FACULTY OF PUBLIC HEALTH

DEPARTMENT OF ENVIRONMENTAL HEALTH SCIENCE AND TECHNOLOGY

# MUNICIPAL SOLID WASTE CHARACTERIZATION, GENERATION RATE AND WASTE TRANSFORMATION THROUGH VERMICOMPOSTING IN ASOSSA TOWN, BENISHANGUL GUMUZ REGION WESTERN, ETHIOPIA

BY

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# MUNICIPAL SOLID WASTE CHARACTRIZTION, GENERATION RATE AND WASTE TRANSFORMATION THOUGH VERMICOMPOSTING, IN ASOSSA TOWN, BENISHANGUL GUMUZ REGION WESTERN, ETHIOPIA

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## Abstract

An increasing in urban population and changing of life style or cultural behavior leads to rising need for consumption materials and raise in the amount and composition waste being generated daily by each house hold. The increasing amount of municipal solid waste generated as well as improper characterization and disposal of solid waste have high social, economic and environmental impacts.

The aim of this study was to assess the current solid waste generation rate, characterization and compositions of HHSW and waste transformation through vermicomposting. Across-sectional study was conducted by using quantitative approaches and purposive sampling technique was employed to select (ketena) and systematic sampling was used to select sefer in each ketene and house hold. For 213 household surveys, sample size was determined using a population proportional formula. The sampling of HHSW was conducted for consecutive 8 days and experimental set up for vermicomposting were preformed May-July/2018. Also some material used for conduct research were plastic bins, weight balance, safety gloves, and laboratory instrument (oven, polyethen, dissectors, soil crusher, spectoro photometer, flam photometer, ASS, balance pH meter etc).

The results showed that solid waste generation rate of Asossa town was 0.144kg/cap/day and the compositions by weight of the household solid waste were, Food waste (35.95%), Ash and dust (18.8%), Leaves (12.69%), Wood (4.94%),Plastic, Catha edulis, Paper, Grasses, Glasses metal and Textile account only 8.15%, 4%, 3.35%,8.19%, 0.40%, 0.76% and 2.65% waste respectively. About 88% and 12% HHSW was bio-degradable and non-biodegradable respectively. And mean results analysis of physicochemical parameters for mature or stable compost found within the range of acceptable limits set by most countries guidelines except C: N. Therefore, the researcher concluded that the town municipal should developed an appropriate house hold SWM technology and implement to properly manage this high amount of solid waste through vermicomposting technology. So the researcher recommended that by using E. fetid a worm it can be produce good quality vermicompost in short period of time and use as organic fertilizer to remediate soil.



**Key words**:-Generation rate, Characterization, Composition, Vermicompost, E.fetida worm, waste transformation, Asossa town.

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## List of Acronyms and Abbreviations

| | |
|---|---|
| AAI | Asossa Agricultural Institution |
| B/G/R/S | Benishangul Gumze Regiona State |
| CL | Confidence Level |
| CSA | Central Statistical Agency |
| gm | Gram |
| HH | House Hold |
| HHSW | House Hold Solid Waste |
| ISWM | Integrated Solid Waste Management |
| JU | Jimma University |
| K | Potassium |
| Kg | Kilo gram |
| L | Litter |
| MC | Moisture Content |
| MSW | Municipal Solid Waste |
| MSWM | Municipal Solid Waste Management |
| NGO | Non-Governmental Organization |
| OC | Organic Carbon |
| EC | Electro Conductivity |
| C:N | Carbon to Nitrogen ratio |
| Fe | Iron |
| Zn | Zinc |
| Cu | Copper |
| Mn | Manganese |
| P | Phosphorus |
| pH | PH meter |
| SW | Solid Waste |
| SWM | Solid Waste Management |
| TN | Total Nitrogen |
| UNEP | United Nation Environmental Program |
| WHO | World Health Organization |

# CHAPTER ONE

# 1. INTRODUCTION

## 1.1 Background of the Study

The human activities which take place in this world create waste. The wastes could be both solid and liquid types; and the way they are going to be handled, stored, and disposed can expose the environment and public health to risks (Hailemariam & Ajeme, 2014; Baba Ymi,& Dauda, 2009).

Solid waste is defined as material which no longer has any value to its original owner, and which is discarded. The main constituents of solid waste in urban areas are organic waste (including kitchen waste and garden trimmings), paper, glass, metals and plastics. Ash, dust and street sweepings can also form a significant portion of the waste(Haile, 2011).

The composition and the quantity of MSW generated from the argument on which the management system needs to be planned, designed and operated. The differences in the MSW characteristics indicate the effect of urbanization and development. In urban areas, the major fraction of MSW is compostable materials (40-60%) and inert (30-50%). If the economic status of society decreases the relative percentage of organic waste in MSW is generally increases. So, urban households generates less organic waste than rural household (Regassa, et al, 2011). Today the work of solid waste management issue are coming a serious global agenda for environment. Because rapidly increasing of population growth rate, consumption frequency and the development of urbanization. This results the increasing amount of waste in the world (Miezah, 2015). Particularly the rapid growth of urbanization and population have direct relationship with the high generation rate of municipal solid waste city/ nation (Englehardt, 2014).

In developing countries like, Ethiopia the amount of solid waste generation depends on the number of the population and the socio-economic level that each household obtain. Also the composition of generated waste is quietly different as the result of life style, seasons, demographic, geographic and local legislation impacts **(**Asmelash,et al, 2014). In Addis Ababa and other fast growing areas of the country the amount of solid waste have been increasing over time, largely attributed to rapid population growth rate and economic factors. For example the solid waste collection coverage in Addis Ababa is about 65%, and about 10%

is recycled. The rest about 25% often dumped in open spaces, ditches paying station and river banks (Assefa & Mohammed, 2017).

Solid waste management (SWM) is one of the critical challenges of developed and developing countries including Ethiopia. So if not properly managed it causes social, economic and environmental problems. Hence in developing countries only 30-50% of the waste generated is collected and managed properly. The rest is either incinerated or left to decompose everywhere or dumped on unregulated landfills, which is affected environment (Kassa, 2008; Korai, et al, 2016).

A solid waste management (SWM) activity includes the collection, storage, transportation, processing, treatment, recycling and final disposal of waste. To achieve the above stated means of management, all community members of a given geographical territory, have their own responsibility. But the degree of the responsibility is varies depending on the way of the town flows: either convectional based or community based approach(Hailemariam & Ajeme, 2014; Haile, 2011).

Proper manage of solid waste was helps to keep the environment and human health, as well as used to reduce high amount of waste problems through waste minimization, reusing and recycling of its components and converting the organic components of the waste into use full products, such as compost.

This can be achieved by converting waste in to(conventional composting and vermicomposting )(Georges, 2015)**.**For example Vermicomposting is simple environmental-friend technology that supports sustainable agriculture and waste management programs. The goal of vermicompsting are for increasing of earth warm number and weight of worms and convert the substrate martial into vermicompost in shortest time and highest recovery as possible(Elena, 2016).

Different substrates give different result on selected vermicomposting parameters. The substrate martial that feed to the earth worm has characteristics that are different from the characteristics of other materials and can influence differently the performance of worms. Because the efficiency of vermicomposting is affected by the bedding materials , worm and food source (Bharadwaj, 2010).

## 1.2 Statement of the Problem

The population growth and the rate of urbanization are alarmingly increasing throughout the African continent and thousands of tons of solid waste are generated daily in Africa (Sankoh & Yan, 2013). But the knowledge, financial capacity ,technology, culture, and the ways of understanding of the community required to properly manage solid waste are not adequately available (Padmavathiamma, et al, 2008).

Knowing of the data on solid waste generation rate and compositions in the town is used for designing and operation of solid waste management. For instance waste generation rates of developing countries are lower than developed ones and attribute to difference in technological advances and consumption materials. Cities like New York have generation rate of 18 liter/cap/day while most developing countries have less than 1 liter/cap/day (Kassie, 2016). And Per capita amount of waste generated in Ethiopia ranged from 0.17 to 0.48 kg/person/day for urban areas to about 0.11 to 0.35 kg/capita/ day for rural areas example, the Addis Ababa municipality of an average household solid waste per capita per day generation rate of 0.15kg/person/day. This is very small compare to about the per capita waste generation rate of 2.1kglperson/day in USA and other developed nations(Hiranmai, 2015) **.**

The main constituents of urban solid waste are similar throughout the world, but, the amount generated, composition and proportion constituent's deferent widely from country to country, from town to town and place to place depending on the level of economic status, geographical location, weather and social conditions.

Urban waste management is a challenge for city and urban governments in the developing world, because of poor infrastructure, bureaucratic competence, and limited finance and institutional capacity of the municipality. Municipalities throughout Ethiopia are facing these problems and a major challenge with solid waste collection and landfill management. For example in Addis Ababa 35 percent of solid waste generated in the city are not collected properly (African Bank, 2011) .

Improper waste management in the living areas causes, environmental pollutions such as water and soil pollutions) and peoples, and results a nuisance and foul-smelling pools and the possible spread of disease (Cheru, 2011).

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In Ethiopia, Horn of Africa, there are different organic wastes being produced annually by different activities like agriculture, agro industries, industries and municipal solid waste. The solid waste are being dumped or burnt without proper recycling. The capital city of Ethiopia, Addis Ababa produce 0.5kg/ca/day solid waste, includes organic and inorganic wastes and management of these wastes is difficult. For instance Jimma city produces a huge amount of waste that needs to be recycled (Getahun, et al, 2012; Dadi, Sulaiman, & Leta, 2012). They suggested that the source separated municipal solid waste can be composted and used as manure.

To handle or to manage this huge amount of solid waste are by using economically and environmentally sustainable solid waste management technologies is composting (UNEP, 2009). From composting technology vermicompost was one of the preferable technologies for managing solid waste. Because Vermicomposting is simple environment-friendly technology that supports sustainable agriculture and waste management programs. Therefore, gives two benefits-producing good qualities of organic fertilizer, and reducing the volume of organic waste by converting it in to bioactive rich soil fertilizer conditioner(Elena, 2016).vermicompost enriches soil with microorganisms, soils with vermicasts have roughly 1000 times more beneficial bacteria than soil without worm .

The vermicompost promotes plant growth from 50-100% over conventional compost and 30-40% over chemical fertilizers. Wastes are degraded by over 75% with the useful products, faster than conventional systems and compost produced are cleansed of harmful microorganisms and toxic substances, and enriched with nutrients and beneficial soil microbes(Elena, 2016).

Solid waste generation rate, characterization of solid waste at source and solid waste disposal would be the main challenges for the responsible body in Asossa town. Because the town is characterized by rapid population growth caused by natural increases and migration. Such increase in population and rapid development of the city has produced high volume, generation rate and composition of solid waste. But town municipal would not have data on them and technology option for reducing the amount and volume of waste. Due to this they simply disposed solid waste at unproved dumpsite and water ways (Drainage system), on open site near to residential area which adversely affect environmental friendless. And adversely affects environment, economy and social when it is not properly managed and disposed (Agwu, 2012) .

Therefore, this study is intended to fill the gap related to the amount of generation rate per capita per day (kg/cap/day), types of waste composition, how it transformed though vermicomposting.

## 1.3 Research Questions

1. What is the rate of household solid waste generation
2. What kind of solid waste composition was existed in Asossa town?
3. Does the characterized house hold solid waste were highly bio degradable or non-biodegradable?
4. Does the generated waste is suitable for recycling or reuse?
5. Is the decomposed vermicompost stable at 45 day?

## 1.4 Research hypotheses

The following hypotheses were then formulated according to the literature review:

- **Hypothesis one**

Generated and composition of HHSW is affected by increasing of population growth, economic level and industrializations.

- **Hypothesis two**

From bio degradable part of solid waste Food Waste can be used as a major feedstock in vermicomposting

- **Hypothesis three**

As decomposition time increase quality of Vermicompost increased.

**Hypothesis five**

Vermicompost, quality is determined by measuring physic-chemical parameters.

## 1.5 Scope of the study

The scope of the study is focused on determination of generation rate kg/cap/day, waste characterization, composition analysis, and finally to transform waste through vermi composting processing & determined the quality (stability) of vermicompst.

## 1.6 Significance of the study

The study is expected to have different significance:

- ❖ To provide data for municipal to used for planning appropriate solid waste management system, such as for designing landfills capacity or volume and kind or types of vehicle for solid waste collection and transportations.
- ❖ To provide information for municipality of the town with the Characterization of solid waste was pave the way for those interested to transform solid waste in to vermicompost.
- ❖ As sources of information about waste generation and type’s composition of solid waste at household level and the main influential factors with scientific evidence.
- ❖ The data used for bench mark for forthcoming interested researcher and NGO in the same or related topic, in Asossa town.

# CHAPTER TWO
# LITERATURE REVIEW

## 2.1. General condition of solid waste

Waste - according to UK environmental protection act (1990)"it is any substance which constitutes scrap materials, an effluent or other unwanted surplus arising from application of any substances or article which requires to be disposed of which has broken, worn out, contaminated or otherwise spoiled." Also code of regulation defined Solid waste is "any garbage, refuse, sludge, and other discarded solid materials resulting from industrial, commercial, agricultural operations, and community activities, but does not include dissolved materials" (U.S. Code of Federal Regulations(Code, 2012).

In Ethiopia according to the Federal Democratic Republic of Ethiopia (Federal Negarit Gazeta of) proclamation No. 543/2007 Solid Waste Management Proclamation "Solid Waste" means anything that is neither liquid nor gas and is discarded as unwanted(Federal Democratic Rebuplic of Ethiopia, 2007). These could be refuses from residential, commercial, or any institutes as yard sweeping, food remains, ash and chat leftover, saw dust, piece of wood papers, glasses, metals, batteries, plastic, grass, and vegetables, bone of animals, dead animals and other materials that cause poor environmental situation (Ayalew, 2014). Municipal solid waste (MSW) refers to materials discarded in urban areas for which municipalities are usually responsible for collection, transportation, and final disposal. And Municipal solid waste management - is an activity of planning and implementation of solid waste management components such as collection, transfer and transportation, recycling, resource recovery, and disposal MSW under jurisdiction of local government.

Solid waste is serious impact on environment and human health in both developing and developed countries. Many developing countries have recently started their municipal solid waste management practices. Improper solid waste management leads to problems that affect human, animal health and ultimately results in economic, environmental and biological loss (Fathi, et al, 2014). Developing countries have solid waste management problems different than those found in fully industrialized countries; because the composition of their waste is different than that of 'developed' nations. Generally, all low-income countries have a high percentage of compostable organic matter in the urban waste stream, ranging from 40-85 percent of the total (Kassie, 2016).

## 2.2 Source of solid waste

Based on source and types of municipal solid waste knowledge, along with data on the composition and rate of generation, is basic to the design and operation of the functional elements associated with the management of solid waste. So, Sources of solid waste categorized into: residential, commercial, institutional, construction and demolition, municipal services, treatment plant sites, industrial and agricultural (Hailemariam & Ajeme, 2014).The sources of solid wastes are dependent on the socioeconomic and technological levels of a society. Communities that live in rural area have known types and known source of solid waste (i.e. the wastes are more homogeneous). For example wastes from industrial and mining source are mostly homogenous. Urban communities (metropolitan cities) have many sources (The wastes are more heterogeneous) (Asfaw, 2007; Ayalew, 2014).

According to Nigatu Regassa reported (2011), the source of solid waste in Addis is 76% from household, 6% from street sweeping,9% from commercial,5% from industry,3% from hotel and 1% from hospital. Another study states that from the total waste generated in the Addis city, 80% by households 5% street, 1% industries, 12% commercial centers and 2% institutions (Ayalew, 2014); in Makurdia, Nigeria household waste stream contributes about 82% of the waste.fom this sources are food waste(left over) ash, wood, leave and floor sweeping and in Ibadan city of Nigeria contain 66.1% are domestic,20.3% commercial and 11.4% Industry from total generated solid waste (Baba Yemi, JO;Dauda, 2009) .There for in Asossa town Solid waste sources were mainly municipal serves. And this study only deals municipal services wastes, such as household solid waste

## 2.3 Composition of municipal solid waste

Composition is the term used to describe the individual components that make up a solid waste stream and their relative distribution, usually based on percent by weight (Zewdu & Mohammedbirhan, 2014). According to (Englehardt, 2014), the waste composition in developing countries is showed by the following characteristics as compared to waste from developed countries: density of 2-3 times, moisture content of 2-3 times, larger fraction of organic waste and a large fraction of smaller components

In developing countries for example Accra, Ibadan, Dakar, Abidjan, and Lusaka has municipal solid waste from those putrescible organic content ranging from 35-80% with general trend leaning toward the higher end of this range; plastic, glass, and metals at less than 10%; and paper with a percentage in the low 10s (Saidou & Aminou, 2015). And 35-70% of total municipal waste generated in large cities of developing countries was organic fraction of waste streams(Nielsen, et al, 1997), reported that in Beijing, the proportion of organic substances (food waste, paper, plastic, wood and fiber) accounted for 86% of total waste generated.

In Kenya, the composition of solid waste from low income areas of urban centers was reported as food (57%), paper (16%), plastics (12%), textiles (2%), grass/wood (2%), leather (1%), rubber (2%), glass (2%), cans (1%), other metals (0) others (4%) (Kariuki & Kinyanjui, 2016).

In Ethiopia the composition of solid waste showed similar trend with the other developing countries. For example according to (Assefa & Mohammed, 2017), the composition of municipal solid waste in Laga Tafo Dadi town is categorized broadly as bio-degradable account(food 76.5%,paper 4.75%, grass 6.37%, leaves 3.33 and wood 0.52%) and non bio-degradable accounted for 14.75% (plastic 9.5%,textile 0.98%, rubber 0.37%, metal 0.65% and glass 1.69%) and miscellaneous (diapers, medical waste and insecticide accounted 4.84%. Even in Ethiopia the composition of solid waste is varies from within one city. Such as Jimma town contains, 54%, 30% and 16% of the waste generated from the town is biodegradable, disposable and recyclable respectively(Padmavathiamma,et al, 2008).

Likewise 75.6% and 24.4% of solid waste composition in Dessie town were bio degradable and non-biodegradable respectively (Zewdu & Mohammedbirhan, 2014). Other studies by (Endrias Goa and solomon Sorsa, 2017) on dumping site of sodo town municipality contains high biodegradable parts (93.7%) from these highest proportional is food waste 81.9% the other composition of waste of total contains 9.1% of waste and the other non-biodegradable portion is very small which accounted (6.3% ).

