***ADDIS ABABA UNIVERSITY***
***SCHOOL OF GRADUATE STUDIES***
***ADDIS ABABA INSITUTE OF TECHNOLOGY***
***SCHOOL OF CHEMICAL AND BIO-ENGINEERING***

# *Life Cycle Analysis (LCA) and Emission Reduction Evaluation of Compost from Floriculture Waste*

*A thesis Submitted to the Research and Graduate School of Addis Ababa University, Addis Ababa Institute of Technology, School of Chemical and Bio-Engineering in partial fulfillment of the requirements for the attainment of the Degree of Masters of Science in Chemical Engineering under Environmental Engineering Stream.*

*By: Abeba Getu Tadesse*

*Advisor: Dr. Tasissa Kaba*

*FEBRUARY, 2014*

*ADDIS ABABA, ETHIOPIA*

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*Approved by the Examining Board:*

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*Chairman, Department's Graduate Committee*

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*Advisor*

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*Internal Examiner*

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*External Examiner*

## *DECLARATION*

*This is to certify that this thesis entitled "Life Cycle Analysis (LCA) and Emission Reduction Evaluation of Compost from Floriculture Waste " Submitted to the Research and Graduate School of Addis Ababa University, Addis Ababa Institute of Technology, School of Chemical and Bio-Engineering in partial fulfillment of the requirements for the attainment of the Degree of Masters of Science in Chemical Engineering under Environmental Engineering Stream,done by Abeba Getu Tadesse under my guidance. The work contained in this thesis has not been previously submitted for a degree or diploma at any other higher education institutions to the best of my knowledge and belief.*

*Student:* ________________________ ___________________
*Abeba Getu* *Date*

*Advisor:* ________________________ ___________________
*Tasissa Kaba (Ph.D.)* *Date*

## Acknowledgments

First and for most, I wish to thank my lord and savior Jesus Christ for his never ending love, mercy and blessings over my life.

I would like to extend my sincere gratitude to my advisor Dr Tasissa kaba. I am extremely grateful for receiving the invaluable guidance, coaching, stimulating suggestions and untiring encouragement that he showed during my research and thesis writing.

I owe my sincere thanks to this blessed great family: my father, Getu Tadesse, for his words of wisdom and direction that has always been my driving force; my mother, Elisabeth Kibret ,for her prayers, guidance and her continual and selfless love which is beyond limits ;my beloved elder sisters and brothers , no words , but thank you for being my role model and best friends always ,I always proud in all of you .But special thanks to Eyerusalem Getu . Long live to all.

I am indebted to Ato Zerihun Abate for his continuous guidance, direction and tremendous partnership throughout the research phases.

I also extend my appreciation to Addis Ababa Institute of Technology Environmental Engineering Laboratory assistants, exceptionally grateful to Ato Yosan Teshome for his heartily and continuous technical support.

I would also like to thank Ato Bilhat Leta, for his support in the research materials collection and experimental setups.

I would like to acknowledge also the Ministry of Environment and Forest Ethiopian Environmental Protection Authority (EPA) soil laboratory staff members, especially Selam; Addis Ababa University Science Faculty chemistry Department Laboratory staff member Ato kahilye and Mechanical engineering workshop staff member Ato Temesigen for your un endless support.

Finally my sincere appreciation also extends to all my colleagues and others who have provided assistance at various occasions.

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## Acronym

| | |
|---|---|
| AAS | Atomic Absorption Spectrometer |
| AD | Anaerobic Digestion |
| CERF | Compost Emission Reduction Factor |
| $CO_2$-eq | Carbon dioxide equivalent |
| ESD | Ecologically Sustainable development |
| EU | European Union |
| GHG | Green House Gases |
| GA | Gas Analyzer |
| LCA | life cycle analysis /Assessment |
| LCI | Life Cycle Inventory |
| LCIA | Life Cycle Impact Assessment |
| MSW | Municipal Solid Waste |
| IPCC | International Panel for Climate Change |
| ISO | International Standardization Organization |
| OHW | Organic Household Waste |

