondents had higher level of education. However, there was a significant negative correlation ($r = -0.051$, $P < 0.05$) between household waste generation and the education level.

The low educational background of the respondents influences their participation and handling of solid waste management.. So, the waste generation will be low. However, the generation of packing waste may be higher in case of a fully employed family as they have less time to prepare food. So, number of educated households has negative relationship with total quantity of solid waste generated.

The more a family is educated and aware of the negative consequences of improper solid waste management, the more it recognizes the importance of effective solid waste management. According to Chen *et al.* (2015), the level of education of the household on daily waste management has a negative effect on the rate of household waste generation. Monaravi *et al*. (2012) concluded that education was negatively correlated with household solid waste generation.

The result obtained from the study area agree to the result reported in Bahir Dar town, (Kassahun Tassie Wegedie, (2018) in Haramaya town, (Bulto, 2017) and the result reported in Chiro town, (Najib, 2019).

The various age groups involved in solid waste generation, ranging from 20 to 70 years old. According to the current findings, households with age group of less than 30 (15.2%) generated 6.82 kg/hh/week 0r 0.97 kg/hh/day solid waste, age group 30 – 40 (50 %) generated 11.35 kg/hh/week 0r 1.62 kg/hh/day solid waste, age group 40 – 48 (19.7 %) generated 13.12 kg/hh/week 0r 1.87 kg/hh/day solid waste, age group greater than 48 (15.2 %) generated 11.67 kg/hh/week 0r 1.66 kg/hh/day solid waste. However, in this study, there was significant Negative association between household generation and the age of the household head ($r = -0.352$, $P < 0.05$). The present finding demonstrated that the age of the household head within 40-48 years generates the most solid waste. According to (Soukopov'a *et al*., 2017), elderly people reaching the end of their working lives or nearing leaving generated the greatest solid waste due to a variety of activities.

The monthly income of the households was estimated by questioning the individuals about their asset. Table 2 shows that majority of the respondents 51.52% had low monthly income of below 1500 Ethiopian Birr and generated 8.23 kg/hh/week 0r 1.17kg/hh/day solid waste and 49(37.12%) of respondents earned middle monthly income between 1501-5000 Ethiopian Birr and generating 10.1 kg/hh/week 0r 1.44kg/hh/day solid waste. The remaining 15(11.36%) of the respondents earned high monthly income above 5000 Ethiopian Birr and generating 27.03 kg/hh/week 0r 3.86kg/hh/day solid waste. There for Increase in income is expected to increase the demand for convenience factors and services embodied in commodities. The correlation between household waste generation and monthly income had shown a positive significant connection ($r = 0.4849$, $P< 0.05$).

This finding is in agreement with (Mazlan *et al.*, 2019), who found a strong positive correlation between household income and solid waste generation ($r=0.96$, $p<0.05$). In Awaday town Banaberu (2012) found a positive correlation between household income group and waste generation rate ($r = 0.468$; $p = 0.53$).

The sign of the coefficient is expected to be positive for total quantity of waste generated. Consumption increases as income increase In line with this, the result reported in Bahir Dar

town, (Kassahun (2018), Hoornweg and Bhada-Tada (2013) reported that the economic status of a country is reflected in SW composition produced that means in high income countries the fraction of organic waste is comparatively low as compared to the low-income countries. Similarily, El-Salam and Abu-Zuid (2015) showed that education level, poverty, population growth and high urbanization rates affect the efficient waste management of developing countries.

The sample household respondents had different occupations: traders, farmers, civil servants and daily laborers (Table 2). About 48(36.4%) generated 12.40 kg/hh/week or 1.77kg/hh/day solid waste of the respondents were traders, 29(22%), 10.27 kg/hh/week or 1.46kg/hh/day solid waste of the respondents were farmers, and 28(21.2%), 9.76 kg/hh/week or 1.39kg/hh/day solid waste of the respondents were civil servants. Daily laborers constitute 27(20.5%) solid waste of generated 10.88kg/hh/week or 1.55kg/hh/day. The occupation of the family had a non-significant negative correlation ($r = -0.0465$, $P < 0.05$) with household waste generation.

The result of the survey showed that 35(26.5%) , generated 9.6 kg/hh/week or 1.37kg/hh/day solid waste of the respondents had less than three family members,39(29.5%), generated 9.87 kg/hh/week or 1.41kg/hh/day solid waste of the respondents had between 3-5 family members, 40(30.3 %) , generated 11.70 kg/hh/week or 1.67kg/hh/day solid waste of the respondents had between 5-7 family members and 18(13.6) , generated 15.05 kg/hh/week or 2.15kg/hh/day solid waste of the respondents had greater than seven (>7) family members, respectively**.** Larger size household are believed to produce more waste compared with small size households ($r=0.1324$, $p>0.05$)

Therefor the majorty of the respondents had between 5-7 family members 40 (30.3%) respectively. therefor the positive coefficient on households famil size, at 5 percent level of highly significance, indicates that holding all other variables constant, large family are generating more solid waste than the small size family. Then the result obtained in the town was similar to the result reported in Haramaya (Bulto, 2017), and Bahir Dar towns (Kassahun Tassie Wegedie, (2018).

The number of persons in a family is related to the amount of food wasted per person (Canali *et al.* 2014). Because of its influence on eating and consuming habits, household size (HH) is associated with solid waste output (Liu *et al*., 2019). Larger size household are believed to produce more waste compared with small size households. According to a study conducted in Awaday town (Banaberu, 2015), the generation of HH waste is positively correlated with family size ($r = 0.879$; $p = 0.05$), indicating that families with more members generate more solid waste per day.

4.2. Existing Households Solid Waste Management Practices

4.2.1. Type of Temporary Storage Materials

The majority of households 39.4% stored their solid waste in plastic bag (madaberiya). Whereas 18.2**%,** 1.5% and 18.2% of the HH stored solid waste in sack, in basket and in hole and 22.7% of HH had no storage materials respectively

4.2.2. Sorting System of Solid Waste

The Solid waste separation practices of the respondents, only 3% of the sample said they separate, the rest of household respondents, 97% did not sort their waste. This might be due to different reasons in the study area. Some of these are, lack of spaces for separation, the households cannot see the importance, cannot have enough money for buying separated containers, separation consumes time,. This result shows the absence of separation and treatment of wastes like many other towns of developing countries.

The result obtained from the present study was similar to the reported in Chiro town, (Najib, 2019), Haramaya town, (Bulto, 2017), Jimma town (Melaku, 2008).

4.2.3. Disposal Places

The common disposal places used by the respondents were drainage line (22%), road side (19.7 %), open space (32.6%), river (12.1%) and burning place (32.6%). Finally, it was observed that there was no proper solid waste management and no clean landfill at all in the Melka Rafu town. As a result, the majority of the households dispose their wastes at open spaces and all of the disposal places in the Melka Rafu town were illegal sites.

Therefore, the total sampled 132(100%) households practice illegal solid waste disposal, this indicates uniform households who receive service from the municipality disposed wastes illegally. It has been observed and concluded that still open dumping of waste is the most prevailing activity practiced by residents of Melka Rafu town and these makes high probability of environmental pollution, breeding grounds of insects, pests and infectious diseases and also produce toxic gases, which spread odor around the dumping places and block drainage channels.

The result obtained from the present study was similar to the result reported in Haramaya, (Bulto, 2017).and in Chelenko towns (Zewdu Kebede, 2017).

4.2.4. Burning of Waste at Household

The majority of households surveyed (75%) burn solid waste on open spaces. Survey result showed that 2.3% of the respondents said they burned solid waste daily, 28 % said they burned solid waste weekly 47.7% of the respondents said they burned solid waste monthly, 22% were not burning soilid waste generated from the house. Monthly burning is the most common as many households clean up their home gardens during the end of month. Waste burning by households mainly includes paper, plastics and yard (grass) wastes.

Therefore, the result shows that agree with the result reported in Haramaya (Bulto, 2017).and Bahir Dar towns (Kassahun, (2018).

4.2.5. Composting

Survey result indicated that 10.6% of the sampled households currently undertake home composting, 1.5% of the households showed interest to use composting in the future and 87.9% of the households showed no interest in composting solid waste. According to the Melka Rafu town environmental protection, plans are underway by Melka Rafu town municipality to start composting as an alternative to transporting solid wastes to disposal site.