Many study indicates bio degradable solid waste constituted major share of the house hold wastes generated in many Ethiopian cities. Therefore the city can transformed this waste by introducing an integrated urban agriculture that might convert this waste in to organic fertilizer through composting system. This providing job opportunity, source of income to young societies and the community, enhances urban agriculture practice (contributes for nutritious food stuff and healthy society), reduce the cost of waste transportation and contribute the clean environment and green town (Assefa & Mohammed, 2017).

## 2.4 Generation Rate and characterization of solid waste

### 2.4.1 Generation Rate of solid waste

According to (UNEP, 2009;Cheru, 2011), Generation rate refers to the "amount of waste disposed during a given period of time and the quantification of it involves different methods: by measurement at the point of generation, through use of vehicle survey and by examination of records at the disposal facility" and Waste generation*:* is an activity in which materials are identified as no longer being of value and are either thrown away or gathered together for disposal (Zewdu & Mohammedbirhan, 2014).

In the world most of the time the constituents of urban solid waste are similar, yet due to economic development social condition geo graphical location the quantity of generated waste, density and proportion of the constituents are vary widely country to country and city to city (Jerie, 2016).Another studies indicated in India also gross national economic development of developed and developing countries influenced generation rate (Jayakrishnan, Jeeja, & Bhaskar, 2013). And the higher the gross national product of a country result the higher the generation of waste. It means due to difference in level economic performance, waste generation rate of developed countries is highly greater than that of developing countries.

On the other hand, people's attitude towards waste can also conditioned solid waste generation rate in the form of their pattern of material use and waste handling, their interest in waste reduction and minimization, and the degree to which they refrain from indiscriminate dumping and littering(KASSA, 2008).

Based on the studies of (Jerie, 2016), daily per capita waste amount generated in developed countries ranges 1.43– 2.08 kg as compared with developing countries where the rate is 0.3–1.44 kg( Englehardt, 2014) reporting that in the United States of America, per capita waste generation varied from 1.22 kg/day in 1960 to 4.65 kg/day in 2000 and in some African cities, generation rates may range from 0.3-1.4 kg/capita/day. For instance solid waste generation rates average only 0.4 to 0.6 kg/person/day, as compare to 0.7 to 1.8 kg/person/day in fully industrialized countries. But the generation rate of solid waste is even lower in some African cities. For example (Regassa et al., 2011), reported that in Addis Ababa, people living in unplanned and poor housing conditions generate 0.15 kg per capital per day of solid waste generated.

Like as other country in Ethiopia the solid waste generation is also defer from one city to other city. Such as the solid waste generation rate of Jimma was 0.138 kg/cap/day and solid waste generation rate of Aksum and Shire-Endaslassie Towns were 0.54 and 0.49kg/cap/day respectively (Mekonnen, 2017;Asmelash Zewdu.etal, 2014). But there is no date and reliable data on generation rate kg/person/day, in Asossa town.

### 2.4.2 Characterizations of municipal solid waste

Characterization**:-**The determination of the physical, chemical, radiological, and biological properties of a pure substance, compound, or mixture to the extent necessary to support informed decision making (Alemayehu.B, 2004). There are four methods for estimating waste quantities and composition identified: direct sampling (also referred to as waste stream analysis and waste audits), material flow, surveying waste generators, and literature sources. But for this thesis the researcher was used direct sampling methods( Padmavathiamma, et al, 2008).

## 2.5 Factors that affect generation rate and composition of solid waste

There are several factors that influence the amounts of composition and generation rate of waste in urban areas. According to the studies of (Jayakrishnan et al., 2013) ,increasing of the population size of an urban area, population growth, living standards rates , per capita waste generation geographical location, energy source, and weather affects the solid wastes generated. According to (Baba Yemi, JO;Dauda, 2009), lack of advancement technology, facility separation at source, strength of policy for solid waste management and enforcement, environmental education and awareness are factors affecting solid waste generation and composition in Nigeria.

The quantity and categories of solid waste generation and composition also varies with socio-economic groups in which the high and middle groups take the lion share (Baba Yemi, JO;Dauda, 2009).

## 2.6 Effects and Impacts of Solid Wastes

If solid wastes are not managed properly there are many negative impacts that may result. In order to give more emphasis for the management work, one must have a good understanding about the effects and risks that may arise from improperly managed solid wastes (Jerie, 2016). The most important effects associated with uncontrolled solid wastes are; blockage of drains, which result in flooding and unsanitary, Flies and Mosquitoes breed, shelter for rats. Polluted water (leach ate) flowing from waste dumps and disposal sites can cause serious environmental pollution. According to (Hailemariam & Ajeme, 2014; KASSA, 2008), the major impacts associated with the solid waste generations are public health, aesthetic , ecological, land use, resources and economic concerns.

### 2.6.1 Associated with Public health

The concerns of public health are related primarily to the infestation of areas used for the storage of solid wastes with vermin and insects that often serve as potential reservoirs of disease. The practices of throwing wastes in to unpaved streets, road ways and vacant land leads to the breeding of rats, with their attendant fleas carrying the germs of disease that results disease outbreak. The most effective control measure for both fleas and rats is proper sanitation

### 2.6.2 Associated with Aesthetic

Aesthetic considerations related to the production of odors and unsightly conditions that can develop when adequate attention is not given to the maintenances of sanitary conditions. Most odors can be controlled through the use of containers with tight lids and with the maintenance of reasonable collection frequency.

### 2.6.3 Associated with Ecological

Ecological impacts, such as water and air pollutions, also have been attributed to improper management of solid waste. For example leach ate from dumps and poorly engineered landfills contaminate surface waters and ground waters as it may contain toxic elements such as Copper and arsenic etc and solid waste, effluent pollution turn to be serious handle to environmental wellbeing and goods and services are returned after use in to the environment as waste and emissions (Hailemariam & Ajeme, 2014).

## 2.7 Solid Waste Management

According to (Agwu, 2012),solid waste management is the process of collecting , treatment and dispose of solid wastes in such a way that they are harmless to plants, animal human and the ecology as well as the environment. Cornerstone of sustainable development is the establishing of affordable, effective and well suitable waste management practice in the developing countries. It must be further emphasized that multiple public health, safety and environmental co-benefits assure from effective waste management practices which strongly protect and improve the quality of life, environment and promote public health (Englehardt, 2014).

The legislation of MSWM is focused on protection of the health of the population, promote environmental quality, develop sustainability, and provide support to the economic productivity. To meet this goal, sustainable solid waste management systems must be applied fully by local authorities in collaboration with both the public and private sectors (Ozcan, et al, 2016). SWM is an increasing complex issue throughout the world, due to the dynamic nature of consumer/end user product, packaging materials, environmental regulation and public attitudes. In developed countries, the issue of SWM (collection, transportation and disposal) are well understood, accepted and workable (Ozcan, et al, 2016; Jerie, 2016).

Although, in developing countries the amount of solid waste generated in urban areas is low compared to industrialized countries, and MSWM is still inadequate and recent events in major urban cities have shown that the problem of waste management has become too complex to handle and has seen dwindling effort of cities authorities, federal governments, sate and professionals alike in addressing the issue (Kadafa, 2017).

Likewise, the Federal Democratic Republic Ethiopia has ratified several international conventions that have meaningful implication to solid waste management proclamation (No.513/2007 article 4 stated that each urban administration shall conformity with the relevant environmental standards, ensure that solid waste disposal sites are constructed and properly used. Moreover with objective to promote community participation in order to prevent the adverse effect and to enhance benefits result from solid waste. The solid waste management action plans designed and implemented at the lowest administration unit and they ensure community participation.

Accordingly, the objective of the proclamation to enhance at all level capacity to prevent the possible adverse effect s while creating economically, socially and environmentally beneficial assets out of solid waste management. However, due to low awareness level about the solid waste management, resources and implementation of proclamation most of the town of Ethiopia is severe physical or mental suffering from the adverse effects of improper management solid waste on urban areas (Jerie, 2016).

Municipal solid waste management is a global issue and has proven a key challenge facing in Africa. In developing countries, it is common for municipalities to spend 20-50 percent of their available recurrent budget on solid waste management. Yet, it is also common that 30-60 percent of all the urban solid waste in developing countries is uncollected and less than 50 percent of the population is served. In high-income countries, collection only accounts for less than 10% of the budget, which allows large funds to be allocated to waste treatment facilities". In most developing countries, open dumping with open burning is the norm (Kadafa, 2017).

More over for solving the community problems of SWM the best approach is integrated solid waste management. The idea behind ISWM is that combination of approaches can be used to handle targeted proportion of waste stream. During ISWM program the activities which have positive impacts on the development of waste management are source reduction, recycling, combustion and land filling. To reduce waste management problems at the national level most effectively, municipality and state must first considered source reduction or reducing the quantity of solid waste generated. Recycling of useful waste materials is the next most desirable approach. Finally composting, incineration and land filling complete the solid waste hierarchy (Alemayew.B, 2004).

According to European Union waste frame work directive (Zewdu & Mohammedbirhan, 2014),waste management hierarchical principle the most preferred options of the waste hierarchy format and will go down towards the least preferred options.

The most preferred options are the options having the best effects on the environment, which have been described here in the hierarchical

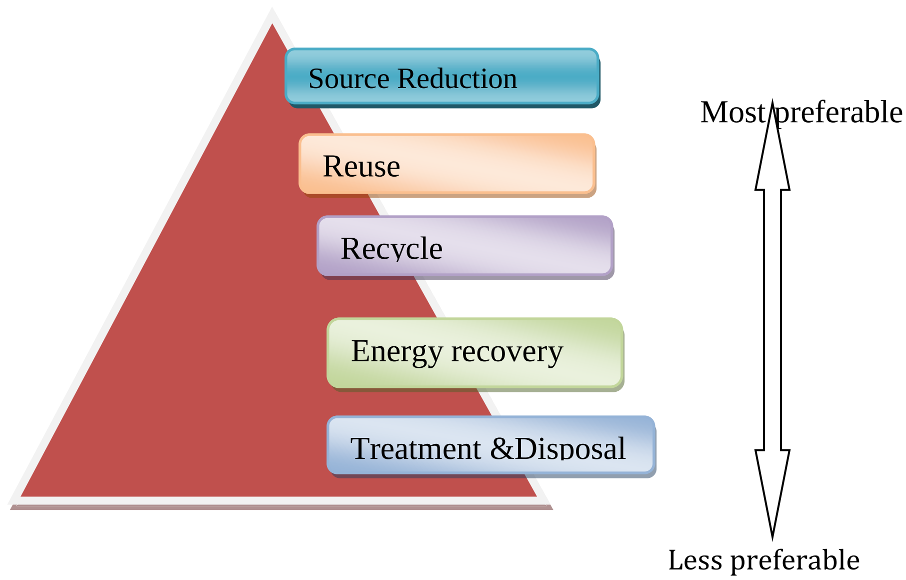


**Figure 1: Waste Management Hierarchy**

### 2.8 Solid Waste Management Technology Options

The solid waste that generated through the consumption of good, serve ices, development established of town and cities can be managed in different methods. The technology used for developing and developed countries, urban and rural population and industrial and residential areas are differing (ISO, 1995).

According to(Vikrant Tyagi, Solomon Fantaw1, 2016).States that for Action endorsed the idea of integrated solid waste management, for reducing of municipal solid waste by managed through several different practices, which can be modified to fit a particular need of society.

There are many technologies to manage solid waste, starting with reducing or preventing its generation through to reuse, recycling, recovery and finally residual management or disposal (Zewdu & Mohammedbirhan, 2014).

According to (UNEP, 2009), the most economically and environmentally sustainable solid waste management technologies are Incineration, composting and land filling.

#### 2.8.1 Modern Incineration

Incineration is the process of control and complete combustion for burning solid wastes. It leads to energy recovery and destruction of toxic waste, for example, waste form hospitals. The temperature in varies between $980^0$c and $2000^o$c. One of the most attractive features of the incineration process is that it can be used to reduce combustible solid waste by 80-90% from the original volume of solid waste. It may be possible to reduce the volume to about 5% or even less (Alemayew.B, 2004).

### 2.8.2 Land filling

Sanitary land filling is an acceptable and recommended method for ultimate disposal of MSW. It is necessary component of MSWM, since all other options produce some residue that must be disposed of through land filling. It involves placing of wastes in a large specially designed cavity, then covering them with soil. Daily cover of waste around landfill was prevents attraction of animal and insects. Federal law mandates many specific requirements for landfills, including that the bottom of the landfill be lined with more than one layer of impermeable materials (synthetic plastic and natural clay) to prevent the contamination of ground water by liquid leaching from the landfill( African development,Bank, 2011)

### 2.8.3 Composting

Composting has been defined (Yadav, et al, 2014) Composting is a biological process in which easily degradable organic matter (OM) is stabilized and converted by the action of microorganisms into a humus-rich product. Therefore, the final product is sufficiently stable for storage and application to land without adverse environmental effects. Composting has been regarded as an efficient and effective way to deal with the organic waste and to achieving 50% regional waste reduction goals. Therefore, MSW composting has been mostly encouraged for as a new environmental protecting standard in waste management system. Soil organic matter is used for increasing and sustains soil fertility, and hence it is suitable for crop production in agriculture. In addition to being a nutrient source for plant, it increases the physic chemical and biological properties of the soil.

Composting may be divided into two categories by the nature of the decomposition process. In anaerobic composting, decomposition occurs where oxygen is absent or in limited amount. The intermediate compounds which dominate in anaerobic process are an anaerobic microorganism which includes methane, organic acids, hydrogen sulphide and other substances. In the absence of oxygen these compounds accumulate and are not metabolized further. Many of these compounds have strong odors and some present phytotoxicity. As anaerobic composting is a low-temperature process, it leaves weed seeds and pathogens intact. Moreover, the process usually takes longer than aerobic composting. These drawbacks often offset the merits of this process, viz. little work involved and fewer nutrients lost during the process.

Aerobic composting takes place in the presence of ample Oxygen. In aerobic process organic matter was break down by aerobic microorganisms and produce carbon dioxide ($CO_2$), ammonia, water, heat and humus, the relatively stable organic end product. Although aerobic composting may produce intermediate compounds such as organic acids.

Composting is widely applied than other technologies, because of eco-computability, easy operational procedure as well as the generation byproduct(Municipal, 2018), and more flexible than anaerobic digestion and incineration interns of size, timeframe for planning and construction and easy for the investment. And the waste volume reduction is accounted as 50-85% (ISO, 1995).

## 2.9 Compost Quality

The quality and suitability of compost which can be used for agricultural application was depends up on physical, chemical and biological parameters such as maturity index, water holding capacity, PH,EC, organic Carbone, C:N ratio total and available nutrients, and the absence of toxic substance, pathogen and weeds.(G Kaosol, 2009)

In developing countries the MSW have high organic content which makes it an ideal for composting and the municipal waste streams also contain high quantities of glass, metals and hazardous substance ( Hartin and Crohn, 2007). Source separating the waste before collection is usually an environmentally and technically better way to improve the quality of the final compost. Source separation simply means putting waste out for collection in separate containers.

## 2.10 Vermi Composting

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. Segregation, decomposition and stabilization of the organic waste by biological action forms the basis of recycling through different natural processes (Alemayew.B, 2004).

Vermicomposting is becoming highly recommended technology for solid waste management strategy because it was mesosphelic processes by which worms are used to convert organic materials (usually wastes) into a humus-like material known as vermicompost. During vermicomposting, the organic waste is converted to a bio-fertilizer by earthworms' action over a certain period of time in a worm bin (Manyuchi, 2016) .

During the process of vermicompsting monitored parameters include pH and electrical conductivity, macro nutrients(P, K, Mg, Ca) and heavy metals( Fe, Cu, Zn and Mn) (Reddy, 2009).Vermicomposting technology is globally becoming apopular solid waste management technique and technology of bioconversion of organic waste in to bio-fertilizer due to earthworm activity. Vermicomposting technology is more preferable than other solid waste management technologies; due to it is economically feasible, easy to handle, low investment cost, Fridley environment, it is soil conditioner and easy to work.

## 2.11 Factors determining quality of vermicompost

### 2.11.1 Substrate (materials)

The quality of vermicompost is mostly depend on the types of substrate (raw materials) used for composting processes. For example cattle dung have been found to be yield most nutrient value of vermicompost by using Eisinea fetida worms (Pramanik, et al, 2007).

According to Pramanikstudy the vermicomposting of four (4) substrates viz. cow dung, grass, aquatic weeds and municipal solid wastes (MSW of the 'nutritional status & enzymatic activities' indicates cow dung recorded maximum increase in nitrogen (N) content (275%) followed by MSW (178%), grass (153%) and aquatic weed (146%) in their resulting vermicomposts over the initial values in their raw materials (Pramanik, et al, 2007). And according to Elena reports as high as 7.37% nitrogen (N) and 19.58% phosphorus as $P_2O_5$ in worm's vermicast. And exchangeable potassium (K) was over 95% higher in vermicompost. There are also good amount of calcium (Ca), magnesium (Mg), zinc (Zn) and manganese (Mn) (Elena, 2016). The materials which used to vermicompsting were selected based on the content of Carbone, nitrogen and C: N ratio contents. For instance adding the cow dung in the processes of vermicomposting set up was provide an extra supplement in nitrogen , phosphorus. And using cow dung for vermicomposting was accelerated nutrient contents (P,K and N) by 75% up to 95%.

### 2.11.2 Species of worms

Vermicomposting is the consumption of Earthworms to digest organic wastes and excrete them as valuable Earthworm castings. Both Earthworms and microorganisms work together to produce the end product, which is nutrient-rich, environmentally stable, and pathogen-free organic mixture of humus and vermicastings that can be applied to agricultural fields(E. Intern & Coordinator, 2013).

Many species of earthworms can be used in a vermicomposting proceses for municipal solid wastes. Most commonly, the species *Eisenia foetida* with the various common names of red worms, brandling worms, manure worms, or compost worm's are used because of their appetite, capable of ingesting and excreting organic materials at high rate, they live on the surface of the compost, they have to tendency to move horizontal through compost, do not create burrows and feed surface litters. Under ideal conditions, red worms can consume.