# Abstract

*Global climate change has increasingly gained worldwide attention. The concentration of greenhouse gases in our atmosphere is becoming an issue of increasing concern. To address this problem, it is believed that examining greenhouse gas emissions from different sources is important .Quantification of greenhouse gas emissions from composting facilities is necessary to quantify actual emissions from these systems and which requires a life cycle (cradle to grave) approach. This thesis identifies, quantifies, evaluates and recommends the environmental impact (global warming potential) associated with the flower farm waste composting process using life cycle analysis (LCA) according to ISO14000(2004). The system considered in this study include receipt of source from the farm , transport to the compost production area , production of mature compost and application of compost to a soil for subsequent agricultural application by planting a plant .Under composting emission (*$E_{total}$*);Transport emission (Te), Process emission (Pe) and Fugitive emission (Fe) were the three Composting system emissions. The result demonstrates that from the three emission categories, transportation is the highest emitter with 59%* $CO_2$ *eq than fugitive and process emissions. The results for* $CO_2$*,* $CH_4$*, and* $N_2O$ *indicate that* $CO_2$ *is the most significant contributor in all three emission categories with values of 145.26 kg/ton for transport emissions, 90.75 kg/ton for fugitive emissions, and 11.18 kg/ton for process emissions. Compared to* $CO_2$ *the contributions of* $CH_4$ *and* $N_2O$ *are insignificant with values running from 0 to 8.09E-03 for* $CH_4$ *and 0 to 3.66E-03 for* $N_2O$*. In general composting emission (*$E_{total}$*) the benefit of post application impact (*$B_{total}$*) and the Compost Emission Reduction Factor (CERF) became 249.403 kg* $CO_2$ *eq, 653.44 kg*$CO_2$*eq and 404.037* $CO_2$*eq per ton of feedstock respectively. The results of this study indicates significant environmental benefits arise from the commercial composting system, including net greenhouse benefits, even where the compost is transported significant distances (200kms radius) for agricultural application.*

**Key words:** *greenhouse gas emissions, global warming potential, cradle to grave, fugitive emission, Transport emission, Process emission, Composting emission, Emission Reduction Factor*

# 1. Introduction

## 1.1 Background

Disposal of Municipal Solid Waste (MSW) has been mainly through land filling, incineration and centralized composting and anaerobic digestion facilities in urban areas around the world. These processes involve direct and indirect emissions of greenhouse gases (GHGs) including carbon dioxide ($CO_2$), methane ($CH_4$), nitrous oxide ($N_2O$) and Non-Methane Hydrocarbons (NMHCs) and contribute to around 3-4% of the anthropogenic GHG emissions in terms of $CO_2$-equivalent ($CO_2$-eq). Anaerobic decomposition of these wastes in the landfills results in the emission of $CH_4$ and as such contributes significantly to the global greenhouse budget.

With the current national environmental focus on greenhouse gas issues, a tendency has developed to compare technologies on this basis, and provide financial incentives for technologies that claim superior greenhouse performance. However, a policy based on a single environmental impact is flawed, as there are many other environmental impacts, which could be more detrimental to the environment. It can be argued that the current implementation of greenhouse gas programs and incentives is distorting priorities and compromising Ecologically Sustainable Development (ESD) in the resource recovery sector.

Two primary principles of ESD are the conservation of biological diversity and ecological integrity and intergenerational equity. Soil and water resources are finite and need to be protected for future generations. Currently the majority of compostable organic materials generated are sent to landfill disposal sites. Such practices diminish soil and water resources and are inconsistent with the principles of ESD. The Waste Avoidance and Resource Recovery Act (2001) define an explicit objective of encouraging the most efficient use of resources and to reduce environmental harm in accordance with the principles of ESD. Composting of organic materials e.g. food organics and garden organics is one method of managing these valuable materials, while at the same time adhering to the ideals of ESD. However, the impacts of composting need to be evaluated and compared with alternative methods of organics management e.g. waste to energy, landfill disposal, etc. in order to understand and compare the total environmental risks and impacts of these different management systems. For decades the approach to environmental issues has been limited to protecting and restoring the environment, while only in recent years the focus has been addressed towards the careful management of resources, based on the life-cycle concept.