The lack of knowledge and experience appears to be the underlying factor for low interest in composting waste. The composting of solid waste is one of the sustainable ways of managing it if a large fraction of the waste is organic in nature. Therefore, composting is one of the best ways to manage solid waste. The high organic fraction and high moisture content of household solid wastes of Melka Rafu town make them suitable for producing good compost.

4.3. Household Solid Waste Generation Rate

The household solid waste generation rate of various income groups throughout the study period was indicated in the Table 4. The average waste generation rate was 0.246 kg/cap/day in the low-income group, 0.258 kg/cap/day in the middle-income group and 0.66 kg/cap/day in the high-income group. Similarly, the daily solid waste generation rate per household by weight for the low-income, middle income and high-income group was 1.176 kg/HH/day, 1.443 kg/HH/day and 3.863kg/HH/day, respectively.

The result obtained from the present study 1.58kg/HH/day and 0.304kg/cap/day was to some extent similar to; 0.304kg/cap/day result reported in chiro town, (Najib,2019), (0.143Kg/ca/day**)** reported in Jimma town (Mekonnen, Dereje, (2017), (0.253 Kg/capita/day) reported in Debre Birhan town**,** (Kebede, Asmamaw, Tadesse Lelago, Takele Gezahegn, TufaKolola, and Wendwesen Dibekulu, (2017), (0.47 kg/capita/day) results reported in Sodo town, (Goa, Endrias, and Solomon Sorsa Sota., (2017).

But much lower than the approximate waste generation rate of the sub-Saharan Africa which **is** 0.65 kg/capita/day (World Bank, (2014), and that of Addis Ababa town which is 0.5 Kg/capita/day (Desta, Hayal, Hailu Worku, and Aramde Fetene, (2014)

Table 4. Average generation rate (kg/HH/day and kg/capita/day)

Income level	No of HH	Family size	Ave Family size	Total Amount in kg	Kg/HH/day	Kg/cap/day
High Income (>5000)	15(11.4)	87	5.8	57.94kg/day	3.863kg/hh/day	0.66kg/cap/day
Middle Income (b/n 1501-5000)	49(37.1)	274	5.6	70.70kg/day	1.443kg/hh/day	0.258kg/cap/day
Low Income (< 1500)	68(51.5)	325	4.8	80kg/day	1.176kg/hh/day	0.246kg/cap/day
Total	132	686	5.2	208.64kg/day	1.58kg/hh/day	0.304kg/cap/day

Source: field survey, 2022

Finlay, the average generation rate of solid waste in the study area was 1.58 Kg/HH/day and 0.304kg/cap/day. The solid waste generation rate found in the town was similar to the result

reported in Chiro town (0.304kg/cap/day) (Najib, 2019), but higher than Haramaya town (0.274 Kg/cap/day) (Bulto, 2017), Jimma town (0.157 kg/cap/day) (Melaku, 2008), Hosa'ina town (0.17kg/person/day) (Abiot et al., 2012). In contrast, the value in the present study is much lower than the rate reported for Aweday town (0.85 kg/person/day) (Beneberu, 2011), the sub-Saharan Africa (0.65 kg/capita/day) (World Bank. 2014) and that of Addis Ababa, (0.5 Kg/capita/day) (Desta, Hayal, 2014). The World Bank Report also revealed that the actual per capita rates are highly variable, as there are considerable differences in waste generation rates across countries, between cities, & within cities.

The reason for the variation of waste per capita quantities between the towns and cities might be the living standard and lifestyle of inhabitants in consumption pattern, population and location of the regions, waste management habit and other considerable factors of the regions. Moreover, Hoornweg and Bhada-Tata (2012) showed that generation rate of urban solid waste is influenced by many factors such as level of economic development, cultural norms, geographical location, energy sources, and climate (environmental conditions).

Table 5. Total household solid waste generation rate per day, per week, per month, per year, per HH/day and per cap/person/day in Melka Rafu town

Income level	No of HH	Family size	T/amount in kg/day	kg/HH/ week (kg)	kg/HH/ month(kg)	kg/HH yr(kg)	kg/HH/ day (kg)	kg/cap/day (kg)
High	15	87	57.94	405,58	1,738.2	21148.1	3.863	0.66
Middle	49	274	70.70	494.9	2,121	25,8055.	1.443	0.258
Low	68	325	80	560	2,400	29200	1.176	0.246
Total	132	686	208.64	1,460.48	6,259.2	76,153.6	1.58	0.304

Source: field survey, 2022

4.4. Physico-Chemical Composition Characterization of solid waste

4.4.1. Physical Composition of Household Solid Waste

Solid waste sampled from the households had eighty (8) sub-fractions (Table 6). Accordingly, yard waste constituted 69.13kg (33.29%), food waste 40kg (17.82%) and manure. 34kg (15.81%). Similarly, studies conducted at Haramaya and Aweday, eastern part of Ethiopia also showed that largest portion of household solid wastes is yard wastes (Beneberu, 2011; Basha, 2017). They noted that large generation of yard waste was resulted mostly from the sharp and significant increase in chat leaves on a daily basis due to high chat consumption habit of the people in the area.

The proportion of household ash waste of the study area is also relatively high. This waste 29kg (14.29%) by weight.. This is because majorities of the communities use biomass as a major energy source. About 79.5% of the studied households use biomass energy that contributes to generate high amount of ash. Around 83.3% respondents were also had only traditional kitchens in which biomass materials is mostly used as sources of energy, which also generate smaller amounts of ashes. Study in Jimma town showed that the ash accounted for 21.5% by weight ranking high among solid waste components (Melaku, 2008).

Plastic waste constitutes 28.76kg (13.53%) by weight of the total waste generated. This waste is a serious problem of the study area. From personal observation, it was found in huge numbers and changes everywhere across the town. After used for short period, people threw it everywhere they like in the town. This attitude has greatly caused the plastic waste problem in the town. The open disposal site and surroundings of the town are being polluted particularly by plastic bottles and plastic bags (*festal*). On the down-side, unselective disposal of plastic materials also poses major environmental burdens including visual intrusion in the town which contributes to the clogging of drains of ditches, threat to environmental pollution as well as significant human and animal health impacts.

Figure 4. Plastic wastes disposed broadly across illegal disposal areas of the Melka Rafu town
Source: field survey of observation, 2022

Food wastes were also produced in substantial (large) amount, accounting for a gradually big proportion of the waste stream. This waste was the most dominant type of the household solid waste next to yard waste, with weight 40kg (17.82%). The proportion was smaller when compared with that reported in other studies. For example, food waste accounted 36.7% by weight in Hosa'ina city (Abiot *et al*., 2012), 59.17% in Arada Sub-city, Addis Ababa (Yitayal, 2005) and 47.26% in Adama town (Lemma, 2007). But it was very large compared to report for Aweday town 3.16% (Beneberu, 2011).

The emerged difference might be due to the lifestyle, standard of living and consumption level (habit) of households, seasonality of foods, or technological advances in different regions of the study areas. For example, greater affluence can pose the people to have a lot of money and a good standard of living. This people have more purchasing power which enables them more than what they actually need and fail to consume all that they affluently have. This can change food waste generation rates and its composition.

The quantities of food waste can also be increased during the growing seasons of vegetables and fruits. Technological advances such as development of the food processing industry have a significant effect on food waste generation. The use of more raw food of fruits and vegetables than the processed can increase food waste quantity. Manure is also other important element in the residential solid waste stream next to Food with 34kg (15.81%) by weight and it

was a proportion type of the waste stream in the town. Likewise, ash Plastic waste constitutes Paper, metals & glass were the less in amount among waste fractions in terms of their weight, which were accounted 29kg (14.29%), 28.76kg (13.53%), 3.25kg (2.26%) 3kg (2.26%) and 1.5kg (0.75%) respectively.