### 2.11.3 Particle size

The particle size of the feed stock affects the composting process (Hartin J. and Crohn D. (2007). The size of feedstock materials entering the composting process can vary significantly. In general, the smaller size of the composting substrate, the faster the composting rate. Smaller

Substrate materials have greater surface areas in comparison to their volumes (Getinet Desalegn (2008).This means that more of the particle surface is exposed to direct microbial action and decomposition in the initial stages of composting.

### 2.11.4 Nutrient Levels and Balance

Efficient processing of compost microorganisms requires specific nutrients in available form, adequate concentration and proper ratio(Sherman 1998). The essential macronutrients needed by microorganisms in relatively high amounts such as carbon (C), nitrogen (N), phosphorus (P), and potassium (K) (Hartin and Crohn, 2007).Carbon used for microorganism as energy sources According to, And microorganisms also need C and N to synthesize proteins, build cells, and reproduce(Othman & Irwan, 2012). In general, about 25 times more carbon than nitrogen is needed by biological organisms, so it is important to provide the right ratio. Although good results can be achieved with C:N ratios from 20:1 to 40:1, the ideal ratio is 25:1 to 30:1 for active composting (Dadi et al., 2012). P and K are also essential for cell reproduction and metabolism. In a composting system, either C or N is usually the limiting factor for efficient decomposition (G. Kaosol, 2009).

### 2.11.5 Process of Vermicomposting

Almost all yard wastes and many food wastes can be vermicomposted. Exceptions consist of any food that is excessively oily, spicy, salty, hard, or contains meat or diary. Examples include fried or overly processed foods, citrus fruits, and hamburgers. The list might seem restrictive, but that still allows for all fruit and vegetable scraps (including peels, rinds, cuttings, and extra bits), dry cereals, and miscellaneous foods such as coffee grounds and tea leaves. Yard wastes including grass clippings, tree limbs, leaves, weeds, and dead plants may all undergo vermicomposting (E. Intern & Coordinator, 2013).

For efficient vermicomposting, specific types of Earthworms are superior to others. Epigamic Earthworms are the best for the job because they live on the surface, tend to move horizontally through the soil, do not create burrows, and feed on surface litter. All of those characteristics are important because the worms need to eat food that is near the surface, live in small vicinity, and not be upset by soil disturbance that would destroy any burrows. The most commonly used epidemic vermicompost worm is *Eisenia fetida*,(E. Intern & Coordinator, 2013)**.**

The basic requirements during the process of vermi composting including suitable bedding, food source, adequate moisture, adequate aeration, suitable temperature and suitable PH

#### 2.11.6 Conceptual Framework

A conceptual framework represents the researcher's synthesis of literature on how to explain a phenomenon. It maps out the actions required in the course of the study given his previous knowledge of other researchers' point of view and his observations on the subject of research. In other words, the conceptual framework is the researcher understands of how the particular variables in his study connect with each other. Thus, it identifies the variables required in the research investigation. It is the researcher's "map" in pursuing the investigation.

The framework adopted a mixed method to answer the what, why and how research questions being relevant to solid waste analysis. The conceptual framework "sets the stage" for the presentation of the particular research question that drives the investigation being reported based on the problem statement. See figure -2

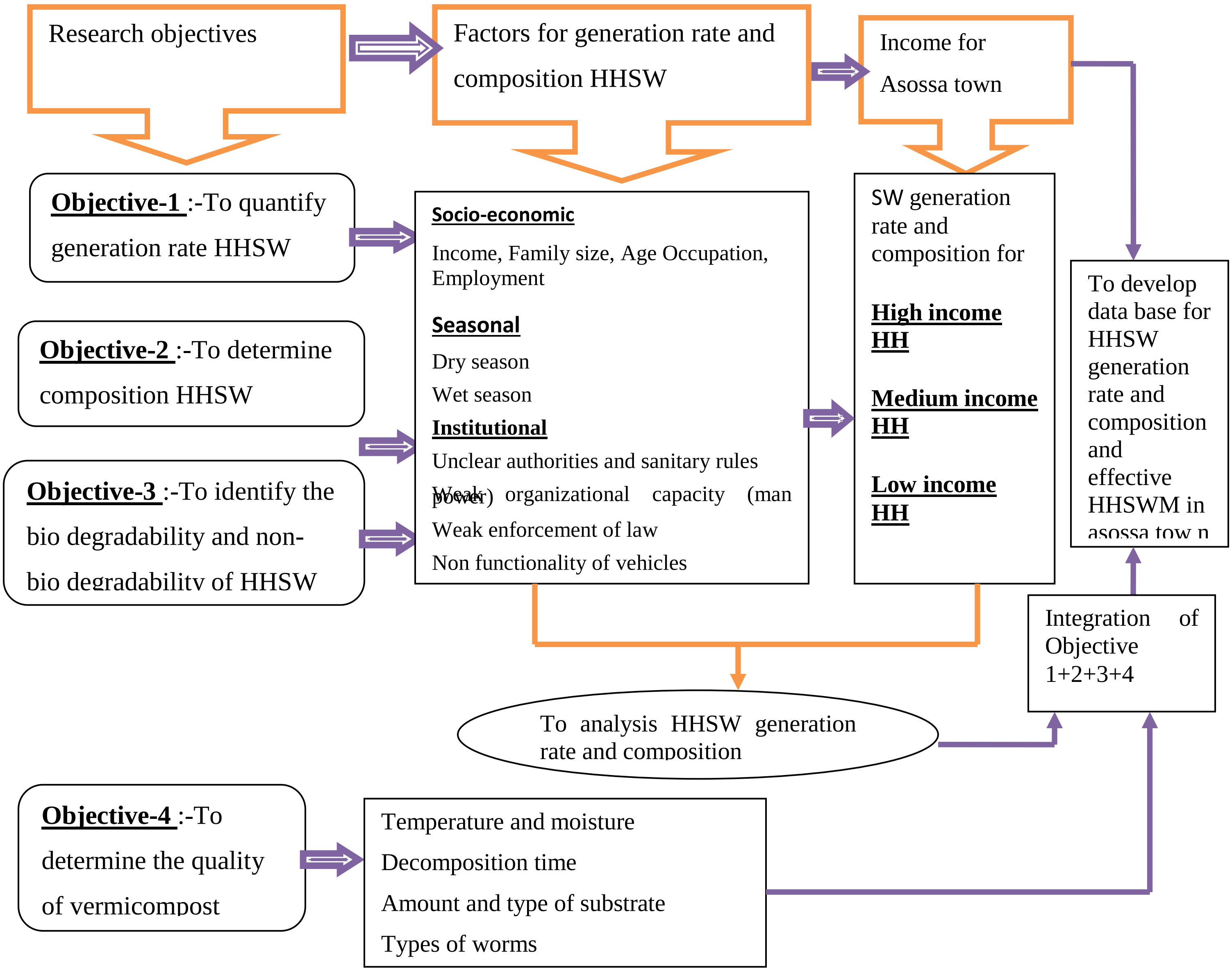


**Figure 2: Conceptual framework for analysis of HH solid waste generation and composition in Asossa town**

# CHAPTER THREE:
# 3. OBJECTIVES OF THE STUDY

## 3.1 General Objectives

The main objective of this study is to assess Municipal Solid Waste Characterization, Generation Rate and Waste transformation through Vermicomposting .

## 3.2 The specific objectives of the study

The specific objectives of the study are to:-

- To quantify solid waste generation rate of households of Asossa town.
- To determine composition of solid waste generated by households of Asossa town.
- To characterize and determine bio- degradability fraction of solid waste generated by household in Asossa town through vermi-composting.
- To analyze quality of compost form vermi-composting and comparing it with control as well as the present compost guide line.

# CHAPTER FOUR

# 4. METHOD AND MATERIALS

## 4.1 Description of the study Area and period

The Benishangul-Gumuz Regional state is located North West part of Ethiopia at $9^0$ 39” and $11^0$ 39’’ N and 34 $^0$ 20 to $36^0$ 30 E. the region shares international border with sudan in west. Nationally it borders with Oromia in the East, Gambila in South and Amhara region in the northeast. The region contains three administrative Zones and one special woreda. There are 600,000 inhabitants, the vast majority lives in rural areas.

The region is relatively small, covering 51000 $km^2$, with the capital city of Assosa located 687 km from Addis Ababa. Asosa is the capital of Benishangul–Gumuz, region located at western part of Ethiopia (10°N and 34.4°E). The town has an elevation of 1570 m with a flat land topographical features.

The mean annual temperature of the town is ranges from23$^o$c to 31$^o$c and annual rain fall is ranges from 800mm to 1000mm

The population of the city was 60474 according town municipalities. The town have two sub woreda & each woreda has five ketena administrative which is total 10 ketena . The five largest ethnic groups reported in Asossa were the Amhara 42%,the Berta 33.8% ,the Oromo 12.4%, shinasha 12.3% the Tigray 5.7% and the Mao 3.7%

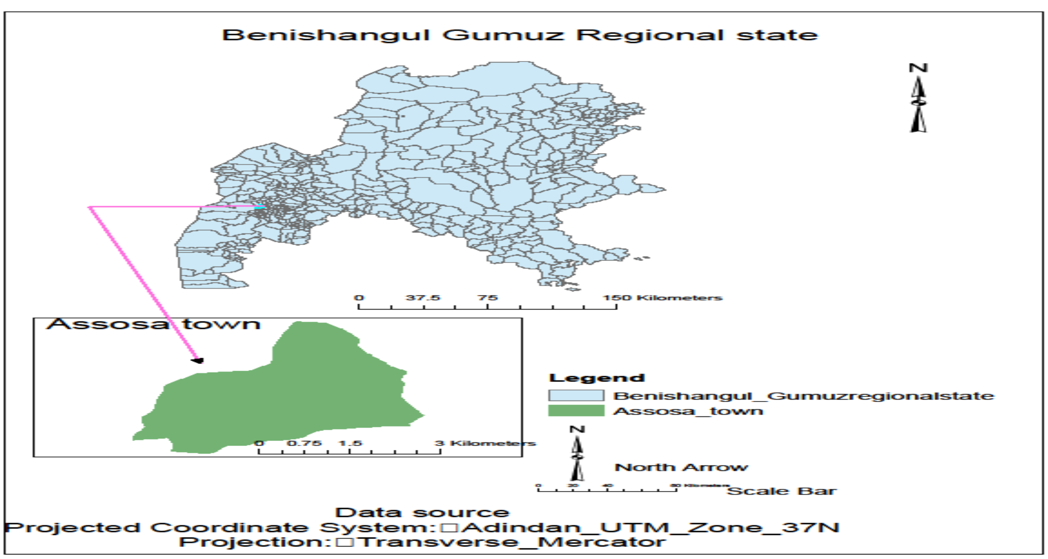


**Figure 3:** Map of Asossa town

## 4.2 Study design and period

Across-sectional study was conducted by using quantitative approaches and used for characterize composition and generated solid waste and field experimental study was used to produce vermi-composting. The study was conducted from March to August 2018.

## 4.3. Population

### 4.3.1 Source Population

All house hold of Asossa town/study areas/.

## 4.4 Sample size and sampling techniques

### 4.4.1 Determination of sample size

The number of samples depends primarily on the cost versus its utility. For higher statistical accuracy and confidence level, the number of samples would be more. There are statistical procedures to calculate the number of samples at each confidence level. Usually for solid waste data, the confidence level (C.L) is set at 80% or 95% (UNEP, 2009). Sample size determination was undertaken through statistical technique, which is developed by (Cochran, 2009; as cited by Haile, 2011). According to the formula the sample size is determined with some degree of precision for general population was used.

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

Where:- n = sample size of housing units

P= Housing unit variable (residential houses) or the proportion in the targeted population estimated to have characteristic to be measured (from previous studies in comparable countries/town/ i.e 0.85 from Haile, 2011)).

Q= Non-residential houses (offices, schools, etc in terms of %age) = 1-P

N= Total number of housing units

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

d = Allowable error (0.05)

According to obtained data from the municipality of the town (Municipal, 2018) there are about 13440 housing units (N): from these about 85% (P) are of residential and the rest 15% (Q) are of non residential.

Thus,

$$n = \frac{NZ^2PQ}{d^2 (N-1) + Z^2 PQ} \quad \frac{13440(1.96)^2 x (0.85)(0.15)}{(0.05)^2 x13439 + (1.96)^2 (0.85)(0.15)} = 193.08$$

Therefore, n = 193.08 is the minimum sample size of housing units for reliable results. To be safe in case of unobservable problem during data collection, non – cooperativeness of households and other causes considering 10% non-response rate, the final sample size is 213 households was selected

### 4.4.2 Sampling Technique and Procedure

In this study 213 HH were selected for data collection of samples and researcher used purposive sampling technique in order to select three ketena from two woreda because among 10 ketena only three ketena have organized document. As far as Asossa town is concerned, by ketena, each „ketena ‟‟has its own sub-section or sefer''. Therefore, systematic random sampling technique was used to select „Sefers‟‟ from each ketena. Based on this, 1, 2 and 3 sefer ‟‟ from ketena-2 and 15,16,17,18 and 19 sefer from ketena-5 where as sefer-1,3, 5 and 7 were taken from woreda-2 ketena-2. Based on this, the lists of each sefer were used as sample frame. Finally, since the „all ketena‟‟ administrations except 3 ketena did not have organized documents for house number of each household, the researcher forced to use house holed name for sampling. Therefore, systematic random sampling technique was applied to select the direct participant households from each „sefer‟‟. The respondent unit was the head of house".

By using the proportional to population from 3 ketena, it can calculate number of sample size for each ketena. Therefore, 213 household for 4422 in 3 ketena, how much house hold for 1278 housing unit in woreda 1,ketena-2.

Ketena-2 4422=213

1278=? $\frac{1278x213}{4422}$ =61.6=62

Ketena-5 4422=213

1627=? $\frac{1627x213}{4422}$ = 78

Ketena-2 4422=213

1517=? $\frac{1517x213}{4422}$ = 73

Then by using the households name from each sefer which registered by ketena and concerned body in each woreda, sefer were used as a sampling frame. Then it calculated the interval k by using the formula: K= N/n N was number of households, n=number of sample size for each ketenea

ketenea 2=213/62 =3,Ketena 5=213/78=3& Ketene 1=213/73=3 which is 3 for all ketena.

From the list of 1 to 3 the first household was selected by using lottery method, the selected house hold's was number 3 for all ketena then data was collected from every 3rd household by random sampling until the required sample size fulfilled . If the selected housing units were not present or households were non-cooperative; the next housing number was directly selected.

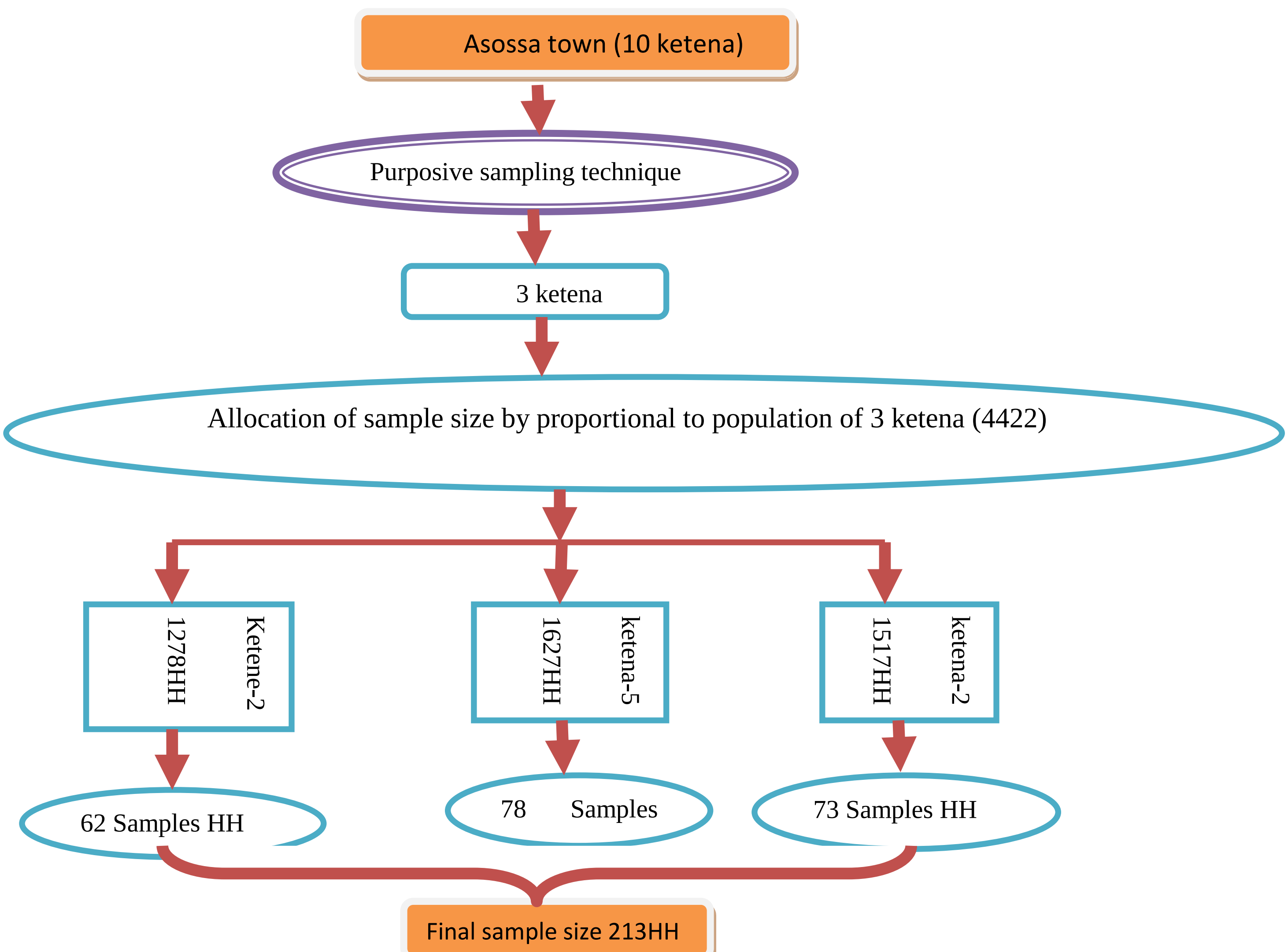


**Figure 4: Diagrammatic presentation of sampling procedure of households of Asossa town 2018**

## 4.5 Waste sample collection and sorting Techniques

Before collecting the samples, two color plastic bags are distributed for each selecting households one day before. And the identification number was labeled bio-degradable (food waste, leaves, wood, chat, grasses and paper waste) and non-biodegradable (plastic, metal, glasses and textile waste) to each household and corresponding level is given for each and every bag distribute for each households. During distributing the plastic bags all households were informed that how and when the sample collectors come back. On the next day early in the morning the collection of samples began.