An international standard for LCA established by the International Standardization Organization (ISO) has emerged and is undergoing evaluation and revision. Life cycle Analysis (LCA) provides a framework and methods for analyzing and assessing the environmental aspects and the potential impact of a material, product or service over the entire period of its life cycle (cradle to grave). Life Cycle Assessment (LCA) modeling to be conducted to enable informed comparison of the environmental impacts of various organics management systems. Life cycle assessment is a valuable tool for the assessment of environmental impacts, giving quantitative and qualitative information on resource consumption and environmental emissions of the system investigated. Life cycle assessment provides a basis for making informed decisions with regard to resource recovery priorities for the management of compostable organic materials.

Clearly there is now recognition that LCA has an important contribution to make to informed decision making in terms of government strategy and priorities. LCA may also be fundamental to developing a consistent whole of government approach to environment management and ESD. The ISO standards (2004) considered were;

- ISO 14040 covering LCA within environmental management
- ISO 14041 covering inventory analysis
- ISO 14042 covering impact assessment
- ISO 14043 covering interpretation

## 1.2 Description of the Study Area

Ziway, a city in the Oromia region of central Ethiopia, has a latitude and longitude of $7^{o}$56’N $38^{o}$43‘E with an elevation of 1643 meters above sea level. Lake Ziway, one of the rift valley fresh water lakes, is an important water source for the community. Adjacent to Lake Ziway, the economy of the town is based on fishing and horticulture. Sher Ethiopia International is the one among the floriculture industries located at the shore of the lake and used as a targeted site for the source of row material. Soil and more Ethiopia, a company for composting the floriculture waste commercially, is found around 5 kms from Sher Ethiopia International.

Fig. 1.1 Map of Ziway and Sher Ethiopia International (near Lake Ziway), (Google Earth, 2014)

## 1.3 Statement of the Problem

Numerous local and international industry and state government agencies have expressed a need for Life Cycle Assessment to inform environmental decision making in relation to the streaming and management of solid waste. To date, the true GHG impacts of the various organics management options remain unknown and are still in debate. The claims regarding the GHG benefits of alternative management options of organics such as composting have yet to be substantiated by real world operating experiences. One of the barriers preventing an assessment of the full environmental benefit of composting has been a lack of life cycle inventory data, that is, measures of impacts and benefits at each stage of the life cycle.

In particular, data has been lacking on the actual impacts of composted flower farm waste products provide to soils and plants which is the so called fertility potential of the compost. It is known that the use of such products have a great impact on global climate change, but these benefits have not been quantified or calculated. Waste recycling and composting of some wastes affects greenhouse gas emissions when viewed from a life-cycle perspective. However, comparative studies today have not addressed in any significant manner. Once composts from organic wastes products have been applied the impacts resulting from the use of recycled products is not known yet.

Ethiopia's favorable climate, comparatively abundant land and labor as well as reasonably good water resources created ample opportunities for floriculture production .Ethiopia is the second largest producer of roses on Africa , with Kenya leading and sixth in the world after Holland, Colombia, Ecuador, Kenya and Isreal.

Among the flower farms at the shore of Lake Ziway, Sher Ethiopia International, found around Zeway, is the largest flower farm. It is estimated that the company generates more than 33 tones of flower farm waste per day which is disposed and accumulated on the farmers' land that was used for farming before. In addition the floriculture industries located at the shore are discharging there wastes directly in to the lake, as a result due this offensive solid waste management;

- The water quality as well as the aquatic life is being deteriorated
- Green house gases may generate at high concentration

- Due to the accumulation of waste , the odors and the leachates are affecting the health of the community and the ecosystem of the city as well
- Large hectares of the farm lands in the city is being covered by the disposed waste instead
- Furthermore the city may lose its aesthetic values, etc

## 1.4 Objectives

### 1.4.1 General Objective

To analyze the life cycle and to evaluate the emission reduction of compost from floriculture waste