Table 6. Description of household solid waste Composition (types)

No	Type of waste	Total GR of SW in kg/day	GR of SW in kg/cap/.day	GR of SW in kg/HH.day	%
1	Manure	34	0.049	0.257	15.81.
2	Food waste	40	0.058	0.30	17.82
3	Yard	69.13	0.10	0.52	33.29
4	Ash	29	0.04	0.21	14.29
5	Metal	3.25	0.004	0.024	2.26
6	Glass	1.5	0.002	0.011	0.75
7	Paper	3	0.004	0.022	2.26
8	Plastic waste	28.76	0.04	0.21	13.53
	Total	208.64	1,460.48	6,289.2	100

Source: field survey, 2022 NB: total HH is 132 and total family size is 686

In Melka Rafu town, households solid waste is also composed of both biodegradable waste fractions constituting food 40kg(17.82%), yard 69.13kg(33.29%) ,and manure 34kg(15.81%) and non-degradable waste includes plastic 28.76kg(13.53%), ash 29kg (14.29%), glass 1.5kg (0.75%), metal 3.25kg (2.26%) and paper 3kg (2.26%).

The residential biodegradable organic wastes in the study area were the dominant component of waste stream, made up of 143.13kg (66.92%) by weight. This was followed by the non-biodegradable inorganic waste types such as glass, plastic, metal, ash and paper which comprised of 65.51kg (33.09%). Similarly, studies showed that low-income and middle-income countries have a high percentage of organic matter in the urban waste stream, ranging

from 40 to 85% of the total (Hoornweg and Bhada-Tata, 2012). Cointreau (2006) also reported that in developing countries a large part of the solid waste flow is organic, decomposable wastes, which originate from households.

Biodegradable organic composition of household waste in low, medium and high-income countries has been estimated to be consists of 40 to 85, 20 to 65 and 20 to 30% respectively (INTOSAI, 2002). Waste in developing cities generally has a high organic content (more than 50%) and a low energy value (CPHEEO, 2000).

Biological treatment processes such as composting and bio gasification are thus well suited (IGES, 2001) for such wastes. Therefore, presence of significant amount of biodegradable organic parts in sampled waste indicated that the organic fraction of the solid waste can be reprocessed in to valuable resources.

Generally, classification of residential solid waste components (types) from study area resulted in different composition values. Studies also showed that the quantity and component composition of solid waste are heterogeneous and vary. Physical composition of the waste varies not only from city to city but even within the same city, as it depends on factors such as the nature of local activities, food habits, cultural traditions, socio-economic factors, developmental level, climatic conditions, and seasons (Takele, 2004; Chattopadhyay *et al*., 2009; Monavari *et al.*, 2011)

Moisture Content of Solid Waste

The moisture content (MC) of the organic waste ranged from 45 % to 65 % with the mean value of 55.7%. This average value is a little higher than the average value of 54% and less than 59% which were reported for low-income and high-income households, respectively (Mohapatra, 2013). However, it is lower than the mean values of the result by Topanou (2011) from his study in Calavi City in Benin, West Africa in which the MC of waste for low, medium and high-income household groups were reported as 73.4± 1.45%, 70.16 ± 1.53% and 57.41± 2.30% respectively.

The emerged differences may be due to nature of waste or climate condition. The mean value falls within the range 40-80% reported for developing countries (Cointreau, 1982; Vogeli,

2007). (INTOSAI (2002) reported that relative MC of household waste in low, medium and high-income countries are 40 to 80%, 40 to 60% and 5 to 20%, respectively.

4.4.2. Chemical Composition of Household Solid Waste

The pH value for composite samples were analyzed, the mean value of solid waste is 6.77 This indicates that the pH values of composite sample are within the standard limits of compost 5.5-8.5 as reported by (Rawat *et al*. 2013). In line with this, similar pH value ranges on MSW composts were reported by (Holmer, 2002).

The mean value of electrical conductivity is 5.99 ds/m3; moreover, this value was within the recommended range (2-6 mS/cm) for composting by (Bordna Mona, 2003). However, high salinity levels (when suspended solids Concentrations are greater than 10-15) can be toxic to plants (Travis *et al*., 2003). Solid waste compost contains large amounts of organic matter and nitrogen content in both organic and inorganic forms. The inorganic nitrogen pool of MSW compost represents a small fraction of the bio available nitrogen, while most of the nitrogen is set up in the organic fraction. On average, MSW compost may contain 0.7 to 1.8 % N on a dry weight basis (Abebe, 2006).

Total organic carbon (TOC) values obtained in this study also ranged between 28.35% to 42.39% with average mean value of the result was 35.83% (Table 7). The result indicated that average value of organic matter was in the range of standard value (>30) of biodegradable waste suitable for composting process (Zucconin and deBertoldi, 1987). This value is lower than the mean value of 60.91% reported for high (63.33 ± 1.85%), medium (66.66 ± 1.73) and low (52.73 ± 2.06) living standard of household groups (Topanou, 2011). The difference may be due to nature or organic matter content of solid waste fractions used for the samples

The results showed that the total N, P and K contents in the RSW ranged from 0.05 to 240 ,0.4 % to1.1% and 0.6 % to 1.7% with the mean of 1.35%, 0.46% and 0.58%, respectively (Table7).

The mean value of N content of organic waste fractions is in the range of standard value (>0.05%) organic municipal solid wastes suitable for composting (Zucconin and deBertoldi, 1987). The mean values of P content in the present work were within the range of the standard

values 0.46% and K content was within the range of the standard values (0.58%) suitable for municipal solid waste composting materials (Moldes, 2007.

The results showed that C/N ratios of the raw organic waste were ranged from 16.53:1 to 50.83:1 with the average value of 28.72:1. The wide range and larger standard deviation of the C:N ratio for the decomposable organic waste materials indicates that there is higher variation of C:N ratio composition in the waste materials over the five days. In other words, the daily waste generated from HHs varies more from one day to another compared to the others physicochemical compositions which are, relatively, less variable.

The average C/N ratio in the study area was within the range value reported for high income (31:1) and low income (39:1) households (Mohapatra, 2013) and higher than 19.84:1 reported for high, medium (16.83:1) and 31.97:1 low-income household (Topanou, 2011). This may be due to nature of carbon and nitrogen content of solid waste fractions used for the samples.

The optimal C:N ratio of raw materials is between 25:1 and 30:1 although ratios between 20:1 and 40:1 are also acceptable. Where the ratio is higher than 40:1, the growth of micro-organisms is limited, resulting in a longer composting time. A C:N ratio of less than 20:1 leads to underutilization of N and the excess may be lost to the atmosphere as ammonia or nitrous oxide, and odour can be a problem (Misra *et al.*, 2003).

As a result, composting of organic solid wastes from residential source could be the most appropriate method of waste management in Melka Rafu town which has an important role in reducing the volume of solid waste going to disposal sites while minimizes environmental pollution. In addition to composting, utilization of biogas energy from residential solid waste through anaerobic digestion by microbial action also could help in designing another efficient waste management option in the study area.

Therefor the Results obtained from the present study show that the mean values of MC, OC, N, P, K, pH, EC, and C/N ratio of the waste composition were 55.7%, 35.83%, 1.35%, 0.46 %, 0.58%, 6.77, 5.99 mS/cm, and 26.54:1, respectively which indicates that the wastes are

suitable for composting and biogas energy recovery. But the wastes had high potassium (0.58%) content and low phosphorous (0.46%). These reports was similar to the previous study results reported in Haramaya town, (Bulto, 2017), and results reported in Jajura Town Of Hadiya Zone, (Melese ,2017).