Sample collectors collected all the distributed bags, with solid waste kept in, early morning and brought to the specific place prepared for sorting purpose using hand push cart and bajaj. Actual collection and sorting of wastes from the participating households were conducted for eight consecutive days but for the quality of the data the first day waste collecting from each household was discard taking into account that these wastes may not be generated on a daily basis. Right after the second day up to the eighth day (8days) sample is collecting on a daily basis.

**Figure 5: Collection and Transportation of waste to sorting site**

## 4.6. Sorting and weighing procedure

### 4.6.1 Sorting procedure

Initial sorting of the waste was carried out by members of the households and further sorting was done by the researcher on sorting site in to(food/kitchen/ waste, leaves, woods, ash, chat, grasses, metal, glasses and textile waste(Miezah, 2015). Two plastic bags were supplied to each household for the sorting and separation, to wastes and all other waste. The organic waste bag was labeled ‘‘Biodegradables which included food/kitchen waste, leaves, wood waste, Ash and agricultural waste) while the ‘‘Other wastes” was labeled non-biodegradable comprised plastics, textiles, metals and glass (Miezah, 2015).

The 6 sample collector, 6 sorters, and 3 recorders total 15 participant were trained in theory and practice on all aspects of the sorting, measurement and recordings on sheet. Number of sorters per ketena per sorting day was ratio 4 sorters to 1 ketena but for the sake of efficiency, the sorters worked in a group of 12. The researcher supervised and coordinated the collection as well as the transportation of the waste to the sorting site and all participants were used personal protective equipment during study.

**Figure 6: sorting of collected house hold solid waste**

### 4.6.2 Weighing of sorted waste

The initially sorted waste was collected using either a hand push cart or bajaj from the household to the main sorting center. The sorted wastes were weighed using a Labe spring balance (1–20 kg) of various capacities: 1 kg, 5 kg, 10 kg and 20 kg. Plastic sheets were placed on the floor to ease sorting, segregation and weighing.


Figure 7: Weighing Of Collected House Hold Solid Waste

## 4.7 Variables

**Dependent variables**

Waste generation rate kg/cap/ day, Waste characterization by type, Waste composition by weight and Physic-chemical analysis for quality compost (pH, E.C, P, K, TN, OC, C: N, Ca, Mg and Zn, Fe, Cu Mn).

**Independent variables**

Independent variables are: Age, Sex, Economic level (income) Educational status, Family size.

## 4.8 Experimental Set Up

### 4.8.1 vermi sheds preparation

vermin sheds were prepared using wood(conidian Africa) with base area is 60cm height, 50cm long(0.3$m^2$) and 20cm width (50cm x 20cmx 60 cm),(0.6$m^3$ in volume) and 0.3cm opening by each direction for ventilation.

Four different treatments each having 3 replicates with the total of 12 sheds were prepared with different composition of food waste, cow dunk, corn stock and soil and mix with well sized or chopped (1-1.5cm diameter) as amendment in different ratio to prepare different vermi beds by addition of 100 Eisenia fetida worm in each treatment.

### 4.8.2 Substrate (Material) and worm Selection

Eisenia fetida worm were collected from Asossa agricultural research center and food waste were collected from household. Eisenia fetida worm was selected due to capable of ingesting and excreting organic materials at high rate, they live on the surface of the compost, they have to tendency to move horizontal through compost, do not create burrows and feed surface litters. The materials which used to vermicompsting were selected based on the content of Carbone, nitrogen and C: N ratio contents. For instance adding the cow dung in the processes of vermin composting set up was provide an extra supplement in nitrogen , phosphorus and potassium and N:C ratio for to test itself. Because it contains high amount of N serves as energy source and carbon serves as protein (reproduction). According to (Othman & Irwan, 2012), using cow dung for vermicomposting was accelerated nutrient contents (P,K and N) by 75% up to 95%

Figure 8: Substrate for vermicompost preparation

### 4.8.3 Species of worms

Eisenia fetida worm was selected due to capable of ingesting and excreting organic matrials at high rate, they live on the surface of the compost, they have to tendency to move horizontal through compost, do not create burrows and feed surface litters

**Figure 9: Eisenia fetida worm produced**

Figure 10: Vermicompost at 45 day decomposition (stable compost)

So that treatment 1 (T1) is composed only food waste and is acted as a control (100%). While, treatment 2 (T2), food waste and cow dung (50:50) %, treatment 3 (T3), food waste, cow dung and soil with (33.33: 33.33:33.33) % and treatment-4(T4), food waste, cow dung, soil and corn stock with (25:25:25:25) % well sized.

The compost bedding was watered for 7 day uniformly for all the treatments before, addition of worms. Continuously cheek the temperature (10-30$^0$c), moisture (60-80)pH (5-8.5)(E. Intern & Coordinator, 2013).Then physical, chemical, quality of compost were evaluate(Dhimal & Gautam, 2013).

**Table 1: Material description of vermi beds used for experimentations**

| **Vermi beds** | **Volume to volume ratio** | **Descriptions** | **Number of worm** | **Weight of worm in g** | **Weight of substrate** |
|---|---|---|---|---|---|
| **T-1** | 100% (1) | Food waste only(control) | 100 | 4.8 | 200 |
| **T-2** | 50:50%(1:1) | Food waste, cow dung | 100 | 4.8 | 200 |
| **T-3** | 33.33:33.33:33.33% | Food waste, cow dung, soil | 100 | 4.8 | 200 |
| **T-4** | 25:25:25:25% | Food waste, cow dung, soil, corn stocks(leaves& grasses) | 100 | 4.8 | 200 |

** T-1=treatment 1,T-2= treatment 2,T_3=treatment 3,T-4=treatment 4

**Figure 11: The house of vermi-composting**

**Figure 12**: **Vermi composting beds used for experimentations**

About 20 g homogenized wet samples (free from earthworms and cocoons) were drawn from each treatment and dried for chemical analysis at 0, 15, 30, 45 days. The changes in the nutrient content were measured at start up time and at the end time in each treatment(Babaei AA, Goudarzi G, Neisi A, Ebrahimi Z, 2016).

## 4.9. Analytical Methods

### 4.9.1 Measurement of Physic-Chemical Parameters for compost quality

Physic-chemical analysis of compost samples was carried out in Asossa regional Soil testing laboratory except heavy metals (Harommaya University). A digital pH meter was calibrated with the help of standard Buffer solution of pH 4.2 and 8.6, and measured in 1/50 (w/v) aqueous solution using a digital pH meter (pH-016) to determined the pH of the compost and electrical conductivity was measured by conductivity meter (JENWAY-470) .

The organic carbon content of the compost samples was determined as by Walkely and Black method (1936) (Dhimal & Gautam, 2013;Pisa C, Wuta Mu, 2017). Soil organic matter is standardized under conditions with potassium dichromate (in excess) in sulfuric acid. The dichromate ions which color the solution orange-red were reduced to $Cr^{3+}$ ions which color to green. The measured amount of potassium dichromate was used in excess of that needed to destroy the organic matter and excess determine by titration with ferrous ammonium sulfate solution, by using diphenylamine indicator to detect the first appearance of un-oxidized ferrous ion.

At the end by titrating both samples and blanks with 0.5N ferrous sulfate solution until the color changes to purple or blue then at the end the color flashes to light green end point. Procedure for soil and plant analysis

So by using the formula

$$\%C = Nx\frac{V_1 - V_2}{S}x0.39xmcf \text{------------------------------------------------------------} (3)$$

Where:

N=normality of ferrous sulfate solution (from blank titration)

V1=ml ferrous sulfate solution used for blanks

V2= ml ferrous sulfate solution used for samples

S=Weight of air dry sample in gram (0.1g)

0.39= $3x10^{-3}$x100% x1.3 (3=equivalent weight of carbon)

mcf= moisture correction factor~1

And the organic matter was calculated by multiplying the percent organic carbon by 1.724 assuming that organic matter is composed of 58 % carbon .Total nitrogen was measured using out loss on ignition with titration and from organic Carbon content determination. As well as C/N ratio was calculated by dividing the total nitrogen by the organic carbon content. Available phosphorus was measured by Olsen's method by spectrophotometer (JENWAY-6305UV/Vis) and exch. Potassium was determined by flame emission by flam photometer (J ENWAY-PEP7).

To determine nitrogen content fist convert %C to %Organic matter conversion of %C to% organic matter is done with the empirical factor of 1.724,which is obtained by dividing 100 by 58(100/58) because organic solid waste contain 58%C(Pisa C, Wuta Mu, 2017).

$$\text{So, } \%N = \frac{\%\text{Organic matter}}{20} \text{--------------------------------------------------} (4)$$

Figure 13: Measurement of physic chemical analysis

Heavy metals (Fe, Cu, Zn and Mn) extrication from compost sample were performed by an aqua regia digestion based on ISO11466 recommended method(ISO, 1995) . he air dried sample was extracted with hydrochloric acid or nitric acid 3:1 mixture by standard for 16 hours at room temperature. Follow by boiling under reflux for 2 hours. The extract was clarified and make up to volume with nitric acid. Then measured by flame atomic absorptions spectroscopy (PG990, China model) and detail apparatus, regents, and procedure were attached in annex-XI

### 4.9.2 Proximate Analysis of solid waste

In proximate analysis of wastes only content moisture determines. The moisture content percentage was determined as a percentage loss in weight before as well as after drying by using Equation (2). Empty crucible was first weighted and then sample size of 50 g of food waste and other wastes were weighted by using balance BP310P Germany with ±0.001and put in an oven at 105ºC for 24 hours according to the ASTMD 3173 in Asossa soil testing laboratory. The samples were placed in desiccators for cooling purpose then weights after heating were also recorded(Korai et al., 2016; E.Lemma et al., 2014).

The weight of the sample before and after gives the moisture content. The different fractions of the waste stream shall have their moisture content measured separately. In order to reduce the magnitude of error arising from the moisture change and from decomposition the analysis of the sample was started within two to three hours after collection. Care was also always taken to make the samples well mixed for this purpose each waste component were randomly taken and then chopped to reduce the size and then the well mixed sample finally was taken for laboratory analysis.

(%) MC= (A-B) x100 ------------------------------------ (5)

B- Weight of tin

Where: - MC is the moisture content

- A = Weight of air dry of soil and tin weight.

A= (Sample in Oven)


B= (Desiccators) C= (Balances)

**Figure 14 : Equipment for determination of %MC4.9.3 Ultimate Analysis of Solid waste**

Ultimate analysis (elemental analysis) is the analysis of waste to determine percent of C, H, O, N and S) are not determine, due to the lack of instrument in the country level. The researcher analysis involves the determination of, pH, C: N ratio total nitrogen content and organic carbon content. The way of analysis is the same to above 4.1 and detail procedures, regents, apparatus were in annex-XI

## 4.10 Solid waste generation rate

To calculate overall average per capita generation rate, contributions of households in different income groups was taken in to account. Therefore per capita solid waste generation rate of household's level in the town (213 household), and can be calculated as follows as cited by(Asmelash Zewdu, 2014).: Per capita per day solid waste generation rate (PCPDSWGR) is given by

$$GR\ (kg/capita/day) = \frac{\text{Total Solid Waste generation within 7 days}}{\text{7 days x total family size of 213 survey households}} \quad \text{------------ (2)}$$

### 4.11 Materials and Instruments

During the study time the following listed materials and equipments were used

1. For solid waste data collection, sorting, weighing

   Hand protective plastic gloves, Mouth & Nose Mask, Wood boxes (for vermicomposting) Balance scale and precision balance, Plastic sheets , Different type and color plastic bags Trash bags ,Audio and Video Cameras
2. For physic chemical analysis and heavy metals

   **Instrument:** PH, EC, oven, fumhood, refrigerator, mini shaker, polyether, pipette, burette, thermometer, flam photometer, sector photometer, Atomic sector photometer etc. Chemical, acid and reagents are list in Annex-XI

### 4.12 Data analysis

The solid waste data generated from household were basically using the statistical package for social studies (SPSS.20) and Microsoft excels 2007. The results were presented in tables, percentage charts and graphs. In the data analysis the compositions of waste was analyzed and per capital generation rate and per household generation rate were determined. Vermi compost quality was also analyzed.

### 4.13 Ethical Consideration

For the survey, ethical clearance was obtained from the Ethical clearance committee of Jimma University. Official letter was written to Asossa Municipality, two woreda &3 Ketena administrative and concerned bodies to communicate about the research and for required. Before entering the study area, local authorities and community leaders were briefed about the objective of the study. Respondents participated in the study was voluntary and each respondent was asked to give verbal consent to participate and each HH was assured that the information provided will be kept confidential.

## 4.14 Limitation of the Study

Due to the time and financial constraints the thesis is concentrates on at one season. And it focused only on the Household solid waste generation rate kg/cap/day, characterization & recycling options. Due to such limitation of the study, the determinant factors that shown in the output of the paper does not give confidence to generalize as a problem of other type of solid waste in town such as liquid waste, institutional waste, hazardous waste, industrial wastes and the like. Also the ultimate analysis(C, N, O, H and S) were not analyzed, due to lack of laboratory instrument.

## 4.15 Operational Definitions

1. **Characterization:-**The determination of bio-degradability and non-biodegradability of house hold solid waste properties of a pure substance, compound, or mixture to the extent necessary to support informed decision making.
2. **Vermicompos**t:- is the product or process of composting using various worms, usually red wigglers, white worms and other earthworms to create a heterogeneous mixture of decomposing vegetable or food waste, bedding materials, and vermicast
3. **Solid waste generation rate**: - is the amount of waste join to waste stream from human activities from house hold.
4. **Vermicomposting** is the process by which worms are used to convert organic materials (usually wastes) into a humus-like material known as vermicompost. The goal is to process the material as quickly and efficiently as possible.
5. **Food waste** is uneaten food and food preparation wastes from residences establishments such kitchens left over".

## 4.16 Data Quality Management

To ensure reliability and validity dunning laboratory and filed experiment work deferent strategy were employed. First for collection of solid waste data all waste collector, recorder and sorter have to be well trained. Second for laboratory all instruments were carefully calibrated and checked well function and acids and chemicals were standardized according to the procedure. Finally researcher restrict flow all activity.

# CHAPTER FIVE

# 5. RESULTS

## 5.1 Socio - Demographic Characteristics of Households

There is currently no official standard that defines the different income groups in Ethiopia. Hence, a system of grouping was devised solely for the purpose of this study. But classification range for family size, Age and Educational status were taken from regional health and buearo of Benishangul Gumz region (2018).

Thus households who earn less than 600 birr per month 73(34.3%) HH were categorized under low income, those who earn 601 – 1000 birr per month 73(34.3%) HH were categorized under middle income and Households that earn greater than to 1000 birr per month 67 (31.4%) HH were categorized under high income groups

**Table 2: Socio -demographic Characteristics of Households**

| Variables | Category | Respondents | |
|---|---|---|---|
| | | Frequency | Percentage |
| **Sex** | Male | 99 | 46.5 |
| | Female | 114 | 53.5 |
| **Age** | 19-35 | 103 | 48.4 |
| | 36-65 | 102 | 47.9 |
| | >65 | 8 | 3.8 |
| **Income level** | <600 | 73 | 34.3 |
| | 601-1000 | 73 | 34.3 |
| | >1000 | 69 | 31.4 |
| **Educational status** | Less than or equal to 4 | 31 | 14.6 |
| | 5 to 8 | 55 | 25.8 |
| | 9 to 12 | 62 | 29.1 |
| | certificate ,diploma, degree and MSc | 65 | 30.5 |
| **Family size** | Less than or equal to 4 | 44 | 20.7 |
| | 5-6 | 100 | 46.9 |
| | 7+ | 69 | 32.4 |
| **Total of HH** | | 213 | 100 |

In the study area total of 213 HH were participated and among them 53.5% were males and 46.5% were females. Were as 48.4% of the respondents were 19-35 years and 3.8%of respondents were >65 years old and 30.5% of respondents have certificate/diploma and above. But 14.6% were complete less than and equal to grade 4(table-2). In the study area 34.3% respondents had in low and medium income level and 46.9% of the respondents had 5-6 children's but, 20.7% of respondents have less than or equal to 4 family size.