### 1.4.2 Specific Objectives

- To develop a comprehensive Life Cycle Inventory (LCI) for floriculture waste composting systems
- To quantify the global warming potential of compost from floriculture waste
- To rank the relative contribution of each life cycle stage of compost from floriculture waste towards the total environmental burden
- To analyze the fertility potential of compost from floriculture waste
- Establish baseline information pertaining to the energy and resource requirements and the environmental burdens caused by composting system

## 1.5 Significance of the Study

This study provides a comprehensive Life Cycle Inventory (LCI) for commercial composting systems and analyzes the environmental impacts of the commercial composting systems from flower farm waste using Life Cycle Analysis (LCA).The LCI data in this study also transparently developed and documented to allow for application in future comparative LCA studies. This study also developed valid life cycle inventory data and conduct a life cycle analysis study so that it will help government strategy for resource recovery decision making. This will enable the environmental assessment of the windrow composting system in Ethiopia, which has not previously been possible.

## 1.6 Scope of the Study

This thesis identifies, quantifies, evaluates and recommends the environmental impacts associated with the flower farm waste composting process using life cycle analysis (LCA) from the point at which compostable organic materials are delivered to a commercial composting facility to the agricultural application of the resulting composted product. The system considered in this study include receipt of source from the farm , transport to the compost production area , production of matured compost and application of compost to a soil for subsequent agricultural application (including planting a plant for the analysis purpose).

# 2. Literature Review

## 2.1. Floriculture Development in Ethiopia

Floriculture can be defined as a discipline of horticulture concerned with the cultivation of flowering and ornamental plants for gardens and for floristry, comprising the floral industry. It can also be defined as the segment of horticulture concerned with commercial production, marketing, and sale of bedding plants, cut flowers, potted flowering plants, foliage plants, flower arrangements, and noncommercial home gardening. Flowers are luxurious products with high social value and rarely used for food. The demand for these luxurious products has increased in the international market in recent years. The Netherlands is the leading exporter accounting for some 54 % of world trade. (Mulugeta Getu, 2009; wikipidia, 2013)

In recent decades, the global demand for cut flowers has grown considerably. This growth in market demands and its diversification value has attracted increasing numbers of developing countries to the global fresh flower trade (wikipidia, 2010)

Though floriculture development in Ethiopia has been blooming in recent years, it started for commercial purpose since 1980/81. The country had established its floriculture sector development corporations to produce regulatory and market of its horticultural products. It showed modest increase in 1990s by 2-3 % of the agricultural output of the country. In 2001 it contributed to $ 4.7 million to the country's foreign currency earnings. It is not yet significant to develop the country's economy. In five years time it is projected that the total export earnings would be increased at least five times that figure (Mulugeta Getu, 2009).

The recently initiated flower production areas are mainly around Addis Ababa, Upper Awash valley and Lake Ziway. Addis Ababa, the capital, with its altitude elevated about 2000 meters is suitable for production of high quality roses. Besides facilities like roads, power, telecommunication and water have been availed floriculture investors. Most of foreign and domestic investors on flower production have started their production on this area. In the Upper Awash Valley with an altitude spanning from the range of 1200 to 1400 meters the farms are located along the length of the River Awash with in 149 – 220 km away from the capital. Lake Ziway which is located in the southern region of the country (165 km from Addis Ababa) the farms situated between Lake Ziway and the main highway with altitude ranges between 1600–1700m above sea level.(Abdulfetah Sherefa, 2012)

## 2.2. Climate Change and Solid Waste Management

Climate change is the defining challenge for human development and ecological well being in the 21st century. Climate change is a significant international concern and is subject to much research and debate. This change is related to a naturally occurring shield of "greenhouse gases" surrounding the Earth. The main function of these gases is to help warm the planet to a comfortable and livable temperature range. Many scientists are concerned, if not alarmed, by a significant increase in the concentration of carbon dioxide and other GHGs in the atmosphere. There is growing international consensus in scientific circles that the buildup of carbon dioxide and other GHGs in the atmosphere will lead to major environmental changes. If no action is taken, concentrations of greenhouse gases in the atmosphere could reach 2 $^0$C higher than their pre-industrial levels by 2035-2050. The consequences of a 2$^0$C temperature rise are grave for potentially millions of people through death, injury and dislocation from flooding, fire and disease, adverse effects on water quality, species extinction and reduced agricultural yields. To address this problem, and also to reduce GHG emissions, it is important to understand which industries are releasing GHG gases and to what extent. For this reason, a greenhouse gas estimator has been developed for commercial composting facilities processing garden organics. The main parameters considered in the greenhouse gas estimator are decomposition of compostable organics, fuel use from mobile and stationary machinery, and electricity use. (US EPA, 1998)