Table 7. Recorded values of physicochemical compositions analysis of RSW for 5 days

Parameters	unit	Composition values over five days					Average	Recommended standard
		Day1	Day2	Day3	Day4	Day5		
1.Moisture content	%	46.6	62	53.3	60	56.6	55.7	45-65
2.Organic carbon	%	26.42	30.50	37.02	40.05	45.15	35.83	>30
3.Power of Hydrogen	_	6.85	6.70	7.05	6.90	6.35	6.77	5.5-8.5
4.Electrical conductivity	mS	4.75	4.95	6.35	7.25	6.65	5.99	2-6
5. Nitrogen	%	0.95	1.20	1.35	2.30	0.95	1.35	0.05/240
6.phosphorous	%	0.65	0.42	0.32	0.33	0.60	0.46	0.4-1.1
7. Potassium	%	0.60	0.40	0.63	0.67	0.62	0.85	0.6-1.7
8.carbon to nitrogen	%	27.81	25.42	27.42	17.41	8.55	26.54	<25

Source: Own result at HU laboratory (2022)

Note: the recommended standard values was cited by (International Journal of Environmental Sciences Volume 2, No 4, 2012)

4.5. Access to Solid Waste Management Services Melka Rafu

Concerning to solid waste management services, all the respondents 132 (100%) responded that there was no solid waste collecting, transporting and disposal services provisions in the town. Beside to this, the researcher also tried to verify the view forwarded by the respondent, through interview with key informants and it revealed that the town municipality focus only on Main In

Street(road) sweeping activities by seven (7) contract-based employees. They also added that there was no any single household had access to such services. In addition to this, information gathered through personal observation confirmed that the absence of waste management facilities and services in the town. Even the households stated that the municipality by itself

sometimes collects solid waste and burn in the surrounding of the community's living area. Such actions or failures of municipality really contribute a lot to environmental pollution and human health problems.

The street sweepers were also clean roads using hand sweepers and after cleaning they used wheel barrows to collect piles of solid wastes from roads, and then most commonly they burn it in gullies around roads. In major cities of most developing country collection service are generally inadequate and in efficient. According to WB (2004) report 350 % of solid waste generated remains uncollected. Likewise, in Ethiopia only 65% of the generated solid waste is collected and the reaming amount disposed illegally.

4.6. Awareness about Solid Waste Management

It's clear that the attitude and level of awareness toward solid waste management have projecting effect on solid waste handling and concept of solid waste minimization. Education is agate way to shape the attitude and raise awareness of the society. As a result, attending a formal education or related trainings will create a productive ground for the awareness creation activity. The survey data indicated that about 132 (100 %) of the respondents had awareness about waste management methods. Respondents who had awareness about solid waste and its management were asked how they got such information or orientation.

Table 8. The way how households got solid waste related information

No	Source of information	Frequency	Percent
1	Medias (from radio, TV, etc)	68	51.5
2	Kebele meeting	27	20.5
3	In health institution	7	5.3
4	Health extension workers	30	22.7
	Total	132	100

Source: field survey, 2022

As it could be seen from Table 10, about 68 (51.5 %) of the respondents got information from medias while the remaining 27 (20.5%), 7 (5.3 %), and 30 (22.7%) of the respondents were aware about the waste management information from kebele meeting, in health institution and health extension workers respectively. Furthermore, The Information obtained from the household's respondents the medias Are the first play great roll in arousing the community

about the impacts of waste on the health & The health extension workers are second play great roll in awaking the community through house-to-house education of the extension package.

However, significant number of respondents does not feel the problem from the waste since they have sufficient space to throw the waste either within their compound or outside. Beside to this, the researcher raises a question whether they participate in cleanup movement or not since from 2015 and the result indicate that 37 (28%) of the respondent didn't participate in any cleanup movement and 95 (72 %) of the respondents participate in cleanup movement which organized by kebeles on average one times a month. With respect to this, the researcher raised an open ended "why" question for the respondents who didn't participate in cleanup movement.

The reason for not participating in the campaign was lack of willingness and absence of such kind of movement in their locality. The result, moreover, also indicated that 37 (28%) of respondents do not know about the rules and regulations of SWM. This indicates that the ways they use to dispose waste suit them but which may not actually be suitable to the environment.

4.7. Respondents' Perception of solid waste management in the town

Solid waste management is a complex task which needs the collaboration and integration of many stakeholders. It needs collective responsibility so as to the sustainability of solid waste management system. Regarding to this, respondents asked 'who do you think is/are responsible to properly manage solid waste in Melka Rafu town?' Their response are indicated in table.

Table 9. Perception of the respondents about the responsible body for managing solid wastes in the town

No	Respondents' observation about manage SW in the town	Frequency	Percent
1	Government/ municipality	5	3.8
2	Households	26	19.7
3	All stakeholders (government/municipality, private sector and households together)	101	76.5
	Total	132	100

Source: field survey (2022)

As the information obtained from the household's respondents are clearly indicated in the above, 5(3.8%) of households included in the survey said that it is completely the government/ municipality responsibility to delivery SWM, whereas 26 (19.7%) selected for the households and 101 (76.5%) of respondents accepted that it is the responsibility of all stakeholders such as government, private sector and households together to deliver the SWM services.

As majority of the sample households who expected to manage municipal solid wastes is all stakeholders (government/municipality, private sector and households) of the town. This indicates as most of respondents were unable to take themselves as a major responsible body for poor management of solid wastes in Melka Rafu town.

Table 10. Status of respondents' stratification on the existing SWM practice of Melka Rafu

No	Status of respondents' stratification on the existing SWM	Frequency	Percent
1	Satisfied	45	34.1
2	Not satisfied	63	47.7
3	I don't know	24	18.2
	Total	132	100

Source: field survey (2022)

As indicated in Table 10, above, the majority 63 (47.7.%) of the respondents were not organized with the present door-to-door collection system of the municipality. while only 45 (34.1%) of respondents were satisfied by the current solid waste management services. The remaining 24 (18.2%) of respondents were said "I don't know". Therefore, it is possible to conclude from the table that, majority of the sample household 63 (47.7.%) of respondents Not satisfied by the existing SWM practice at Melka Rafu town. This may relate with spatial coverage of service provision of the municipality who gives not more attention for the town. because of its economic activities related to transport, trade and other public services.

The result obtained from the present study was similar to the result reported in Bahir Dar town, (Kassahun Tassie Wegedie, (2018).

4.8. Impact of Socioeconomic Factors on SW Generation Rates

The result of statistical analysis on these socioeconomic parameters of the study indicates that two of these characteristics i.e., household's monthly income, average family size of the households were the main influential factors that highly significantly affect the amount of household solid waste generation.

This finding is steady with the finding of Sankoh *et al*. (2012) and Eawag (2008), which discovered that household income and family size are widely accepted as important influences on solid waste generation. However, the other resident's socioeconomic factors (Level of Education, and occupation status) are found to have a statistically significant impact on the amount of waste generation rate. Table 11 shows that the influence of income levels, and Age group of the households and family size on household waste generation rate was highly significant at $P<0.05$ & $p<0.01$. This study revealed that high income earner households generated more waste than less income earners which highly significantly affect the quantity of waste generated.

The table indicates that the average waste generation rate has increased by 0.4849kg as household income increased by one unit. The study also showed that waste generation has increased by 0.13kg as number of family size increased by one unit. Thus, there exists a highly significant positive influence of income levels and family size, on per household waste generation in the study areas.

Therefor the results obtained from the present study was similar to the results reported in Bahir Dar town, (Kassahun Tassie Wegedie, (2018), and the results reported in Bale Robe town (Duguma *et.al*,2018).

Table 11. Regression analysis of socioeconomic factors impact on RSW generation rate

Variables	**Coef.**	**Std. Err.**	**t**	**P>t**	**[95% C.I]**	
					LB.	UB.
Gender	-0.3561*	0.0531	-6.71	0.000	-0.4612	-0.2937
AGroup	-0.3522*	0.0295	-11.92	0.000	-0.4107	-0.2510
FSrange	0.1324**	0.0270	4.90	0.000	0.0789	0.1858
LEducation	-0.0511*	0.0174	-2.94	0.004	-0.0855	-0.0167
Income	0.4849**	0.0401	-12.09	0.000	0.5643	0.4056
Occpn	-0.0465*	0.0232	-2.00	0.047	-0.0924	-0.0006
_cons	5.7113**	0.1776	32.15	0.000	5.3598	6.0629
Number of obs = 132		R-squared = 0.7291				
F(6, 125) = 56.08		Adj R-squared = 0.7161				
Prob > F = 0.0000		Root MSE = 0.29531				

Note: * and **: Significant at p<0.05 and p<0.001

The data illustrated on the figure above shows that the daily amount of waste generated from households was directly proportional to each of income. As the household income increased, the significant increase in amount of waste is also likely to increase. This confirms with the idea that waste quantities generated are directly proportional to household income level (Medina, 2013; Beneberu, 2011). MUDC (2012) also revealed that income is an important factor where the consumption of residents with higher income is comparatively higher than the lower income group with corresponding generation of relatively higher amount of solid wastes.