## 5.2. Existing Situation of Household Solid Waste Management in Asossa

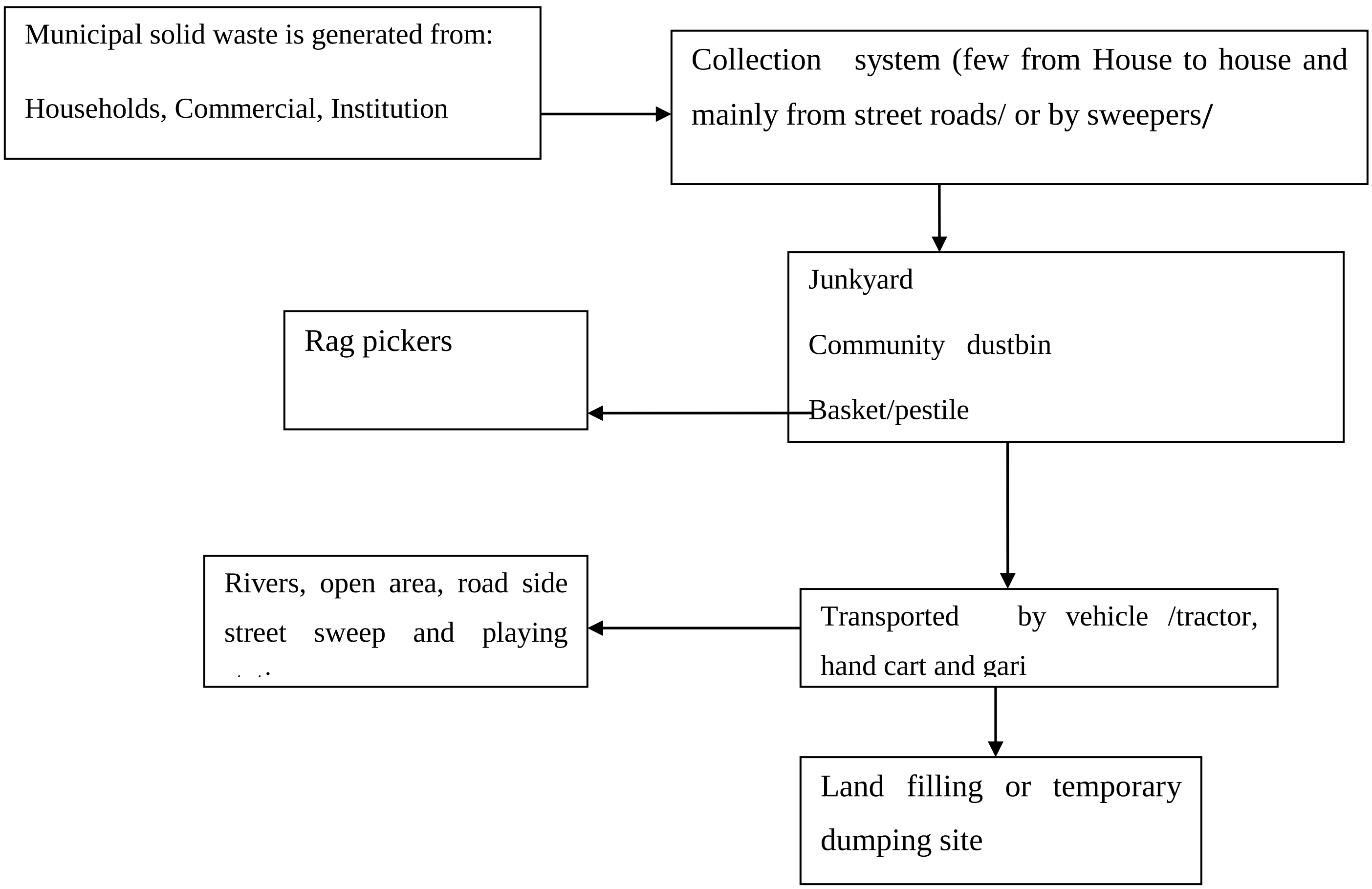


**Figure 15: Current solid waste management practice in the Assosa town**

## 5.3 Solid waste generation rate

The daily solid waste generation rate of Asossa town for low income (<600 ETB), medium income level (601-1000 ETB) and high income level (> 1000 ETB) households were 0.108 kg/cap/day, 0.137kg/cap/day and 0.189kg/cap/day respectively. And average daily solid waste generation rate was 0.144kg/cap/day (table-3)

Table 3: Solid waste generation rate of HHs in Asossa town (n=213).

| Description | Low income | Medium income | High income | Mean | Stand.dev. | Total |
|---|---|---|---|---|---|---|
| Monthly income (per capita) | (<600 birr) | (601-1000 birr) | (>1000 birr) | | | |
| No. Population | 268 | 273 | 249 | | | 791 |
| No. of HH | 73 | 73 | 67 | | | 213 |
| Average family size | 3.67 | 3.75 | 3.71 | 3.71±1.5 | 1.516 | 3.71 |
| Total waste kg/day | 203.2 | 263.7 | 330.3 | 34.6 4±0.93 | 0.932 | 797.3 |
| Kg/HH/day | 0.39 | 0.51 | 0.7 | 0.534±0.23 | 0.236 | 0.534 |
| Kg /cap/day | 0.108 | 0.137 | 0.189 | 0.144±0.11 | 0.1158 | 0.144 |

### 5.4 Solid Waste characterization

In this study solid waste characterization can be subdivided into two major components called bio-degradable and non bio-degradable. The biodegradable component of urban solid waste constitutes organic wastes such as food waste (35.94%), leaves (12.69), grasses (8.19%) Catha edulis(4%) Ash and dust (18.87%),Wood(4.94%) and paper (3.35%). While non bio-degradable waste includes inorganic materials which can't be decomposed and degraded it includes different types of plastics (8.15%), textile (2.65%) and 0.76% and 0.40% were metal and glasses respectively (table 4 and fig 16).

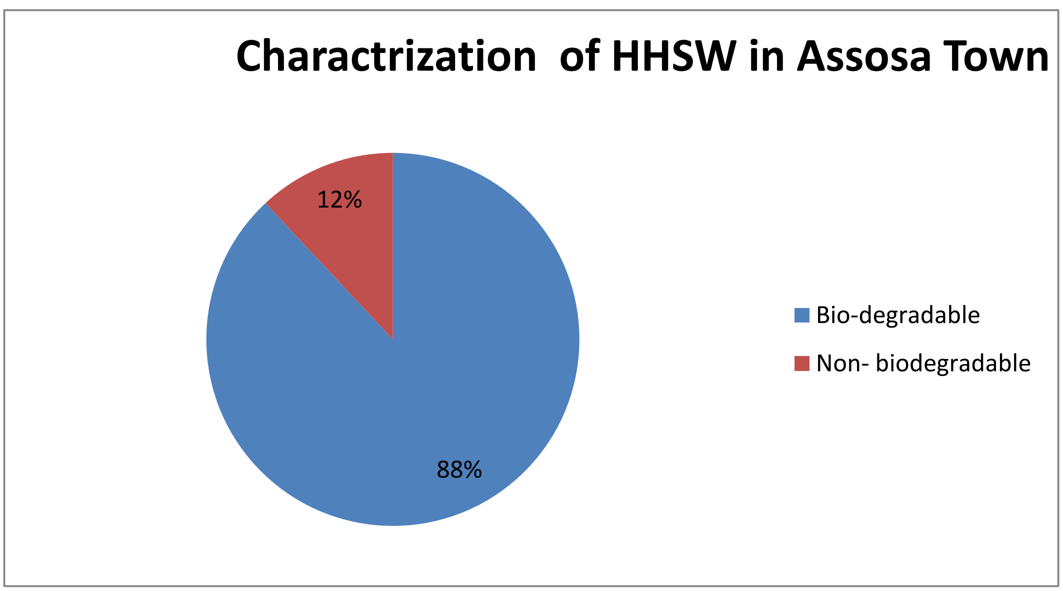


**Figure 16: Characterizations of solid waste stream.**

Table 4: Category of residential solid waste in Asossa town 2018

| Category | Sub- category | Weight kg | Percentage share |
|---|---|---|---|
| **Bio-degradable** | Food waste | 286.6 | 35.949 |
| | Leaves | 101.2 | 12.69 |
| | Grasses | 65.3 | 8.19 |
| | Catha edulis | 31.9 | 4.08 |
| | Paper | 26.9 | 3.354 |
| | Ash and dust | 150.5 | 18.871 |
| | Wood | 39.4 | 4.94 |
| **Non-biodegradable** | Plastic | 65 | 8.15 |
| | Metal | 6.1 | 0.766 |
| | Glasses | 3.2 | 0.402 |
| | Textile | 21.2 | 2.65 |
| | Total | **797.3** | **100** |

## 5.5 Solid Waste Composition

The physical composition by percent of HH solid wastes of Asossa town extracted from 213 sample households was summarized in (table 5 and fig 17).

**Table 5: Household solid waste composition and volume in Asossa town**

| No. | SW component | Weight kg | % by weight | Volume in litter | %by volume |
|---|---|---|---|---|---|
| 1 | Food waste | 286.6 | 35.94 | 541 | 14.34 |
| 2 | Ash and dust | 150.5 | 18.871 | 589.5 | 16.89 |
| 3 | Paper | 26.7 | 3.354 | 221.5 | 14.83 |
| 4 | Wood | 39.4 | 4.94 | 323 | 8.39 |
| 5 | Plastic | 65 | 8.15 | 723 | 7.72 |
| 6 | Catha edulis | 31.9 | 4 | 304 | 8.57 |
| 7 | Leaves | 101.2 | 12.69 | 532 | 14.46 |
| 8 | Grasses | 65.3 | 8.19 | 231.3 | 7.12 |
| 9 | Metal | 6.1 | 0.766 | 48.1 | 1.41 |
| 10 | Glasses | 3.2 | 0.402 | 21.7 | 0.80 |
| 11 | Textile | 21.2 | 2.65 | 166.3 | 5.42 |
| | Total | 797.3 | 100 | 2447.6 | 100 |

As can be seen from table 5, food wastes constitute 35.9%, Ash waste (18.9%), paper (3.35%), wood (4.94), plastic (8.15%), Catha endulis (4.18%), leaves (12.69%), grasses (8.19%), metals (0.76%), and glasses and textile contain 0.4% and 2.65% respectively.

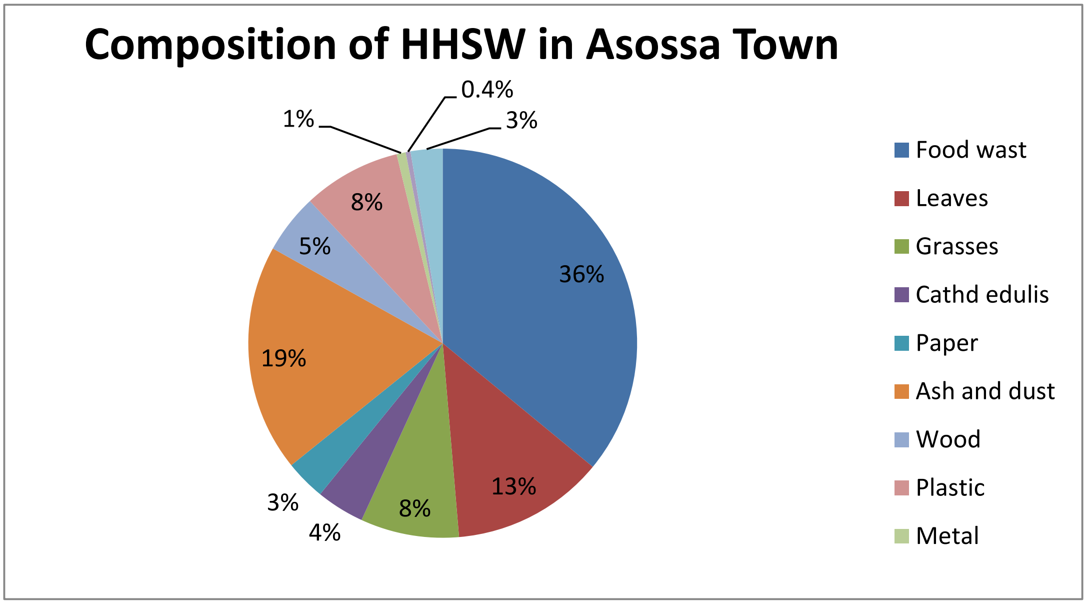


**Figure 17: Percent (wt %) distribution of HHSW composition generated in Asossa town**

## 5.6 Proximate Analysis of HH solid waste

### 5.6.1 Moisture content (%)

Moisture content is a very important factor that influences the decisions for converting organic waste into compost.

**Table 6: Proximate Analysis of the collected sample found in HHs solid wastes**

| | **Proximate Analysis of the collected sample** | |
|---|---|---|
| **No** | SW components | (%)moisture content |
| **1** | Food waste | 60.12 |
| **2** | Ash and dust | 13.32 |
| **3** | Paper | 10.23 |
| **4** | Wood | 42.05 |
| **5** | Plastic | 4.98 |
| **6** | Textile | 26.60 |

The above table 6 shows moisture content of food waste (60.12%), ash (13.3%), plastic (4.98%), wood (42.05%) and textile (26.6). It is the range of %MC of solid waste for low and middle income level country (40-80%).

## 5.7 Ultimate Analysis of solid waste

As showed in table7, the ultimate analyses are used to characterize the chemical composition of the organic matter, PH, total nitrogen and C: N ratio in the solid waste. Therefore, the value of the ultimate analysis shows that the carbon content and nitrogen content of all the waste components have higher percentage compared with the other studies of domestic solid waste except paper waste.

Table 7: Ultimate analysis of household solid waste

| | **Ultimate Analysis of the collected sample** | | | |
|---|---|---|---|---|
| **waste component** | Carbon content | Nitrogen content | C:N | pH |
| **Food waste** | 50 | 4.3 | 50:4.3 | 5.78 |
| **Yard( Leaves& grasses)** | 58 | 5 | 58:5 | 6.1 |
| **Paper waste** | 7 | 0.6 | 7:0.6 | 7.8 |

## 5.8 Evaluation of potential composting by household solid waste in Asossa town

Based on the generation rate, composition and physic- chemical (approximate and ultimate) analysis of HHSW in Asossa town estimated the potential of composting. Therefore the study areas contained C/N (54:4.6), pH (5.9), organic matter (69%) chemical composition of solid waste and %MC (60.12) (table 8

**Table 8:.Average chemical composition of HHSW in Asossa town and the standard values Suitable for composting**

| NO | parameter | Average value analyzed from biodegradable waste | standard value suitable for composting |
|---|---|---|---|
| **1** | Organic matter | 69 | >20 |
| **2** | Organic Carbone | 54 | No |
| | Nitrogen content | 4.6 | >0.6 |
| **3** | C/N(C:N) | 54:4.6 | 25-50:1 |
| **4** | pH | 5.9 | 5.5-8 |
| **5** | Moisture content | 60.12 | >50 |

Source: extracted from (Regassa et al., 2011)

## 5.9. Physic-chemical parameters for quality of vermicompost

The nutrient values of vermicompost obtained in this study ranges pH (6.45-7.8), EC (13.65-6.6) , %OC (28-11) , TN (2.6-0.9) and C:N (10:-30:1). Whereas the value of P, K, Ca and Mg are 7.2-10.9, 0.5-0.69, 25-36 and 18.95-26 respectively in treatment-1(control) up to treatment-4(food, cow dung, soil and corn stock) during 0-45day decomposition (table 9).

**Table 9: Changes in physic-chemical parameters (mean values) during different stages of vermicomposting in deferent treatment.**

| Treatment | Parameters | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | PH | EC(ms/cm) | %OC | %TN | C:N | P(ppm) | Exa.K(me/ 100gsoil | Ca2++(cmol/100g soil) | Mg2++(cmol/100 g soil) |
| T-1 | 6.46±0.18 | 13.65±0.56 | 28±1.43 | 2.6±0.38 | 30:1 | 7.2±0.52 | 0.52±1.8 | 24.97±3.8 | 18.95±0.02 |
| T-2 | 7.2±0.021 | 19.67±0.97 | 18.2±2.23 | 1.75±0.07 | 21:1 | 10±0.71 | 0.6±0.04 | 28.45±4.9 | 22.7±4.8 |
| T-3 | 7±0.107 | 7.87±0.15 | 13.2±0.74 | 1.15±0.03 | 13:1 | 10.5±0.19 | 0.64±0.1 | 31.3±4 | 23.2±0.48 |
| T-4 | 7.8±0.045 | 6.62±0.46 | 11±1.27 | 0.89±0.08 | 12:1 | 10.95±0.26 | 0.69±0.2 | 35.6±1.2 | 25.5±1.44 |

N.B: the values are means of triplicate

The laboratory result indicates that some nutrient values were decrease with in the treatment (T-1 to T-4) at deferent composition in the decomposition date increases such as EC,% OC, C:N and % TN others are increases such as PH, PK and Ca, Mg concentrations(fig 15).

### 5.9.1 Concentration PH, EC and %OC

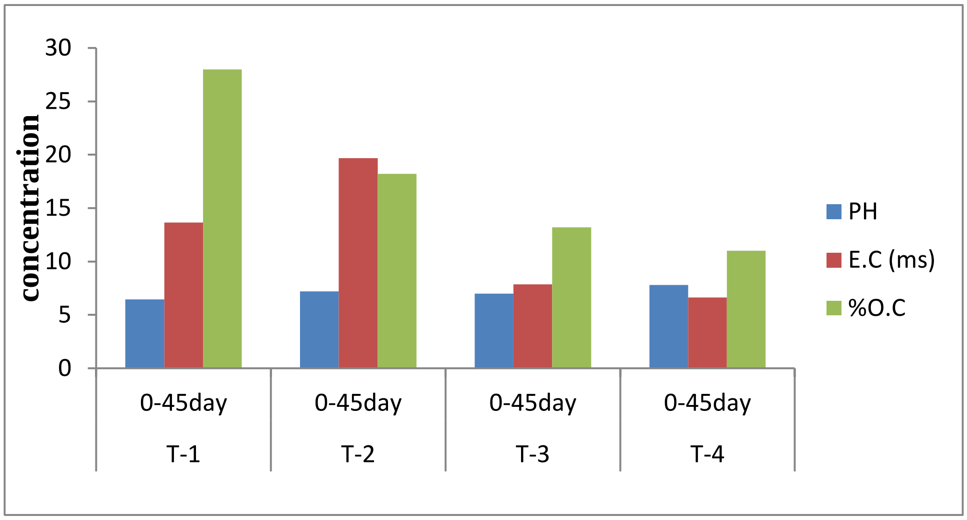


**Figure 18: The effect of vermicompostng on nutrient (pH, EC and %OC) values in each treatment**

The total OC and EC value decreases within the passage of time (0, 15, 30 and 45 day) during vermicomposting processes in all treatments. But PH value is increases.

### 5.9.2 Concentration of NPK

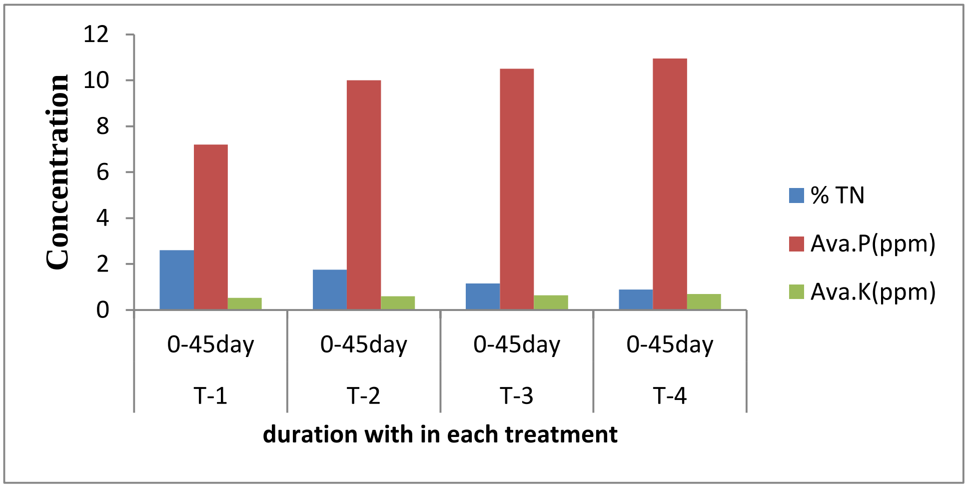


**Figure 19: The effect of vermicompostng on nutrient (%TN, P and K) values in each treatment**

In fig 19 show that concentration of Phosphorus and potassium in treatment (2,3 and 4) of vermicompost is higher as compared to control (food waste only) but the percentage of TN is uniformly decreases throughout treatment within the time interval (0-45day).