Many composting and anaerobic digestion (AD) proponents and landfill opponents have viewed co-technologies is currently a popular topic for discussion among policy makers, regulators, and and/or AD as superior alternative solid waste management options to replace land filling of organic wastes. One of the primary reasons given for diverting organics from landfills is to reduce fugitive landfill GHG emissions. (US EPA, 1998)

## 2.3 Methods of Organic Waste Recycling

Three types of methods are common for the recycling of organic wastes, (UNEP, 2009)

- **Aerobic composting -** occurs when organic material is decomposed to stable humic substances in the presence of oxygen. In aerobic composting, living organisms utilize oxygen in air, feed upon organic matter and develop cell protoplasm from nitrogen, phosphorus, some carbon and other nutrients. Much of the carbon serves as a source of energy for the organisms to grow and multiply and is respired as carbon dioxide.
- **Anaerobic digestion -** is carried out in the oxygen deprived environment inside the closed chamber.
- **Vermin composting -** is similar to aerobic composting except that the composting and aeration processes are aided by the use of detritivorous worms.

## 2.4 Composting

Composting is a natural aerobic degradation of organic material by microorganisms ending in a nutrient rich product therefore it is a natural recirculation or recycle of nutrients. The waste that can be composted has a wide range of all organic material and a mixture of it such as municipal solid waste, garden waste and food waste. (Recycled Organics Unit, 2007)

The composting process is a complex process of biological transformation governed by the activity of naturally occurring microorganisms and involving highly variable heterogenic substrates or materials. In the process, organic materials provide the substrate to produce fully mineralized products such as carbon dioxide ($CO_2$), water ($H_2O$), ammonium ($NH_4^+$), and stabilized compost products that is organic matter dominated by humic substances that are heavily populated with competitive microbial biomass and ash. (Recycled Organics Unit, 2007)

The most common waste fractions composted are garden waste, OHW, sludge, manure and most often a mixture of these fractions. In addition to these central facilities, home composting of OHW and garden waste is a preferred treatment option in some countries, especially in the EU.

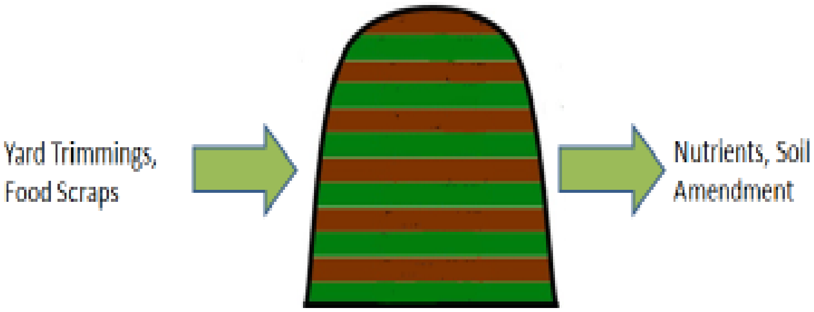


Fig2.1 Input - Output model of composting (composting in WARM manual, 2012)

One of the main differences between central and home composting is the lower additions of waste and lower temperatures for home composting, as the temperature development increases significantly during central composting and is often above 70°C. As easily degradable organic matter is degraded, microbial activity decreases and so do temperature. In contrast, the temperature in home composting is normally not elevated due to the low volume of material. In the case of home composting, the temperature did not exceed 30°C at any time during composting and was always 1-10°C higher than the ambient temperature. (Anderson , 2010)