4.9. Factors Affecting SWM Practices in Melka Rafu Town

Understanding why absence of waste collection and disposal service provisions are essential to design effective solutions to address the problem. The data collected from sample households and interviews conducted with selected key informants in the town municipality, exposed the existence of the following major factors behind the existing poor waste management practice of the town.

4.9.1. Lack of Awareness

Effective solid waste management relies on the awareness level of the society. With this regard schubler et al (1996) said that the sustainability and effectiveness of municipal waste management system depend on the degree to which the served population identifies with and take ownership of the system and facilities. Nevertheless, the involvement and the sense of

ownership of the society depend on the awareness level of the society towards waste and waste related issues. According to Enger and Smith (2008), awareness should be created among residents to manage household refuse and educate them on the hazards that ill-disposed waste could pose to the environment and to them. There were no sufficient trainings and awareness creation activities implemented on SWM to community and stakeholders on one hand, and lack of effective coordination among the town municipality, community and stakeholders on the other hand. This shows that no attention paid by the concerned bodies to develop and implement such activities.

4.9.2. Poor Implementation of Rules and Regulation

Related to solid waste management, different rules and regulations were formulated though their implementations have been not that much effective. For instance, solid waste management standard of Ethiopia states that every household have the responsibility to keep the sanitation within 20 meters radius of the vicinity and 50 meters for the institution (MUDCUPSBB, 2012).

However, there was the problem of the implementation of those rules and regulations were in line with the awareness creation activity. Similarly, an effort to monitoring and controlling illegal waste dumper was weak in the town. The result of document review also indicated that this task is not a mandate of *kebeles*. However, the interview result indicated that there was no monitoring and controlling mechanism put in place to control the illegal waste dumping practice.

4.9.3. Lack of Adequate Human Resource

Lack of adequate and professional human resources to plan and implement ISWM is one of the serious problems facing the town municipality. There were not adequate human resources in terms of number and qualification. For example, the wide and very complex activities under the town municipality are not many employees.

Moreover, majority of staff members in the office were assign and responsible for duties not related with their backgrounds. This clearly indicates that capacity to plan and implement ISWM is weak as well as the consideration given to the sector by the higher officials and

management body of the town is very low. In line with this, lack of education opportunity, trainings, and awareness creating activities to enhance employees' performance capacities related to SWM also intensify the existing problems in the town.

4.9.4. Inappropriate Working Condition of Street Sweepers

In addition, lack of appropriate personal protective equipment's for street sweeping such as gloves, eye and face protection, footwear, etc. are challenges which were raised by workers and also confirmed by observing their situation when they were doing their day to day sweeping activities. They work in unhygienic (polluted) working condition some of them used mouth and hand cover they bought form their own pocket whereas the protection is not adequate and standardized. However, using proper personal protective equipment and sweeping materials can reduce health risk and it contributes to the professionalization of waste workers to alleviate social humiliation (stigma).

4.9.5. Financial Constraints

Shortage of budget is one of the major factors that limit the capacities of the sector to establish and provide waste management services in the town. Even though the annual budget allocated for such activities (street sweeping, for cleaning drainage lines, cleaning road etc) was become increasing from time to time, the nature and extent of the problem, population growth and the like had also shown increment.

As compared to high income countries, municipalities in low- and middle-income countries allocate the majority of their solid waste management budget to collection and transportation services. Final disposal costs are minimal because disposal is usually accomplished through open dumping (Djk, 2006). Above all it is a financial problem that made the town municipality not to give the necessary attention for SWM, because shortage of various social services (clean water, standardized road) made the municipality to give priority of fulfilling those services in the town.

4.9.6. Limited and Lack of Continuity of Community Participation

The level of community participation in both decision-making process and in cleaning up campaign activities was so poor sometimes few were participated voluntarily. Due to this,

local administrative bodies, especially kebele, use '*Aba genda'* means representative of the 'villages' to pass house to house to collect people.

Therefore, residents in the study area participate in these activities as a result of such measures. The interview made with the key informants in the town municipality also indicated that the causes for such limitations were, Lack of responsibility and commitments on the part of concerned public officials in coordinating and managing community participations in such areas and Lack of awareness among community members about the benefit of solid waste management both on human health and the surrounding environment. Therefore, it can be concluded that weak participatory approach of the town municipality is put its own impacts on community's participation in SWM activities at a town level.

4.9.7. Lack of Stakeholders and Private Sectors Participation

According to the discussion made with selected key informants, there was poor stakeholders' and private sectors participation in decision making process, waste collection and dumping service provision and financial support to improve waste management system in the town. They also added that the causes for limited participation of these bodies were lack of experience to participate stakeholders and more dependent on regular budget for expenditures to manage waste. Participatory strategy must consider the role of private sectors and stakeholders.

In spite of the apparent advantage of participatory approach to SWM, it is fair to say that participation of stakeholders' and private sectors was quite limited in the town. Daniel, 1999 stated that municipal governments are usually the responsible agency for solid waste collection and disposal, but the magnitude of the problem is well beyond the ability of any municipal government. They need help. In addition to other levels of government, businesses and the general community need to be more involved in waste management. More and more, governments are realizing that they cannot handle waste management alone.

4.10. Impact of Existing Waste Management Practice in the Town

Environment and human healthy are certainly interlinked and health environment are essential to the health and well – being of the community. Based on this, to identify the main impacts of the existing SWM practice of the town, open ended questions were forwarded to the households and interview was conducted with selected municipal experts. Accordingly, the following impacts were identified and summarized below: Access to waste collection, transporting and disposal services is important as a health and development issue at the town and local levels.

However, absent to such services in Melka Rafu town, resulted in prevalence of the residents to sanitation related diseases, particularly, wastes generated from residential areas are disposed on open spaces, in an uncontrolled manner and this allow free access to waste pickers, animals and flies, and often produce irritating odor and unpleasant landscape in the town. As a consequence of economic growth and increase in population, the volume of waste generated in many Ethiopian towns is increasing from time to time.

Therefore, if the waste generated is not handled and disposed properly, it will negatively impact the health and productivity of the public and environmental protection. Solid waste which is not handled and disposed properly will cause various problems on the densely settled urban population. Improper municipal solid waste disposal and management causes all types of pollution: air, soil, and water. Indiscriminate dumping of wastes contaminates surface and ground water supplies. In urban areas, municipal solid waste clogs drain, creating stagnant water for insect breeding and floods during rainy seasons (Sandra, 2006). The survey results also confirmed that solid waste thrown into floodways was clogging waterways and deteriorating.

5. CONCLUSIONS AND RECOMMENDATION

5.1. Conclusion

Solid waste management is in disasters in many towns of developing countries. Although waste management is one of the important mandatory functions of municipalities, this essential service is not efficiently and properly performed by the concerned bodies of Melka Rafu town in particular. Presently, substantial household solid wastes are being generated daily dumped along roadsides and into open areas, posing adverse impacts. Consequently, while walking across the town, inadequate solid waste management is observed through accumulation of waste particularly packaging materials like plastics and papers on the road, open lands, in drains and other disposal areas, which in turn results in sanitation, social and environmental problems in the town when disposed of improperly

As a result, the study was conducted in Melka Rafu town for the duration of a week using the solid waste and socioeconomic characteristic data extracted from selected households as the baseline information for characterization of solid waste composition and generation rates in the town. The study has shown that the daily per capita (kg/cap/day) and per household (kg/HH/day) generation rate were estimated to be 0.304 kg/cap/day and 1.58 kg/HH/day, respectively. About 208.64kg/day of total solid waste were produced daily by households of the town and annually from the entire population of the town, respectively.

The RSW of Melka Rafu town were further separated into eighty (8) various sub-fractions. The residential solid waste by weight based percentage composition were yard waste 69.13kg(33.29%) ,food 40kg(17.82%), manure 34kg(15.81%) plastic 28.76kg(13.53%), paper 3kg(2.26%), ash 29kg(14.29%), glass 1.5kg(0.75%), and metal 3.25kg(2.26%) of the solid waste fractions, yard waste formed the highest fraction (33.29%) followed by food (17.82%) and manure (15.81%). Similarly, the result of this study showed that the biodegradable organic waste which was the dominant component of waste stream; the non-biodegradable inorganic solid waste were accounted to about 66.92% and 33.09 % respectively.