**5.9.3 Concentration of Ca, Mg and C: N**

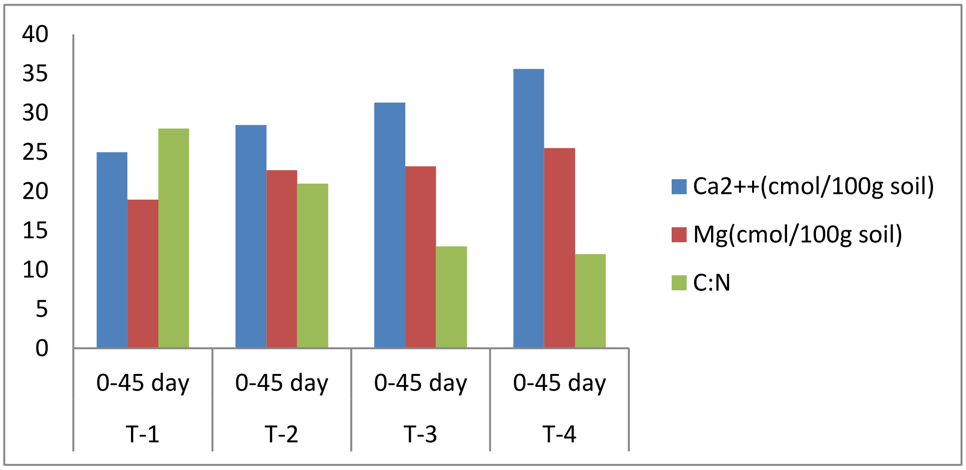


**Figure 20: The effect of vermicompostng on nutrient (Ca2++, Mg2++ and C: N) values in each treatment.**

The study result indicated that the concentration of Ca and Mg in T1(24.97,18.95), T2(28.45,22.7), T3(31.3,23.2)and T4(35.6,25.5) respectively. And C: N ratio is decreases within each treatment during the decomposition processes.

## 5.9.4 Heavy metals concentrations in vermicompost

**Table 10: Concentration of heavy metals (Fe, Cu, Zn and Mn) in vermicompost of Asossa town**

| Treatment | Duration | Parameters | | | |
|---|---|---|---|---|---|
| | | Fe(ppm) | Cu(ppm) | Zn(ppm) | Mn(ppm) |
| T-1 | 0-45 day | 6.7±0.02 | 0.67±0.02 | 4.12±0.13 | 3.6±00 |
| T-2 | 0-45 day | 4.34±4.8 | 0.51±00 | 4±0.17 | 2.41±0.15 |
| T-3 | 0-45 day | 3.1±0.02 | 0.62±00 | 4.41±0.08 | 3.44±0.05 |
| T-4 | 0-45 day | 4.3±0.04 | 0.6±00 | 4.7±4.5 | 3.8±0.07 |

N:B : the value is mean triplicates.

The above table shows Fe and Cu have highest concentration in treatement-1 (food waste only ) and compare to other treatment in 0-45day. And Zn and Mn contain high concentration (4.7ppm and 3.8ppm) in treatment- 4 (25,:25,:25,:25 food, cow dung, soil and corn stock) in all decomposition period (0-45 day). But the lowest concentration value Fe and Cu, Zn and

Mn were found in T-3 and T-2 respectively (table 10)(Hiranmai, 2015). This was supported by (Amaludin & Ahmood, 2010)

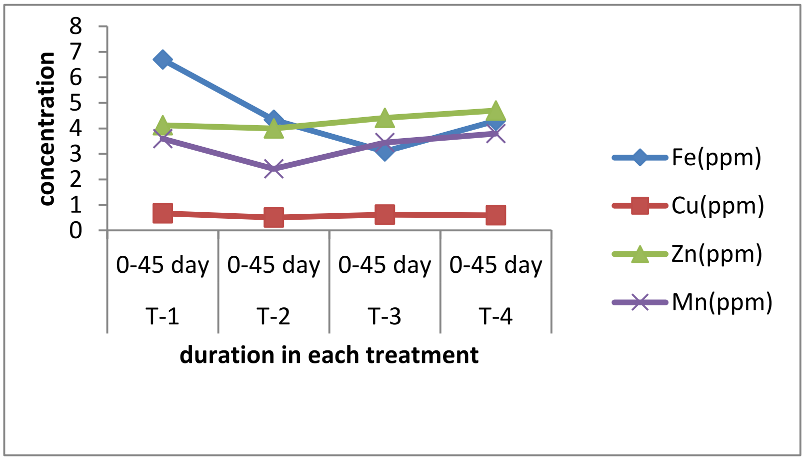


**Figure 21: Concentration of heavy metals ( Fe, Cu, Zn and Mn in vermicompost in deferent treatment and period of Asossa town**

## 5.10 Harvested Earth worms

Results of the present study showed that number of worms was highest inT4 which have the ratio 25:25:25:25 of food waste ,cow dung ,corn stock and soil at 45 day increasing by 164 worm numbers(62%) and the lowest number were in treatment one(T1) which have only food waste 9 worm number (8.3%). The combination of substrate gives the highest number of worms in T4 and lowest number in control (T1). Because the former one was contain high feeding value. This were supported by (Yadav et al., 2014;Elena, 2016).

## 5.9.5 Comparison of vermicompost nutrient value with EEPA,WHO and deferent country standards

Table 11 showed Comparison of the quality of stable vermicompost (0-45 days) with the EEPA,WHO Italy and Belgium standard for evaluating good quality compost at stable stage for selected parameters ( %organic carbon, percentage of total nitrogen, C/N ratio, EC and pH , macro and heavy metals.

**Table 11: Table 10: comparison of vermicompost nutrient value with EEPA, WHO and deferent country standards**

| Parameters | Duration of vermicompost | | | | Standards | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 0-day | 15-day | 30-day | 45-day | EEPA | WHO | USA | Italy | Belgium |
| PH | 6.45 | 7 | 7.2 | 7.8 | - | 6-9 | 6-7 | 6.5-8.5 | 6.5-8.5 |
| EC(ms/cm) | 13.65 | 17.67 | 7.87 | 6.62 | - | <1200ds/cms | <2ms/cm | 3.4-4 | 3.4-4 |
| %OC | 28 | 18.2 | 13.2 | 11 | >30 | 8-50 | 30 | >25 | >25 |
| %TN | 2.6 | 1.75 | 1.15 | 0.89 | | 2-3 | 1-3 | >0.7 | >0.7 |
| C:N ratio | 30:1 | 21:1 | 13:1 | 12:1 | 29:1 | 20-25:1 | - | <25 | <25 |
| P(ppm) | 7.5 | 10.1 | 10.9 | 11.5 | - | 0.02-0.03 | 8-25 | - | 8-25 |
| K(meq/100g soil) | 0.52 | 0.57 | 0.64 | 6.9 | - | - | 5-20 | | 5-20 |
| Ca2++(cmol/100gsoil) | 25.3 | 29.55 | 31.45 | 35.7 | - | - | - | - | - |
| Mg2++(cmol/100gsoil) | 18.95 | 22.67 | 23.12 | 25.27 | - | - | - | - | - |
| Fe(ppm) | 6.7 | 0.67 | 4.12 | 3.6 | - | - | - | - | - |
| Cu(ppm) | 4.34 | 0.51 | 4 | 2.41 | 80 µg/kg | - | 15 | 280 | 90 |
| Zn(ppm) | 3.1 | 0.62 | 4.41 | 3.44 | 300µg/kg | - | 287 | 300 | 300 |
| Mn(ppm) | 4.3 | 0.6 | 4.7 | 3.8 | | - | - | - | - |

Source: extracted from (World Bank (1997) and (Brinton, Ph, & Gardner, 2000)

**Table 11: Harvested earth worms**

| Treatment | Duration | Harvested worms number | | | |
|---|---|---|---|---|---|
| | | Initial numbers of worms | Final numbers of worms | Increased numbers | Increasing by % |
| T-1 | 0-45 day | 100 | 109 | 9 | 8% |
| T-2 | 0-45 day | 100 | 112 | 12 | 11% |
| T-3 | 0-45 day | 100 | 131 | 31 | 24% |
| T-4 | 0-45 day | 100 | 264 | 64 | 62% |

# CHAPTER SIX DESCUSION

## 6.1 Socio - Demographic Characteristics of Households

In the study area total of 213 HHs were participated and among them 53.5% were males and 46.5% were females. Whereas 48.4% of the respondents were 19-35 years and 3.8% of respondents were>65 years old and 30.5% of respondents have certificate/diploma and above. But 14.6% were complete less than and equal to grade 4(table-2). In the study area 34.3% respondents were in low and medium income level and 46.9% of the respondents have 5-6 children's but, 20.7% of respondents have less than or equal to 4 year children's. And the low income, middle income and high income household family size were 3.67, 3.75 and 3.71 respectively and the average for Asossa town was 3.71 persons.

## 6.2 Household Solid Waste Generation rate

The amount of waste generated from house hold of the study area was estimated based on the data collected from the selected household. Considering the population of Assosa town (213) in to account, the average per capita daily solid waste generation for household was 0.144 kg/cap/day and house hold daily generation rate was 0.534kg/HH/day (table3). But the daily, weekly, monthly and yearly solid waste generation rates of Asossa town by kg/cap/day and tons are 0.144, 1.008, 4.32 and 52.56kg/cap/day and 0.000144, 0.001, 0.00432 and 0.0526 tons respectively.

This study shows similar result with other studies in Ethiopia, such as (KASSA, 2008;Mekonnen, 2017),(Asfaw, 2007) and (Lemma, 2014) ,0.157, 0.140kg/cap/day, 0.15kg/cap/day and 0.14kg/cap/day respectively. But there is some variation when it was compared with other studies. Such as in Ghana the average solid waste generation rate of house hold for ten regions are 0.51kg/cap/day as reported by (Miezah, 2015) and average solid waste generation rate of Jimma and Wolayta sodo town according to report of (Getahun, et al, 2012) and (Endrias Goa and Solomon Sorsa, 2017) were 0.55 kg/capita/day and 0.47kg/cap/day respectively and this is greater than most major town of Ethiopia and Asossa town studded result. This was due to seasonal, life style, socioeconomic, and mainly by number of population found in the study area. Generally per capita daily solid waste generation for developing countries ranges 0.2-4kg/cap/day (UNEP, 2009), such as Addis Ababa contain 0.15kg/ca/day whereas developed country such as USA generated 2.1kg/cap/day (Hartin J. and Crohn D, 2007)

### 6.2.2 Socio economic conditions

Thus households who earn less than 600 birr per month 73(34.3%) HH were categorized under low income, those who earn 601 – 1000 birr per month 73(34.3%) HH were categorized under middle income and Households that earn greater than to 1000 birr per month 67 (31.4%) HH were categorized under high income groups. The rate of daily waste generation per capita and per day in the low, middle and high income family level of households were 0.108kg/day, 0.137kg/day and 0.189 kg/day and 0.39 kg/day, 0.51 kg/day and 0.7 kg/day respectively(table4).

### 6.2.3 Solid Waste characterization

Table 4 and fig 16 indicated that 88% of households solid waste stream of Asossa town is covered by bio-degradable waste such as food waste (35.9%), leaves waste (12.69%), Grasse (8.19%) waste, Catha edulis waste (4.18%), paper waste (3.35), wood waste (4.94%) and Ash and dust waste (18.87). And 12% of the household solid waste was non-biodegradable. Such, as plastic (8.15), metal (0.76), Glasses (0.40%) and Textile (2.65%).

This result shows similar result with other Ethiopian town includes Hossana town contains 91.5% organic materials(Lemma, 2014), Wolayta Sodo town 97% bio-degradable (Endrias Goa and solomon Sorsa, 2017), Jimma town 89.4%(KASSA, 2008; Getahun et al., 2011).

### 6.2.4 Solid waste Percentage composition

As can be seen from table 5 and fig17 food wastes constitute 35.9%, Ash waste (18.9%), paper (3.35%), wood (4.94%), plastic (8.15%), Catha edulis (4.18%), leaves (12.69%), grasses (9.19%), metals (0.76%), and glasses and textile contain 0.4% and 2.65% respectively. The finding indicates from table 5 large portion from the total house hold solid waste was food waste constitute 35.9%.

Similarly study reported that high amount of solid waste of developing countries is food waste. For instance in Ethiopia high proportion house hold food waste produced towns were 59.5% Wolayita Sodo town (Endrias Goa and solomon Sorsa, 2017), in Laga Tafo Laga Dadi town 37.69% by weight of food wastes (Assefa & Mohammed, 2017), in Jimma town food waste accounts as 36.03%(KASSA, 2008; Getahun et al., 2011), in Bole sub-city, Addis Ababa 36% (Ayalew, 2014), and other African countries showed large amount of food waste, such as 42.6% in Abujai-nigeria (Kadafa, 2017), and in Indian city of Guwanat(Kalamdhad, 2011)**.**

Next to food waste, Ash and dust accounts for (18.9) by weight in Asossa town, which is large compare to some towns. This might be due to the life style and economic level of population of household use traditional kitchens whose energy source sources are mainly natural forest (fire wood) and charcoal wastes. In addition to this all fine wastes including fire residue were included in ash components during the study time.

The studies also shows similar to other town which contain high amount of ash and dust waste, such as Jimma town 21.5% in (KASSA, 2008), shire Endaslsssie town 21% in (Zewdu & Mohammedbirhan, 2014), Hawassa town 31.4% (Alemayew.B, 2004) and Adama town(Asfaw, 2007). Leaves, Catha edulis and Grasses wastes also accounted for 12.69%, 4.18% and 8.19 %by weight. Because Asossa town is one of the areas which have 5-6 month range of rainy season, most people plant trees (Neem and Mango are common) and garden in their compounds to break wind. Similar report was conducted by (Asfaw, 2007) in Adama town.

From Table 5 the least solid wastes in terms of weight are Glass, Metal and textile wastes constituting only 0.4%, 0.8% and 2.65% in weight, respectively. Among those metal and glasses can be reused, recycled or remolded to other durable useful materials. As well as collector collected and sold to retailers and plastic, wood martial's are replacing most metal furniture's. Due to this reason the amount is very few. Lastly Plastic wastes constitute 4.9% by weight of the total waste generated. Due to its easy to handling materials and found everywhere, all community used for carrying daily consumed materials as well as easily move by wind. Particularly the final disposal site and its surroundings are being polluted by "Festal".

## 6.3 Approximate and ultimate Analysis of household solid wastes

The above table 6 shows moisture content of food waste (60.12%), ash (13.3%), plastic (4.98%), wood (42.05%) and textile (26.6). And the value of ultimate analysis in (table7) indicated that for food waste, carbon content (50), nitrogen content (4.3), C: N ratio (50:4.3) and PH (5.8) and yard waste contains carbon content (58), nitrogen content (5), C:N ratio (58:5) and PH (6.1). This study has similar result with other studies in Jimma town(Mekonnen, 2017).

## 6.4 Evaluation of potential composting by household solid waste in Asossa town

The chemical composition of bio degradable fraction of house hold solid waste (table 8) indicated that the C/N ratio (50:4.6), pH (5.9), and organic matter (69%). But they contain high average value of the HHSW samples against those of standards value. This value showed that the biodegradable fraction of solid waste was suitable for composting, because the value is in the limited range of standards (Fathi et al., 2014; Jilani, 2007).

Also the study presented that the kg per capital and per household solid waste generation rate of the town is 0.144 kg/cap/day or an average of 0.534kg/HH/day respectively (table3). This does not include generation rate for other municipal solid waste streams. And the composition of the waste generated in Asossa town was highly bio-degradable (88%) and especially in the study area high amount of household solid waste was food waste (35.9%). So, this provides the management options/technology/ to reduce this high amount of generated HHSW, high portion of biodegradable fractions of wastes and to avoided high accommodations of waste at dumping site and other storage site.

This indicates the bio-degradable waste (88%) of the town was suitable for microbial metabolism and composting processes. However, to obtain good quality compost, the C/N ratio of the waste can be adjusted to an optimum level by bio-degradable materials (Fathi et al., 2014). Generally the finding shows that the solid waste at the study area is suitable for compost and food wastes in particular. So that composting as an organic fertilizer would be the primary conversion technology and the best option for sustainable domestic solid waste management in Asossa town.

## 6.5. Analysis of physic-chemical parameters for quality of vermicompost

### 6.5.1 PH, EC and % Organic carbon

The nutrient values of vermicompost obtained in this study are presented in Table 9. The pH of food waste (control, T-1) value was 6.45, T2 (7.2), T3 (7) and T4 (8.7) during 0-45 day of decomposition period. This result indicates that the minimum and maximum PH value found in T1 and T4 respectively. The augmentation of PH value during the period (0-45 day) of vermicompsting process in T-2,T-3,and T-4 when compare to control(T-1) was the result of the metabolic degradation of organic matter and the presences of short-chain fatty acid in organic nitrogen (proteins, amino acids etc) helps to produce amines and ammonia salts or through mineralization or ammonification.

This leads to the continuous utilization of organic acids and increase in mineral constituents of waste (Majlessi,etal, 2012 and Othman & Irwan, 2012). The production of ammonia or $NH4^+$ ions that reduce the concentration of $H^+$ ions and the activity of calciferous glands in earthworms containing carbonic anhydrase that catalizes the fixation of $CO_2$ as $CaCO_3$, thereby preventing the decreasing of PH(Reddy, 2009).The value of pH initially slightly acidic (6.45) in control (T-1) but at finally decomposition period (45day) neutral or basic (Dadi et al, 2012).

Data in table 9 (fig-18) showed that continuous a decrease of the %OC content in the treatments (T2-T4) during vermicomposting period (0-45 day) compare to control (100% food waste) .The mean value of %OC at the end of the vermicomposting process was 28%,18.2%,13.2% and 11% in T1,T2,T3 and T4 respectively(table5 and fig 18).