## 2.5 Requirements for Compost Making

a. Plant materials both dry and green-Crop residues , Dropped leaves ,Weeds, grasses and any other plant materials except plants which have tough leaves, or leaves and stems with a strong smell or liquid when crushed, like Eucalyptus. Wastes from cooking and cleaning, food leftovers and different drinks particularly coffee, tea, home-made beer, etc. they are good source of carbon. (TMECC field sampling protocol,2001)

b. Animal materials-Dung and droppings from all types of domestic animals, including from horses, mules, donkeys and chicken. Chicken droppings, Urine from cattle and people are important to include because they are rich in nitrogen.(TMECC field sampling protocol,2001)
c. Water - Enough water is needed to wet all the materials and keep them moist, but the materials should not be made too wet so that they lack air and thus rot and smell bad. Both too little and too much water prevent good compost being made. Water does not need to be clean like drinking water.
d. Air - Including dry materials in the compost e.g. old leaves and stalks, provides space for air to circulate inside the compost. Air is needed because the soil organisms need oxygen.
e. Heat - Decomposition of organic wastes produces heat. Compost needs to be kept hot and moist so the plant and animal materials can be broken down quickly and thoroughly. Heat destroys most of the weed seeds, fungal diseases, pests and parasites.

Table2.1 Percentage composition of row materials for compost making (Soil & more international certification and composting standards, 2010)

| Row material | % composition of raw materials |
|---|---|
| Brown | 40 |
| Manure(caw dung ) | 20 |
| Green | 30 |
| Conditioning components | 10 |

f. Micro-Organisms -The more types of micro-organisms in the soil, the better micro-organisms are the soil's digestive system, help to decompose organic matter quickly and efficiently and unlocking minerals for plant nutrition. Managing soil microbes is like managing livestock. Feed them, house them and make sure that they have sufficient air everything they need to thrive. There are hundreds of species of soil micro-organisms, numbering up to a billion microbes per gram of soil. (EOSTOFF Technical Support, 2012). The following are the most important among them ;

- **Actinomycetes** - are the key to forming humus and are responsible for the earthy smell in compost or good soil. Found three to four inches below the surface, their digestive process helps free the soil's carbon and nitrogen, which can then be used by plants. They also produce antibiotic substances, which inhibit undesirable bacteria, and stimulate beneficial ones.
- **Bacteria** - are the primary decomposers of all organic matter and utilize carbon, nitrogen, sulphur and iron as food. Some of the most important bacteria are the ones which convert unavailable nitrogen in the soil's organic matter to ammonia and those which convert ammonia to nitrites and then to nitrates. These bacteria are also some of the most sensitive to chemical inputs. Fungicides and fumigants applied to soil greatly reduce their activity or kill them.
- **Fungi** - break down cellulose in compost and like bacteria they are initial organic matter decomposers. They decompose crop residues, increase soil aggregation and increase the availability of plant nutrients. Minority of the fungi pray on plants but the majority of them are beneficial and are absolutely necessary for breaking down organic matter. Obviously, fungicides kill both good and bad fungi indiscriminately.
- **Nematodes** - are the most numerous multi-cellular animals on earth. A handful of soil will contain thousands of the microscopic worms, many of them parasites of insects, plants or animals, including man.

## 2.6 Compost Making Phases

Composting involves two critical phases that are characterized by the temperatures achieved within the composting pile or windrow. Temperature is the best indicator of the rate of decomposition occurring in a composting pile. (Fernandes et.al, 1994)

- **1st phase** - High temperature (thermophyllic) phase.-Temperature exceeds 55°C but needs to be maintained below 70°C by turning and forced aeration.

Conventional outdoor composting usually requires six to eight weeks and regardless of the composting method, it should be greater than three weeks considered to be the minimum requirement for in vessel processes. This phase culminates in the production of stable compost that can be stored safely. It is the period of greatest volume reduction. Effective pasteurization and control of diseases, pests and weeds will occur if temperatures above 50-55°C are maintained for four to five days. The beneficial microbes that are responsible for the composting process can survive temperatures up to 70°C.Well managed aerobic composting generates temperatures that kill the disease, pest and weed contaminants that can be present in organic materials. With completion of the thermophyllic phase, the composting material stabilizes, meaning that it can now be considered to be compost. At this point, the composting temperatures and more importantly, the production of carbon dioxide or the consumption of oxygen, have begun to decline.