The study indicated that solid waste generation is highly dependent on population of the study area. Furthermore, analysis of waste generation projection and trend for the Melka Rafu town showed that solid waste generation rate was rapidly increasing with population growth. The

population of the town was increasing extremely every year and so does its waste generation. This trend should call for the planning of sustainable solid waste management options in the town.

Physico-chemical analyses of household solid waste showed that the waste had average of moisture content of 55.7%, pH 6.77, electric conductivity 5.99mS/cm, carbon/nitrogen ratio 26.54:1, organic carbon 35.83%, nitrogen1.35%, phosphorous 0.46% and potassium 0.85%. The study also shows that household solid waste is suitable for composting because of the dominant biodegradable organic waste materials with acceptable moisture content, pH, electric conductivity and carbon to nitrogen ratio compositions in the analyzed solid waste samples.

The amount of waste generation from residential source in the study area is closely linked to socio-economic parameters of household. The findings of this study shown that the household waste generation in Melka Rafu was significantly affected by household family size and monthly income at $P<0.05$. It also had strong positive relationship ($p<5\%$) with household income and family size and weak relationship with age, education sex and occupation of households. As the household economy grows and the population becomes denser, the substantial increase in amount of waste generated is probably the most obvious change. The study showed that the households that have larger incomes and more family members generate more waste than their complements.

Moreover, the responsible body involvement on the solid waste management particularly from collection area was less and an integrated with society. Most of the respondents (97%) told that they did not separate Solid Wastes properly. Similarly, the majority of the household's respondents answered that they didn't understands about waste separation. But, the only (10.6%) of the household's respondents were used compost from their biodegradable solid wastes to use as fertilizers for agricultural purposes, but the remaining part of the household's respondents (87.9%) did not use compost. This may be due to lack of awareness among the respondents.

According to field observation and respondent information most of the solid waste collection and transportation activity of the town is carried out by door to door types of collection methods. But, door to door solid waste collection and transportation process was not properly

managed because the study result from field observation showed that solid waste collectors are not paid regularly by the respondents, due to this they did not work effectively.

It is concluded that the residential solid waste generations of Melka Rafu town is increasing in line with growth in socio-economic parameters, which is significantly affected by household family size and monthly income, which is mainly the function of wealth status and number of household family members. The more economic wealthy and the higher percentage of town's population, the more amount of solid waste produced. The great majority of waste generated in the town is mainly biodegradable organic consisting mostly of yard, food and manure solid waste materials. Consequently, the high compostable organic content of the waste materials with acceptable ranges of physico-chemical composition indicates that residential solid waste can be profitably converted into useful products like compost and biogas energy, required for the contribution of appropriate waste management technology in the town.

5.2. Recommendation

The conclusion of the study showed that the existing municipal solid waste management practices and the generation rates in town were very poor and the services given by the concerned people and institutions were inadequate. Therefore, to improve this, the following recommendations were drawn:

- ✓ Municipality of the town should organize unemployed at small enterprise and provide solid waste management in the town
- ✓ Temporary storage disposal sites and permanently land filling place should be provided to the residents
- ✓ Awareness campaigns about the adverse effects of haphazard solid waste disposal are essential.
- ✓ The town administration should provide the proper primary collection protective equipment for workers
- ✓ Community should have the effort and out looks of solving the problems of handling solid waste generated at home rather than externalizing.
- ✓ Motivates or encourage the private sector and social clubs to involve in solid waste management activities particularly in the solid waste collection, transportation and disposal services.

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APPENDIX part A

Questionnaire Prepared for Sample Households in Melka Rafu Town.

My name is Adem Mume. I am a master's student in Haramaya University studying in Department of Environmental Sciences and Management. I was conducting my Thesis on the Household Solid Waste Generation Rate Determination and Its Management Practices in Melka Rafu Town, Kombolcha District of East Hararghe Zone, Ethiopia. Therefore, I kindly request the response to fill this questionnaire and I was assure that all the information filled is confidential and were used only for purpose of the research alone. I thank you in advance for your cooperation and time.

Instruction

1. This questionnaire is to be filled by household head / the wife can substitute her husband.

2. Dear enumerator, please circle the letter representing respondents answer from given alternatives and or write their answer for the rest of questions requiring quantitative and other responses.

Name of household heads: _____ sex___ Age____

Address: Kebele: _____ House No._____

Questionnaire for socio- economic data collection from household

1 Sex of the household head (1) male (2) Female

2. Age of the household head (1) 16 – 20 (2). 21 – 30 (3) 31 – 40 (4) 41 – 50 (5) >50

3. Level of education of household (1). Not to read and write (2) 0-4grade (3) 5-8grade (4) 9-10grade (5) 11-12grade (6) Diploma and degre

4. Family size of the household (including yourself) (1) Male ___ (2) Female ____ Total ____

(1) 1- 3 (2) 4- 6 (3) 7- 9 (4). Greater than 9

5. Average Household's monthly income (in birr):

(1) Less than 1500 (2) 1501-5000 (3) greater than 5000

6. Occupation (Hujii): (1) Trading (2). Farming (3). Government employee (4). Daily laborer (5) Others

7. Duration of stay in the town (1) < 2 years (2) 2-5 years (3) 6-10 years (4) Above 10 years

8. Respondent marital status (1). Married (2). Single (3). Divorced (Kan hike) (4). Widowed (kan jala dute)

9. Type of Kitchen:(1) yes (2) No if yes what type of kitchen

(1) Modern (2) Traditional (3) both Modern and Traditional (4) No kitchen

10. Toilet facility (1). Modern (2). Traditional (1). Private (2). Public (3) No Toilet

11. Source of energy? (1). Electricity (2). Electricity and kerosene (3). Charcoal, wood, paper, dung (4). Electricity, Charcoal and kerosene

12. Do you have container for temporary storage of solid waste at your home? Households' Solid Waste Management Practices (1) yes (2) No

13. If yes, what type of temporary storage container? (1) Basket (2) Sack (3) plastic bags (4) Prepared hol (5) No storage system (6) writes, if any _____

14. Does your household practice waste separation/sorting? (Households' Solid Waste Management Practices) (1). Yes (2.) No

15. Households' Solid Waste Disposal Ways at the town? (Households' Solid Waste Management) (1) On river bank (2) On the Road side (3) drainage lines (4) open space (5) buring place

16. The way how households got solid waste related information (Awareness about Solid Waste Management Practices)? (1) Medias (from radio, TV, etc) (2) Kebele meeting (3) In health institution (4) Health extension workers

17. Did you make compost at your home (use sold waste as soil fertilizer)? (1) Yes (2) No if yes (1) currently undertaking home composting (2) Have interest (3) Have no interest

18. Access for house-to- house collection and disposal service by formal waste collector?
(1) Yes (2) No if yes (1) Regular (2) Irregular and inadequate

19. If yes by whom? (1) Municipality (2) Private agency

20. Do you burn solid waste? (1) Yes (2) No

21. If yes, the frequency of burning? (1) Daily (2) Monthly (3) Weekly (4) once in two or three day's

22. The collection and disposal services provided by the municipality or private agency?

. (1) Satisfied (nugamachisa) (2) not Satisfied (nu hin gamachisu) (3) Don't know

23. Who do you think is responsible to properly manage solid waste in Melka Rafu town?

(1) Municipality (2) households (3) All stakeholders (government/municipality, private sector and households together)

24. Do you think the major sources of the solid waste are generated from which area?

(1) Commercial sources (2) HHs/Residential sources (3) Institutional sources D) Others_____

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APPENDICES part B

Interview for Head of Municipality Dear respondent, I would like to inform you that this questionnaire is for academic purpose only. My name is Adem Mume. I am a master's student in Haramaya University studying in Department of Environmental Sciences and Management. were conducting my Thesis on the Household Solid Waste Generation Rate Determination and Its Management Practices in Melka Rafu Town, Kombolcha District of East Hararghe Zone, Ethiopia. Therefore, I kindly request the response to fill these questionnaires and I will assure that all the information filled is confidential and will be used only for purpose of the research alone. I thank you in advance for your cooperation and time.