As reported by (Majlessi, 2012),the combined interaction of earthworm and microorganisms through bio chemical degradation of waste martial and adding mucus and enzymes to the ingested materials and homogenization leads to OC loss in the form of $CO_2$ from the substrate during the decomposition of organic waste. In addition, some parts of organic fractions are converted into worm biomass during vermicomposting. Increasing the bulking agent proportion in the treatment of control (T1) and T4 increases the loss of carbon. And the existence of labile organic compounds, such as simple carbohydrates, fats and amino acids in high proportion food waste (100% of food waste in T1) and compare to other treatment (T2,T3and T4) that are degraded quickly in the first stage of vermicomposting(Nasiru, Ismail, & Ibrahim, 2013).

The mean values of EC all the treatments of vermicompost were range to be between 13.6±0.56-6.6±0.46ms/cm. this results had higher result compare to standards and recommended range for most plant growth. Generally the soluble salt content the vemicompost will not be highly harm for plants because it decrease continuously from T1to T4, and if the decomposition period increase may it came to the range.

### 6.5.2 NPK

The mean concentrations of PK in final treatment (T2,T3 and T4) were higher than initial T l (control) in all duration of vermicompsting. The mean concentration value ranges of P

(7.2±0.52-10.95±0.26ppm) and K (0.52±1.8-0.69±0.2ppm) in T1 and T4 respectively. The raising of PK concentration was due to mineralization of PK during vermicomposting was attributed to increasing alkaline (PK) by presence of PK-solubilizing bacteria, worm and enzymes activities(Padmavathiamma, et al; 2008). Therefore, the earthworm affects PK mineralization in wastes during organic matter passes through the gut of earthworms, unavailable PK are transformed to more soluble forms with enhanced microbial activity, which enhances the rate of mineralization. The highest increase in KP content was in T-4 followed by T-3, T-2 and T-1(table9).

The longer duration from 0 to 45 day of vermicomposting resulted in increasing of PK in all treatments *T1*, *T3* and T4 except T-2 for P decreases as shown in table 9 and Figure15. Another researcher supported the increasing of P and K contents is a direct action of earthworms gut enzymes and indirectly by stimulation of the micro flora(Amaludin & Ahmood, 2010; Dadi et al., 2012).

The total nitrogen content in all treatments was decreasing during the vermicomposting processing (T1-T4). The decline in the total nitrogen during the decomposition time might be attributed to the loss of nitrogen in the form of ammonia, this is apparent during the active phase of vermicomposting (Pirsaheb, et al, 2013). And the decreasing of %TN during vermicomposting, may be due to ammonification and ammonia volatilization, nitrification and denitrification. And the results is in the agreement with the quality of compost criteria which is used by most country (Dadi et al., 2012).(table9).

Table 10 showed Comparison of the quality of vermicompost (0-45 days) in deferent treatment with the EEPA,WHO, Italy USA and Belgium standard and the standard was used for evaluating good quality compost for selected parameters (%organic carbon, percentage of total nitrogen, C/N ratio, EC and pH ,macro nutrients and heavy metals).

### 6.5.3 Concentration of Ca, Mg and C: N ratio

The study result indicated that the concentration of Ca and Mg in T1(24.9,18.95), T2(28.45,22.7), T3(31.3,23.2)and T4(35.6,25.5) respectively. In vermicomposting process for the duration of 0-45 day the higher concentration of Ca in vermicompost, substrate attributable to the catalytic activity of carbonic anhydrase preset in calciferous glands of earthworms generating Ca $CO_3$ on the fixation of $CO_2$. The increasing of Ca and Mg sconcentration in vermicompost with in 0-45 day in different treatment was reported ( Padmavathiamma, et al, 2008).

The carbon/nitrogen (C: N) ratio is an important indicator for maturity/stability/ of organic wastes and its changes reflect the degree of mineralization and stabilization during the process of vermicomposting. The C: N ratios of substrate materials showed a decrease considerably during vermicomposting. The highest decrease in C: N ratio was in T4 (12:1) followed by T3 (13:1) and T 2(21:1) but it is continuously decreases during decomposition period from T1 (28:1) to T4(12:1)(control). The reduction in the C: N ratio during composting time may attribute to bio chemical degradation and release of organic carbon in the form of $CO_2$ . Reduction in C:N was recorded during vermicomposting of deferent waste(Ali Akbar Babaei1 , et al, 2016). The quality of final compost in the T4 was better than other treatment and it should be applied as a soil conditioner in agriculture and soil remediation. Treatment with higher amendment ratio obtained better quality due to aeration with increasing amendment(Elena, 2016).

The results of Fe and Cu have highest concentration in treatement-1 (food waste only) compare to other treatment in 0-45day. And Zn and Mn contain high concentration (4.7ppm and 3.8ppm) in treatment 4 (25 :25,:25,:25 food, cow dung, soil and corn stock) in all decomposition period (0-45 day). But the lowest concentration value Fe, Cu, Zn and Mn were found in T-3 and T-2 respectively. The result of heavy metal bioaccumulation in side earthworms' body showed that heavy metals concentration including Fe, Cu and Mn decreased as increased vermicomposting time. But concentration of Zn was increases may be due to less solubility (Shamini & Fauziah, 2014).s

## 5.7 Appropriate solid waste management technology for Asossa town

Appropriate SWM is the vital role for the development of a country. For the specific study, the biodegradable solid waste (88%) is leading. Specifically in household solid waste composition food waste contains 36.98% and results found from the laboratory (approximate and ultimate analysis), indicated suitable for compost(Fathi et al., 2014) and characteristics and compositions of waste that found the study area, enhance the appropriate solid waste management for Asossa town is composting.

Secondly, as the population of the town is not aware of the waste generation, on site handling and separation as well as recycling and reused. So that appropriate awareness should be given.

Thirdly and finally there is a need of a holistic approach like integrated solid waste management (ISWM) and steeled effort from all dominion of society, otherwise it will continue to adversely affect all three pillars of sustainability viz. social–environmental–economic.

# CHAPTER SEVEN

# 7. CONCLUSION AND RECOMMENDATION

## 7.1 Conclusions

The study indicated that per capital and per house hold solid waste generation rate was 0.144kg/cap/day and 0.534kg/HH/day respectively. And the daily, weekly, monthly and yearly generation rate of Asossa town by kg and tons were: 0.144kg, 1.0kg, 4.32kg, 52.52kg and 0.000144, 0.001, 0.00432 and 0.0525tons respectively. This does not included other municipal solid waste streams.

The composition of the waste generated in Asossa was dominated by food waste (36%), Ash and dust waste contains 19%, grasses (8.19%), leaves (12.69%), paper (3%), wood (4.94%), Catha edulis (4.18%), plastic (8.15%), metal (1%), glasses (0.4%) and textile (3%). From the composition of house hold solid waste biodegradable fraction was contributed (88%) and non biodegradable contributed (12%). With this high portion of 'bio-degradable' waste, composting of the waste would be advisable to Asossa town.

The proximate analysis results showed that the moisture content of the food waste (60.12%), ash (13.3%), plastic (4.98%), wood (42.05%) and textile (26.6) and chemical composition analysis results of bio-degradable house hold waste OC,(54), TN(4.6),C/N (54:4.6), pH (5.9), organic matter (69%) respectively. Based on the physic- chemical (approximate and ultimate) analysis of HHSW in Asossa town estimated the potential of composting.

In the vermicompost experimental result explained that the concentration of phosphorus and potassium as well as Ca and Mg were increased the decomposition period increase in all treatments. But C:N ratio, is decreases. And when you compare to composition of treatment, treatment-4 is greater than the control (food waste only). The differences of the concentration indicated that presence cow dung and leaf waste added increase the amount of phosphorus and potassium. This provides energy for worms in order to microbial activity that produce microbes. Then, the increase of the concentration of P, K, Ca and Mn is due to the earthworms feeding activity as well as durning decomposition of organic matter there was mineralization process and unavailable PK are transformed in to more soluble forms and enhanced microbial activity and helps for PK increments. And some physic chemical parameters results showed that the vermicompost in each treatment are in recommendation of EEPA, WHO ,USA standards as well as Italy and Belgium table 9 and vermicompost produced in 45day has good quality and suitable for soil conditioner and replacing of inorganic fertilizers. Therefore, the production of vermicompost from organic waste (food) waste can be considered as entrepreneurship for youth and community (farmers), their by economically and eco friendly ways can be developed.

## 7.2 Recommendation

- Findings of this study indicated that the biodegradable fraction which generated from household of the study area account for about 88% of the total. There for the municipality highly encouraged to apply a new ways of composting technology to transform biodegradable organic waste materials generated to convert in to natural fertilizer though vermicomposting which can be used in agriculture finishing a self-sustainable cycle and in Asossa town should be considered as a technically as well as economically visible option for SWM
- Because of eases to produce and economically feasibility to society and environmentally friend , municipality should be create awareness to the community and cooperate with all responsible body and community to use vermicomposting technology and reduced house hold solid waste by weight and volume and to remediate soil as well as to reducing solid waste at disposal site in Assosa town
- Based on the generation rate and composition of solid waste Asossa town integrated solid waste management system which combines a range of solid waste treatment options like, source reduction, composting, recycling and waste to energy transformation is recommended
- Further studies should be conducted to develop efferent integrated soil fertility management practices using food waste in combination with organic wastes available to the farmers. And additional study can be conducted in different seasons to compare the results of HHSW composition and generation rate and vermicompost quality above 45 day up to maturity level by the same composition of substrate materials.
- The municipality has to incite and motivate workers who have direct contact with waste and increase public awareness. Wastes disposed of illegally at any open spaces are not only because of lack of nearby containers or lack of municipal waste collection services but also due to lack of awareness of the consequences of mismanaged municipal wastes.
- From this study results, the 2$^{nd}$ large proportion of the generated wastes is Ash and dust so to reduce this and to keep environmental disturbance municipality should encourage other option of energy sources from solid waste.

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**Annex- II Changes In Physic-Chemical Parameters (Mean Values) During The Different Stages Of Vermicomposting**

| Parameters | Duration of vermicomposting | Treatment-1 | Treatment2 | Treatment 3 | Treatment 4 |
|---|---|---|---|---|---|
| | | Mena value | Mena value | Mena value | Mena value |
| pH | 0-day | 5.2 | 7.2 | 7 | 7.2 |
| | 15-day | 6.7 | 7.16 | 7 | 7.2 |
| | 30-day | 6.9 | 7 | 7.1 | 7 |
| | 45-day | 7 | 7.3 | 7.2 | 7.3 |
| EC(ms/cm) | 0-day | 5.6 | 6.5 | 2.8 | 2.9 |
| | 15-day | 4.5 | 6.6 | 3.3 | 2.9 |
| | 30-day | 21.3 | 31.3 | 12 | 9.8 |
| | 45-day | 23.2 | 34.3 | 13.4 | 10.9 |
| %OC | 0-day | 37 | 22.9 | 10.8 | 8.4 |
| | 15-day | 35.3 | 10.7 | 14.4 | 17.3 |
| | 30-day | 21.2 | 21.3 | 13.9 | 13.9 |
| | 45-day | 18.8 | 17.9 | 13.8 | 12.8 |
| %TN | 0-day | 2.9 | 2 | 0.9 | 0.7 |
| | 15-day | 2.8 | 0.9 | 1.2 | 1.4 |
| | 30-day | 1.8 | 1.8 | 1.2 | 1.2 |
| | 45-day | 2.9 | 2.3 | 1.3 | 1.4 |
| C:N ratio | 0-day | 37:1 | 23:1 | 11:1 | 9:1 |
| | 15-day | 35:1 | 11:1 | 14:1 | 17:1 |
| | 30-day | 21:1 | 31:1 | 14:1 | 14:1 |
| | 45-day | 19:1 | 18:1 | 14:1 | 13:1 |
| P(ppm) | 0-day | 5.6 | 10.4 | 10.1 | 9.2 |
| | 15-day | 5.8 | 11.3 | 11.7 | 10.9 |
| | 30-day | 9.2 | 10 | 9.9 | 11 |
| | 45-day | 9.5 | 11 | 10.4 | 11 |
| K(meq/100gsoil) | 0-day | 0.39 | 0.95 | 0.69 | 0.7 |
| | 15-day | 0.53 | 0.9 | 0.63 | 0.65 |
| | 30-day | 0.5 | 0.9 | 0.6 | 0.69 |
| | 45-day | 0.68 | 1 | 0.67 | 0.75 |
| Ca2++(cmol/100g soil) | 0-day | 4.5 | 28 | 25.8 | 18.5 |
| | 15-day | 28 | 26.9 | 36.5 | 30 |
| | 30-day | 40.4 | 59 | 36.2 | 27.3 |
| | 45-day | 28.5 | 44.3 | 35.3 | 39.1 |
| Mg2++(cmol/100g soil) | 0-day | 24.2 | 24.9 | 21.2 | 8.7 |
| | 15-day | 17.1 | 13.8 | 14.4 | 27.3 |
| | 30-day | 13 | 19 | 16.7 | 17.1 |
| | 45-day | 21.5 | 23 | 16.2 | 20 |
| Fe(ppm) | 0-day | 6.7 | 0.7 | 4.1 | 3.5 |
| | 15-day | 6.8 | 0.6 | 3.9 | 3.8 |
| | 30-day | 6.7 | 0.67 | 4.2 | 3.6 |
| | 45-day | 6.6 | 0.7 | 4.3 | 3.6 |
| Cu(PPm) | 0-day | 4.3 | 0.51 | 4 | 2.3 |

| | | | | | |
|---|---|---|---|---|---|
| | 15-day | 4.2 | 0.51 | 4 | 2.4 |
| | 30-day | 4.4 | 0.5 | 4.2 | 2.3 |
| | 45-day | 4.3 | 0.52 | 4 | 2.4 |
| Zn(ppm) | 0-day | 3.2 | 0.63 | 4.4 | 3.5 |
| | 15-day | 3.1 | 0.62 | 4.3 | 3.4 |
| | 30-day | 3.1 | 0.63 | 4.5 | 3.4 |
| | 45-day | 3.1 | 0.6 | 4.2 | 3.2 |
| Mn (ppm) | 0-day | 4.4 | 0.6 | 4.7 | 3.9 |
| | 15-day | 4.3 | 0.62 | 4.5 | 3.7 |
| | 30-day | 4.2 | 0.6 | 4.8 | 3.8 |
| | 45-day | 4.4 | 0.6 | 4.7 | 3.4 |

N.B:-The values are means of triplicates

# Annex-III Summary of Household solid waste Collected within 7 day

| Day | Woreda | Ketene | Component of collected solid waste in 213 household | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Food waste | Ash and dust | Plastic | Paper | Wood | Leaves | Grasses | Catha edulis | Metals | Glases | Textile |
| 1 | 1 | 2 | 15 | 17.5 | 6 | 1 | 1.5 | 7.5 | 4 | 1.4 | 1.5 | - | 0.5 |
| 2 | | | 30.5 | 8 | 10.5 | 1 | 1.5 | 3.5 | 3 | 2.5 | 0.5 | 0.5 | 4.5 |
| 3 | | | 16 | 13 | 5 | 0.5 | 2.5 | 3.5 | 2 | 2 | 0.1 | 0.1 | 0.5 |
| 4 | | | 16 | 29 | 3 | 2 | 3 | 10 | 0.8 | 1.5 | - | - | 0.2 |
| 5 | | | 14 | 10 | 2 | 1 | 1.5 | 9 | 3 | 2 | - | 0.5 | 0.3 |
| 6 | | | 13 | 9 | 3 | 2 | 2 | 8 | 4 | 1 | - | 0.3 | 0.5 |
| 7 | | | 12 | 5 | 2 | 1 | 1 | 7 | 3 | 1.3 | 0.2 | - | 1 |
| | | Total | **116.5** | **91.5** | **31.5** | **8.5** | **13** | **48.5** | **19.8** | **11.7** | **2.3** | **1.4** | **7.5** |
| 1 | | 5 | 21 | 30 | 4 | 1 | 4 | 4.8 | 8 | 1.5 | 0.5 | - | 1.5 |
| 2 | | | 12 | 0.5 | 4 | 2.5 | 3.5 | 7 | 0.7 | 1 | - | | 0.2 |
| 3 | | | 10 | 0.8 | 3 | 1 | 1 | 2 | 1 | 2 | 0.5 | 0.2 | 1 |
| 4 | | | 10.5 | 2 | 1.5 | 2.9 | 2 | 1.6 | 1 | 2.5 | - | | 1.5 |
| 5 | | | 13 | 2.5 | 1.9 | 3 | 2.5 | 1.7 | 1.5 | 1.8 | 1 | 0.5 | 1 |
| 6 | | | 14 | 3 | 2.5 | 1.5 | 1.5 | 2.6 | 1.5 | 1 | 0.3 | 0.3 | 2 |
| 7 | | | 13 | 1 | 1.5 | 1 | 1 | 2.5 | 1 | 1.5 | - | | 1.5 |
| | | Total | **93.5** | **39.8** | **18.4** | **12.9** | **15.5** | **22.2** | **14.7** | **11.3** | **2.3** | **1** | **8.7** |
| 1 | 2 | 2 | 10.5 | 1.7 | 3 | 0.5 | 1 | 4 | 3 | 1.2 | 0.3 | - | 0.4 |
| 2 | | | 9 | 2 | 2 | 0.8 | 2 | 3 | 6 | 0.7 | - | 0.2 | - |
| 3 | | | 9.1 | 3 | 1.8 | 1 | 1.4 | 3.5 | 5 | 1.1 | 0.5 | 0.1 | 0.5 |
| 4 | | | 13 | 1.5 | 2 | 0.7 | 1.6 | 2 | 2.8 | 1.2 | - | - | 3 |
| 5 | | | 12 | 2 | 2.3 | 1 | 1.9 | 6 | 6 | 1.3 | - | 0.2 | - |
| 6 | | | 10 | 4 | 1 | 0.5 | 2 | 7 | 3 | 1.5 | 0.3 | - | 0.5 |
| 7 | | | 13 | 5 | 3 | 1 | 1 | 5 | 5 | 1.9 | 0.4 | 0.3 | 0.6 |
| | | Total | **76.6** | **19.2** | **15.1** | **5.5** | **10.9** | **30.5** | **30.8** | **8.9** | **1.5** | **0.8** | **5** |
| Total of 7 day in 3 ketena | | | | | | | | | | | | | |

## Annex-Iv Survey semi Questioners

Deer respondents, this is Damtew Mekonene I would like to inform you that this semi questionnaire is prepared for academic purpose only; that is, I am conducting a research, which is entitled on **"Municipal solid waste generation rate, Characterization and waste transformation through vermicomposting",** for the fulfillment of MSc Degree in Environmental science and Technology in Jimma University, Ethiopia.