Name _____ Position _____ Sex___ Qualification _____

1. Current population of the town _____

2. Total number of housing units _____

Residential houses---------- Non-residential houses----------

3.The existing technical arrangement of SWM system of the town?

_____

_____

4. Is there private agency that is involved in the solid waste management of the town?

(1)Yes (2) No

5. If yes what is the responsibility and actual practice of this agency?_____

6. What are the challenges for proper management of the solid waste of the town?

_____

7. Vehicles or trucks for collection and disposal service? (1) yes (2) No if yes

(1) Owned by municipality (2) owned by private specter

8. Estimate of solid waste generated by of household? (1) Yes (2) No if yes

(1)Daily (2) Weekly (3) monthly (4) Annually

9. Quantity of solid waste collected daily? (1) Yes (2) No if yes (1) by Municipality (2) by Private

10. Is there centralized composting of SW in the town? (1) Yes (2) No

11. Number of shared containers (community bins) for temporary storage (primary collections) (1) yes (2) No

12. Is there house-to-house collection service by the municipality? (1) Yes (2) No

13. Frequency of collection and disposal service provided by the municipality?

(1) Daily (2) Once every two or three day's (3) Once a week (4) once a month

14. Are the collection and disposal services cover all corners of the town? (1)Yes (2) No

15. Willingness of the residents to pay to have clean environment? (1) Yes (2) No

16. How many public bins are there along the major roads for control of littering? _____

17. Is there a problem in using these bins? (1) Yes (2) No If yes what type of problem?

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APPENDICES part– C

The field observation cheek list of Melka Rafu town

Name of the researcher_____ Date_____

1. Is their dumping site was properly? (1) Yes (2) No

2. Most of the time solid waste was disposed in dumping site? (1) Yes (2) No

3. House-to-house collection and transportation service by the municipality? (1) Yes (2) No

4. The people disposed solid waste properly? (1) Yes (2) No

5. The municipal solid waste storage container putted every were in the town? (1) Yes (2) No

6. Is it seen peoples putted solid waste in the derange? (1) Yes (2) No

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APPENDICES - D

Interview questions for kI from the municipality of Melka Rafu J town Dear respondent, I would like to inform you this Interview questionnaire are considered to an academic purpose for the fulfillment of Masters Degree in Environmental Sciences and Management. The main objective of this study is the Household Solid Waste Generation Rate Determination and Its Management Practices in Melka Rafu Town. Therefore, your responses are very important enable to successful assessment of the study to analysis and conclusion of the research. So, you are kindly requested to give your response. Please be informed that your response is keptin confidential. I would like to thank you for your polite responses.

Part one: back ground of respondent general information

A. Sex Male_____ Female_____

B. Responsibility in your office _____

C. Work experience on the present work _____

Part two: Instruction: in order to answer the following question, put aright sign in the boxes that located in front of your choice.

1. From which source are mostly municipal solid wastes generates?

A. Institutional sources B. Commercial sources C. Residential sources D. household sources

2. Is there any labor in charged with daily removal of solid waste in your town ?

_____

3. If your answer to question number 2 is yes, do you think there are enough labors in your town? They are effectively working? Explain. _____

4. If your answer to question number 2 is no, what do you think are its negative impacts SWM activities of your town? _____

5. How many landfill sites Melka Rafu town have? _____

6. Is the landfill site protected (Fenced etc)? If no, what do you think for next?

_____

7. Are there Roads cleaning organizations in the town? _____

7.1 If your answer to question number 7 is yes, which are organized by whom?

_____

7.2 If your answer to question number 7 is yes, how many Roads cleaners are theirs in the Melka Rafu town?

_____

8. Do you think the existing municipal solid waste management of the municipality is satisfactory? _____

8.1 If no, what measures do you think should be taken to improve?

_____._____

9. How many have lifting tracks Melka Rafu town?

_____

9.1 It is functional now?_____

9.2 If No, what means does the municipality use? _____

10. Does the municipality practiced to create awareness about M SW and its positive and negative consequences to the community? If no‟ what you think for futures?

_____

11. What actions does the municipality take on individuals who improperly dispose Waste?_____

12. Do you think existing financial, technical, material and manpower support for the control of MSW of Melka Rafu town satisfactory?

_____

13. If no, in your opinion, what must be done to improve solid waste management of Melka Rafu Town? _____

14. Do you have access of solid waste collection, transportation and disposal from municipality? If no, how do you manage solid Melka Rafu wastes?

_____

15. Do you think the (MSW) municipal solid waste disposal sites used for disposal of solid wastes generated from different sources are properly selected? If no‟ what you think for next?

_____

APPENDICES part E;

Data sheets for household waste generation rate record

Amount of waste generations (Kg) over days

Name of household (code)	Day 1	Day2	Day 3	Day 4	Day 5	Day 6	Day 7	Tot al	A

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Kutaa 1ffa

Gaafileen Kun Kan Qopha'eef Abbooti Warra Magaala Malka Rafu Keessa Filatamaniif.

Anii Maqaan Koo Barataa Adam Mummeetin Jedhama.Kaniin Irra Dhufe Yuuniversiitii Haramaya,Damee Kollejii Qonna Fi Saayinsii Egumsa Naanno Yoo Tahu, Waniin Dhufeefis Xalaya Qorano Digri Lammaffa Koo Qopheesu Waaniin Barbadeefi.Sababnii Ijoon Qoranno Tanaatis Bulchinsa Magalaa Malka Rafuu Keesati Haala Kosii(Qushaasha) Ittin Sasaabaniifi Itti Baleesan ,Akkasumaas Amala Phisicala FI Kemikaala Kosii Keesa Jiru Qorachun Adda Basun Barbachisa Wan Ta'efi.Kanaafu Namooni Gafi Kana Gafatamtan Amantuman Ragaa Sirri Ta'e Akka Nuuf Kenitan Kabajan Isiin Gafana.Namooni Raga Kana Gutuu Irratis Yero Kessan Nuuf Kennitani Degarsa Barbaachisu Nuuf Gotanis Galatoman Isiniin Jedha.

Qajjelfama

1. Gaafileen Kun Guttamu Abba Warra / Hadha Warra Bakka Abba Warra Butteeni

2. Gaafilee Kanaa Yero Guttan Filanno Kenamee Abba Warraatif Sirriti Adda Baasun Deebi Inni Kenne Irrati Maraa /Jala Mura(Circle) Godha.

Maqaaabbawarra/Hadhawarra_____

Saala_____ Umri_____Aradda_____ Lakk/Manaa____

Gaafilee Ragaa Sassaabuf Qopha'ee Abba Warraa /Hahda Warra Malkaa Raafu

1. Saala Abbaa Warra/ Hadha Warra? (1) Dhira (2) Dhala

2. Umri Abbaa Warra/ Hadha Warra? (1) 16 – 20 (2). 21 – 30 (3) 31 – 40 (4) 41 – 50 (5) >50

3. Sadarkaa Barnoota Abbaa Warra/ Hadha Warra ? (1). Kan Dubbisuufi Barressu Hin Dandeenye (2) Kutaa 1-4 (3) Kutaa 5-8 (4) Kutaa 9-10 (5) Kutaa 11-12 (6) Diplomaa Fi Digrii.