Besides, the outcomes of this research will help the efforts made by the responsible bodies or individuals to resolve or mitigate the problems of solid waste management in the city.

Thus, respondents by understanding the importance of this research work, I kindly request you to fill this check list honestly without any hesitation. Thank you in advance for your cooperation!!!!

**N.B**

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

2. You are not required to write your name

3. You are kindly asked to read carefully and respond to each and every questions included within the check list

4. You are required to fill the questioners/ check list/, 30min to complete

5. Please put a **"×"** mark in the box of your choice.

Code: ______________

Name of enumerator:____________________________

Name of supervisor:________________________________

Woreda ------------ketena------------- sefer------------------------

## I.DEMOGRAPHIC CHARACTERISTICS

1. Age of the household head: (1) 19-36 (2) 37-65 (3) >65

2. Sex of the household head is (1) male (2) female

3. Educational status of household head is: (1) <4 (2)-5-8 (3) 9-12 (4) 12+

4. How long have you stayed here in the city of Asoosa? ___________year (s)

5. Could you please tell me your household's monthly income<600,601-1000,>1000birr/month

6. Could you please tell me the size of your HH including yourself (1) <4 (2) 5-6 (3) 7+

## II.CURRENT SITUATION OF HOUSEHOLD SOLID WASTE MANAGEMENT

7. What are the major solid wastes that your household averagely generates per day?

(**Rank** them in terms of higher proportion in volume of all of the wastes)

| | (1) | (2) | (3) | (4) | (5) |
|---|---|---|---|---|---|
| Ash | [ ] | [ ] | [ ] | [ ] | [ ] |
| Food wastes | [ ] | [ ] | [ ] | [ ] | [ ] |
| Wood | [ ] | [ ] | [ ] | [ ] | [ ] |
| Grasses | [ ] | [ ] | [ ] | [ ] | [ ] |
| Leaves | [ ] | [ ] | [ ] | [ ] | [ ] |
| Catha edulis | [ ] | [ ] | [ ] | [ ] | [ ] |
| Paper | [ ] | [ ] | [ ] | [ ] | [ ] |
| Metals | [ ] | [ ] | [ ] | [ ] | [ ] |
| Glass | [ ] | [ ] | [ ] | [ ] | [ ] |
| Plastics | [ ] | [ ] | [ ] | [ ] | [ ] |
| Textile | [ ] | [ ] | [ ] | [ ] | [ ] |
| Other, please specify | [ ] | [ ] | [ ] | [ ] | [ ] |

______________________________________________________________

8. Do you have a temporary solid waste storage in your house?

(1) YES (0) NO

If No, go to question 9

10. What kind of storage do you use?

(1). Basket (2) plastic bags

(3) Plastic dust bin

(4) Wooden container

(5) Sack (6) write, if any -------------------

9. If No, how can you store solid wastes or how you come across with the problem of solid waste storage?

___________________________________________________________________

10. Is solid waste disposing container available in your neighborhood?

(1) YES (0) NO

12. If your answer for question No. 9 is "NO", what other means do you use to dispose off the solid wastes of your household?

(1) Throw it on an open space, in sewerage or on street

(2) Digging a hole around the house and burn it

(3) Disposing on the backyards of the house

(4) Throw it in to the nearby rivers

(5) Private collectors take it

(6) Others, please specify__________________________

13. Have you ever seen solid wastes from residential houses thrown away (dumping) on streets, in sewerages or in nearby rivers?

(1) YES (0) NO

14. If your answer for question No. 13 is "YES", how frequent do you come across these solid wastes thrown away illegally?

(1) Always (3) some times

(2) So many times (4) rarely

15. How frequently do you usually dispose your wastes to either of your choice dumping place?

(1) Every day (4) every week (7) Once a month

(2) Every 2 to 3 days (5) every two weeks (8) if any other: ---------

(3) Every 4 to 5 days (6) every three weeks

16. What time do you prefer to dispose your household wastes?

(1) Early morning (3) noon (5) early night

(2) Late morning (4) afternoon (6) the time of private waste collectors

17. Is there any micro and small enterprises that collect solid wastes via door to door system in your ketena?

(1) YES (2) NO

If NO, go to question 21&22

18. How long have you been getting the service?

(1) For one year (3) for 3 years and above

(2) For 2 years (4) indicate if any other ____________________

19. How often do the MSEs collect solid wastes from your house?

(1) Weekly (2) monthly

(3) Twice a month (4) please indicate if any other ______________________

20. How much do you pay for the MSEs Services, indicate in birr? _______________

21. What do you do with the solid waste from your household if the MSEs or the municipality truck did not come at the right time and find your temporary storage full?

(1) I keep the waste at home until the collectors are coming by using other storage

(2) I burn it in the back of my home

(3) I dump it on open space, which is far from the main road

(4) I dump it in sewerage

(5) Indicate if any other alternatives _________

**III.AWARENESS AND ATTITUDE TOWARDS SOLID WASTE MANAGEMENT**

22. What do you think of solid wastes? Do you think solid wastes are?

(1) Useless (3) useful

(2) Somewhat useful

23. Do you agree with the importance of solid waste management?

(1) YES (2) NO

24. Does your household practice waste separation?

(1) YES (2) NO

25. If YES, how do you separate it? -------------------------------------------

26. If NO, what do you think the reason behind?

(1) I do not have the understanding about waste separation

(2) I did not think as it is my responsibility

(3) I did not visualize the importance of separation

(4) if any other reason, please specify it --------------------------------------

27. Do you know that your solid waste generation is affected by or related to your consumption pattern?

(1) YES (2) NO

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

29.1 If Yes,

- Type of reused wastes ________________________________________
- Purpose of Reused wastes _____________________________________
- Do you compost wastes? Yes ___________ No _____________

30. Energy availability is

- Firewood and cow dung ____________________
- Firewood, cow dung and charcoal ____________________
- Firewood, charcoal, kerosene, electricity ________________

If others specify_____________________________________

30. Who do you think is responsible for solid waste management?

(1) The municipality (5) The municipality and the private waste collectors

(2) The private waste collectors (6) municipality and household

(3) The households (7) All of the above bodies are responsible

(4) The household and the private waste collectors

31. Do you know that there are rules and regulations of solid wastes in Asossa city?

(1) YES (2) NO

32. How do you evaluate the follow – up by the responsible bodies to practice the rules and regulations of solid waste disposal in Asossa?

(0) none at all (1) regulation is weak (2) regulation is strong

33. In what way did you get solid waste related information from your town municipality?

(1) In general meeting of the town (3) in edit meeting

(2) In ketena meeting (4) if any otther ------------

## Annex- V Check list about Asossa Town

1. Is there municipality service for managing the MSW? Yes _______ No ______

1.1 If yes, specify the department _____________________________________

2. How many landfill sites Asossa town have? __________

3. How far are/is the dumping site from the town in km? ________. Is the landfill site protected (Fenced etc…) _____________________________________________

4. Are there street cleaning organizations in the town which are organized by the municipality? Yes _________ No ____________

4.1 If yes, their number. Male ______ Female ______ Total ______

5. Are their Micro Enterprises organized in the town for collecting solid waste?

Yes ____________ No______________

If yes, Please list names of MSE and their numbers;

| Name of MSE | Male | Female | Total | Kebele |
|---|---|---|---|---|
| A. ________________________ | ____ | _____ | _____ | ________ |
| B. ________________________ | ____ | _____ | _____ | _________ |
| C. ________________________ | ____ | _____ | _____ | _________ |
| Total | _____ | _____ | _____ | |

6. How many containers are there in the town? __________

7. How is the distribution of the containers in each ketena ______________________

8. How many lifting tracks Assosa town have? ___________ Is it functioning by now?

Yes _______ No ____________

8.1 If No, what means does the municipality use? ______________________________

8.2 Are there NGOs or any organization who support the municipality to control or to lift solid waste ?____________________________________________________

# Annex-Vi Household Solid Waste Composition Form-1

| S/N | Code | | Initial HH Waste composition weight(kg) | | | | | | | | | | | | | | | | Remark |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Weight (kg)B-1 | | | | | | | | Weight (kg)NB-2 | | | | | | | | |
| | | | **WOREDA-1,KETENA-2** | | | | | | | | | | | | | | | | |
| | | | Day | | | | | | | | | | | | | | | | |
| | | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | |
| | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | |
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| | | | | | | | | | | | | | | | | | | | |

NB2=non biodegradable Remark-B1= Bio degradable

Annex-Vii Household Solid Waste Composition Summery Form-2

| S/ N | | | Woreda-1 Waste Composition Weight(Kg) | | | | | | | | | | | | | | | | | | | | | Remark |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | KETENA-2 | | | | | | | | | | KETENA-5 | | | | | | | | | | | |
| | Sampling date | Food waste | Ash | Plastic | Paper | Wood | Leaves | Grasse | chat | Metals | Glass | | Food waste | | | Paper | Wood | Leaves | Grasse | chat | Metals | Glass | Textile | |
| | | | | | | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | | | | | | |
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| | | | | | | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | | | | | | |
| Volume(L) | | | | | | | | | | | | | Volume(L) | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | | | | | | |

**Annx-XI. Reagents, Apparatus, Procedures and Formula Using to Analysis Physic-Chemical Parameters**

1. **MOISTURE CONTENT**

**1.1APPARATUS**

- Moisture tins (aluminum dishes) or flasks with fitting lid.
- Drying oven
- Desiccators
- Analytical balance.

**1.2 PROCEURE**

1. Weigh out precisely 5g of air dry soil in a clean, dry, pre- weighed and recorded moisture-free tin with 0.001g accuracy (weight A= air-dry soil + tin weigh)

2. Put the moisture tin with sample in an oven at $105^0$c overnight or for at least 6hours, with the tin.

3. Remove the tin from oven, close with lid and put into desiccators to cool off (for 30 minutes).

4. Remove the tin from desiccators and weigh once more.

**1.3. CALCULATION**

The moisture content in % by weight is obtained as follows

$$\text{Percent moisture} = \frac{(\text{A} - \text{B})x100}{\text{B} - \text{weight of tin}}$$

Where A= weight of air-dry soil (5g) + tin weight

B= weight of oven-dry soil in grams + tin weight

The corresponding moisture correction factor (mef) for analytical results or the multiplication factor for the amount of sample to be weighed for analysis is

$$\text{Moisture Correction} = \frac{100+\%\text{moisture}}{100}$$

## 2. Soil pH

### 2.1. APPARATUS

- Ph meter with glass-calomel combination electrode
- Automatic stirrer with timer(glass rods can also be used to stir mechanically)
- 100ml beakers
- Analytical balance with 0.1g precision
- Thermo meter

### 2.1 REAGENT

- Standard buffer solution with pH values of 4.00, 7.00, and 9.00(10.00); Dilute standard analytical concentrate capsules according to instructions.

### 2.3 PROCEDURE

**Measuring PH in water suspension**

**1.** Weigh 10gair-dried <2mm soil in to 100ml beakers.

**2.** Add 10ml distilled water from a measuring cylinder for 1:1 soil/water suspension or 25ml distilled water for 1:2.5 soil/water suspension.

**3.** Transfer the samples to an automatic stirrer, stir for 30 minutes and measure pH on the upper part of the suspension.(if you are using a glass rod stirring, stir for 1 minute and allow the sample to equilibrate and measure pH after 1 hour on the upper part of the suspension at  an accuracy of 0.1 unit)

## 3. ELECTRICAL CONDACTIVITY

### 3.1. APPARATUS

- Analytical balance (0.1g)
- Oven
- Conductivity meter
- Spatulas
- 1000 and 500 ml volumetric flasks
- 250 ml beakers
- Desiccators
- Thermometer

### 3.2. REAGENTS

- Standard buffer solution with pH values of 4.00, 7.00, and 9.00(10.00); Dilute standard analytical concentrate capsules according to instructions.

### 3.3 PROCEDURE

**Extraction**

1. Weigh 10g of soil sample into a 250 ml beaker.
2. Add 50ml of distilled water and shake on the automatic stirrer for 30 minutes (or use a glass rod to stir the mixture periodically for 30 minutes).

## 4. ORGANIC CARBON

### 4.1 APPARATUS

- 500 Ml Erlenmeyer flask
- 10ml pipette
- 10 and 20ml dispense
- 50ml burette
- Analytical balance
- Magnetic stirrer
- Incandescent lamp

### REAGENT

1. Potassium dichromate solution, 1N; Dissolve 49.04g $K_2Cl_2O_7$( dried at 105°c) in distilled water in a 1 liter volumetric flask and make to volume with distilled water store in a glass stopped bottle.
2. Concentrated sulfuric acid (Sp. gr. 1.84) 98% (*w*/w).
3. Concentrated orthophosphoric acid ( $H_3PO_4$) ( Sp .gr1.75).
4. Barium diphenylamine sulphonate indicator, 0.16%; Dissolve 0.16g of barium diphenylamine sulphate in 100ml of distilled water.
5. Ferrous sulphate solution 0.5N; Dissolve 139 g Fe $SO_4$ $7H_2O$ in 750 ml of water and add 20ml, conc. $H_2SO_4$. Transfer to a 1 liter volumetric flask and make to volume with water

**4.2 PROCEDURE FOR VISUAL END POINT TITRATION**

1. Weigh 0.1-2g air-dry soil (<2mm) and transfer to a 500ml Erlenmeyer flask. Use up to 2g of sample for light colored soils and 0.1g for organic soils. Include two blanks.
2. Add 10ml 1 N $K_2CL_2\ O_7$ solution with pipette to both samplers and blank.
3. Carefully add 20ml conc.$H_2SO_4$ with measuring cylinder in the fume cupboard and swirl the flask and allow standing on an asbestos or cork pad for 30 minutes.
4. Then add 200ml distilled water and allow it to cool.
5. Add 10ml conc.orthophosphoric acid and just before titration add 0.5ml of barium diphenylamine sulphonate indicator.
6. Titrate both samples and blanks with 0.5 N ferrous sulfate solution until the color changes to purple or blue, then add ferrous sulfate solution drop by drop until the color flashes to green they continue to alight green end point.

**4.3 CALCULATION**

$$\%C = N \times \frac{V1 - V2}{S} \times 0.39 \times mcf$$

Where

N = normality of ferrous sulfate solution (from blank titration)

V1 = ml ferrous sulfate solution used for blank

V2 = ml ferrous sulfate solution used for sample

S = $3 \times 10^{-3} \times 100\% \times 1.3$ (3 = equivalent weight of carbon)

Mcf = moisture correction factor.

**5. PHOSPHOURS SOILUBLE IN SODIUM BICARBONATE**

**(Extraction according to Olsen et al.)**

**5.1 APPARATUS**

- Spectrophotometer suitable for measurement at 880nm.
- Polythene shaking bottles 250ml
- Reciprocating shaking machine
- Analytical balance
- Funnel racks
- Funnel

- What man No 42 filter paper ( or equivalent)
- Volumetric flasks and pipettes as required for preparation of reagent, standard solutions color development.

### 5.2 REAGENT

**1.** Sodium bicarbonate solution 0.5 m, PH 8.5 (extracting solution); Dissolve 42.g Na $HCO_3$ in water and make to 1L. Adjust the PH to 8.5 by adding NaOH 1M (4GGGG/100ML). In case of over shooting of PH above 8.5, add some $NaHCO_3$.

**2.**Sulfuric acid 4 M; Slowly add 56ml concentrated $H_2SO_{4(}$96%,5.G 184) to about 150ml distilled water in a graduated beaker under constant stirring .After cooling make to 250ml with distilled water.

**3.** Ammonium molybbdate solution 4%, Dissolve 4g of $(NH_4)_6Mo_7O_{24}4H_2O$ in water and make to 100ml Store in polythene or Pyrex bottle.

**4.** Potassium antimony titrate solution 0.275% (1g/1sb);Dissolve 0.275g $KSbOC_4$ $H_4O_6$ in water and make to 100ml.

**5.**Ascorbic acid solution, 1.75%; Dissolve 1.75g ascorbic acid in water and make to 100ml prepare fresh daily.

**6.** Mixed Reagent successively add with a measuring cylinder to a 500ml polythene or Pyrex bottle and homogenize after addition of each of the following.

50ml of 4M $H_2SO_4$

- 15ml of$NH_4$-molybdatesolution
- 30ml of ascorbic acid solution
- 200ml of water
- 5ml potassium antimony titrate solution

### 5.3 Standard solution (prepare fresh daily)

- Standard phosphate solution, 100mg/1p;Dissolve 0.4394g $KH_2PO_4$(dried at $105^0$C for two hours in an oven ) in distilled water in a liter volumetric flask and make to volume with distilled water.

- Standard phosphate solution, 4mg/1p pipette 10ml of the 100mg/1p Standard solution into a 250ml volumetric flask and make to volume with extracting solution.
- Standard serious; pipette in to 100ml volumetric flask 0-10-20-30-40-50 ml of the 4mg/ 1p standard solution .Make to volume with extracting solution the standard series is 0-0,4-0,8-1,2-1,6-2, 0mg/p.

**5.4 PROCEDURE**

1.Weigh 5g of <2mm soil (accuracy 0.0111g) in to a 250ml polythene shaking bottle include two blanks and reference sample.

2. Shake for 30 minutes on a mechanical shaker.

3. Filter through what man no.42 filter paper.

4. If filtrate is not clear add 1 spoon p-free charcoal, shake again and filter.

5. Pipette in (short) test tube 3ml of the standard series the blank and the sample extracts.

6. Slowly adds 3ml of the mixed reagent by pipette and swirl ($CO_2$ evolution)

7. Allow the solutions to stand for at least 1 hour for the blue color to develop to its maximum

8. Measure absorbance on spectrophotometer at 882or 720nm

**5.5 CALCULATION**

$$P\ (\text{ppm or mg/100kg soil}) = (a\_b) \times \frac{100}{S} \times mcf = (a\_b) \times \frac{100}{s} \times mcf$$

Where

a = mg/1 p in sample extract

b = mg/1 p in blank

s = sample weight in gram (5)

mcf = moisture correction factor

100 = ml of extracting solution

Conversion factor $P_2O_5$ = 2.29 X P