4. Baayina Maati (Abbaa Warra/ Hadha Warra Dabalatee) ? Dhira___ Dhala____ W/G_____(1) 1- 3 (2) 4- 6 (3) 7- 9 (4). Kan 9 Ol Qabu

5. Galii Abbaa Warra/ Hadha Warra Ji'aan Argatu Qarshidhan (ETB) ? (1) 1500 Gadii(Low Income) (2) 1501-5000(Middel Income) (3) 5000 Olii(High Income)

6. Guyyati Kossi (Qushaasha) Hangam Takka Gadi Nayxaa(Facaafta) ?

(1) 1kg (2) 1.5kg (3) 2kg (4) 2.5 (5) 3kg (6) 4kg (7) 5kgisa Oli

7. Gosa Hujii Abbaa Warra/ Hadha Warra Hojatanii ?): (1) Daldala (2).Qonnaan Bulaa (3) Hojataa Motummaa (4).Hojataa Guyya (5) Kan Biro Yoo Jiraate

8. Haala Turtii Abbaa Warra/ Hadha Warra Magaala Malka Raafuu Kessa Turaani ?

(1) Wagaa 2 Gadi (2) Wagaa 2-5 Years (3) Wagaa 6-10 (4) Wagaa 10 Olii

9. Haala Fudhaa Fi Heerumaa ? (1) Kan Fudhe (2) Kan Hin Fudhin (3) Kan Hike (4). Kan Jala Dute

10. Gosa Alawada/Kushina Inni Qabu? (1) Kan Ammayaa (2) Kan Aadaa (3) Kan Ammayaa Fi Kan Aadaa (4) Kushina Kan Hin Qabne

11. Gosa Mana Fincaanii Isaan Qabani ? (A) Niin Qaban (B)Hin Qaban Yoo Kan Qabaatan Ta'e ? (1)Kan Dhunfa (2). Kan Ummataa/Waliini (3) Kan Ammayaa (4) Kan Aadaa

12. Madda Humna Anisa (Energy) Essa Argatu ? (1). Electricity Irra (2). Electricit Fi Gassi Irra (3) Cilee(Kasala), Mukka Qoraani , Waraqa , Dikee Hori Irra (4). Electricity, Cilee (Kasala) Fi Gassi Irra

13. Meesha Yeroodhaf Kossi (Qushaasha) Itti Waliitti Qabdan Nii Qabduu ? (1) Eyye (2) Mitii

14. Yoo Gaafi 11 Eyye Jettan Gosa Meesha Akkamitii Qabdu ? (1) Zanbiila (Basket) (2) Joniyya (Sack) (3) Luqaa Lastika (Plastic Bags) (4) Boolla Kosii (5) Iddo Ittii Kufnu Hin Qabnuu (6) Kan Biro Yoo Jiraate Haa Bareefamu

15. Kosii (Qushaasha) Yero Manaa Keessa Hartan Gosa Gosaan Addaan Baftani Nii Hartani ?

(1) Eyye (2) Mitii

16. Magaala Malka Rafu Kessati Kosii(Qushaasha) Iddo Akkamitii Gadii Nayxaan(Facaaftan) ?

(1) Bo'oo(Ya'aa) Bishaani Kessati (2) Karaa Makinaa Irati (3) Ya'aa Galanaa Kessati (4) Bolla Dhunfa Kessati (5) Iddo Waliti Qabanii Itti Gubaniti Harra

17. Akka Magalaa Malka Rafuuti Hubanno(Information) Wa'ee Kosii(Qushaasha) Fi Naanno Keessan Qulqulleesu Essarra Argatu) ? (1) Radi'o Fi Tv Irra (2) Yero Wagahi Aradda Irrati Gonu /Aradda Irra (3) Bufata Fayya Irra (4) Extenshini Fayya Irra

18. Naanno Mana Kessaniti Kosii(Qushaasha) Irra Komposti(Dike) Nii Hojatu ? (1) Eyye (2) Miti

19. Yoo Gaafi 17 Eyye Jette) ? (1) Yero Amman Tana Hojachati Jirtu (2) Fulaa Duraaf Hojachuf Fedhi Niiqabdu (3) Hojachuuf Fedhii Hin Qabdani

20. Bulchinsi Magaala Malka Rafuu Tajaajila Mana Manaati Demudhan Kosii (Qushaasha) Isinira Nii Fudhani (Nii Guraa) ? (1) Eyye (2) Miti

21. Yoo Gaafi 19 Eyye Jette ? (1) Dhabataadha(Yero Hunda Itti Fufinsaan Isinira Nii Fudhani (2) Ciccitaadha (Itti Fufinsan Nurra Hin Fudhan) Nama Hin Gamachisu

22. Yoo Gaafi 19 Eyye Jette Enyuutu Isiinirra Fudhee Gadii Naquti Jira ? (1) Bulchinsa Magalatii (2) Dhabata Dhunfatii

23. Hojatoota Kosii (Qushaasha) Issinirra Fudhani Gadii Naqaniif Kafalti Mallaqa Nii Kafaltaniifi ? (1) Eyye (2) Mitii

24. Yoo Gaafi 22 Eyye Jette Ji’ati Qarshi Meeqa Kafaltanif ?

(1) 15-25 Birr (2) 26-35 Birr (3) 36-45 Birr (4)) 46-50 & Abov

25. Kosii(Qushaasha) Naanno Mana Keesaniti Walitti Qabdani Niigubdu ? (1) Eyye (2) Miti)

26. Yoo Gaafii 22 Eyye Jette Yero Akkam Gubdanii ? (1) Guyyati (2) Torbaaniti

(3) Ji’ati 4) Guyya Lamati Yokin Guyya Saditi Yero Tokko

27. Tajaajili Bulchinsi Magalaa Malka Rafuu Kosii(Qushaasha) Isinirra Guruu Irrati Qabu Maal Fakaata ? (1) Nugamachisa) (2) Nuu Hin Gamachisu (3) Hin Beknu

28. Magaala Malka Rafuu Itti Fufinsaan Qulquleesu Keesati Enyutu Dirqama Qaba ?

(1) Bulchinsa Magaala Malka Rafu (2) Abboti Mana Yokin Hawaasa Magalatii Hunda (3) Qoda Fudhatoota Hunda (Mootuma , Bulchinsa Magala, Dhabile Dhunfaa Fi Hawaasa Magalati Hunda

29. Maddi Ijon Kosii(Qushaasha) Magalaa Malka Rafuu Eessa ?

(1) Magala Dha (2) Hawaasa Magalati Irra (3) Dhabilee Motummaa Irra (4) Kan Biro

APPENDIX: Tables in Appendix

Table 2 Percentage and frequency distribution of Socio-economic characteristics of HH participated in this study

Variables	Category	Freq	Percent
Gender of household	Female	69	52.3
	Male	63	47.7
Education level of the respondents	Degree	9	6.8
	elementary and junior	53	39.4
	high school education and Diploma level	40	30.3%
	unable to read and write	30	23.5
Income Level of the HH	High income	15	11.4
	Low income	68	51.5
	Middle income	49	37.1
Occupational status	Civil servants	28	21.2
	Daily labor	27	20.5
	Farmer	29	22
	Trade	48	36.4
Marital status of the HH	Divorced	7	5.3
	Married	101	76.5
	Single	9	6.8
	Widowed	15	11.4
Source of Energy for HH	Charcoal, Wood, Dung &Paper	105	79.5
	Electricity	5	3.8
	Electricity, Charcoal & Gas	20	15.2
	Electricity gas	2	1.5
Age group of HH	Less than 30 years old	20	15.2
	Between30-40 years old	66	50
	Between 40-48	26	19.7
	Above 48years old	20	15.2
range of family size	<3	35	26.5
	3-5	39	29.5
	5-7	40	30.3
	>7	18	13.6
Duration of stay HH	2-5yrs	24	18.2
	6-10yrs	41	31.1
	>10 yrs	67	50.8
	Total	132	100

Table 3. Solid Waste Management Practices of Melka Rafu Town

Variables	Category	Frequency	Percent
Temporary Storage Materials of SW	No	30	22.7
	Yes	102	77.3
	Total	132	100.0
Type of Temporary Storage Materials	Basket	2	1.5
	hole	24	18.2
	No storage materials	30	22.7
	plastic bag	52	39.4
	sack	24	18.2
	Total	132	100.0
Sorting System of SW	No	128	97.0
	Yes	4	3.0
	Total	132	100.0
Disposal Place	Burning pl	18	13.6
	drainage line	29	22.0
	open space	43	32.5
	River	16	12.1
	Road	26	19.7
	Total	132	100.0
Time to Prepare Compost	Currently Undertaking	14	10.6
	Have Interest Future	2	1.5
	Have no Interest	116	87.9
	Total	132	100.0
Time of burning solid waste	Daily	3	2.3
	Monthly	63	47.7
	No burning	29	22.0
	Weekly	37	28.0
	Total	132	100.0

Source: Field Survey (2022)