Table 2.2: Composting temperature range and its associated result (ORBIT, 2006)

| Temperature | Result |
|---|---|
| Above 70°C | Microbes die |
| 55-70°C | Pathogens are inactivated |
| 50-60°C | Weed seeds are inactivated |
| Below 40°C | Slow composting rate |

- **2nd phase** -The cooling or maturation (Mesophyllic) phase-As maturation progresses, the core temperature of the composting pile continues to decline and will eventually reach ambient temperatures. By definition, compost must have achieved stability; however it will still be too immature for use in many situations and generally should be matured further. Composts that are relatively immature provide greatest nutritional benefits but highly matured compost has higher humus levels and delivers better outcomes in terms of soil quality. Continued management is important throughout the maturation phase.

## 2.7 The Contributions of Different Compost Making Materials

### 2.7.1 Carbon and Nitrogen Balance

Both carbon and nitrogen are needed to make good compost. They are used by the micro-organisms to grow and multiply, and to get energy. Some of the carbon is converted to carbon dioxide, and this escapes to the atmosphere. Most of it remains and becomes humus, and the nitrogen becomes nitrates. Methane is not produced if there is a good supply of air to the organisms carrying out the decomposition process.

C:N ratio is used as a measure of stability. A ratio of less than 25 likely indicates the composting process is finished from which nitrogen will be more available as mineral nitrogen (nitrate and ammonium).Materials with good nitrogen content help in making good compost, but they should be less than the carbon-containing materials. Carbon containing materials should always be more than those containing high nitrogen. A good balance of carbon and nitrogen is needed to make good compost. Most kinds of manure have a good supply of nitrogen, but they do not have enough carbon for the microbes, which need 20 to 25 times more carbon than nitrogen. This is why straw bedding had to be added to achieve the minimum C:N ratio of 20:1. Table 2.3 below gives the carbon to nitrogen balance for some types of composting materials. [Michael Leaon, 1995]

High figures for the carbon in the Carbon-to-Nitrogen column indicate high carbon content. These items are good for making compost. Items with low carbon content, like urine and chicken manure, are useful to provide nitrogen. But they must be mixed with materials with high carbon content.

- High figures for the carbon in the Carbon-to-Nitrogen in column (table 2.3) indicate high carbon content. These items are good for making compost. Items with low carbon content, like urine and chicken manure, are useful to provide nitrogen. But they must be mixed with materials with high carbon content.

Table 2.3: The Nitrogen and Carbon content of some selected composting materials [Sue Edwards and Hailu Araya, 2010]

| Type of composting material | Nitrogen content (%) | Carbon-to- Nitrogen ratio (C:1N) |
|---|---|---|
| Urine | 15–18 | 0.8:1 |
| Blood | 10–14 | 3:1 |
| Horn | 12 | - |
| Bone | 3 | 8:1 |
| Chicken manure | 3–6 | 10–12:1 |
| Sheep manure | 3.8 | - |
| Horse and donkey manure | 3.8 | 25:1 |
| Manure in general | 1.7 | 18:1 |
| Maize stalks and leaves | 0.7–0.8 | 55–70:1 |
| Wheat straw and chaff | 0.4–0.6 | 80–100:1 |
| Fallen leaves | 0.4 | 45:1 |
| Young grass hay | 4 | 12:1 |
| Grass clippings | 2.4 | 20:1 |
| Straw from peas and beans | 1.5 | - |

- When there is enough air and moisture in the compost, nitrogen-containing materials are broken down and the nitrogen is changed to nitrates that can be used by plants
- When there is too much water and little air, the nitrogen is changed into ammonia. This is a gas that escapes from the compost, and gives the compost a bad smell.
- When there is a bad smell, the compost needs to be turned over bringing the top to the bottom and the bottom to the top, and mixing in more dry materials and

some good soil. This puts more air into the compost, which stops the process of making ammonia so that proper mature compost can be made

### 2.7.2 Moisture and Air Balance

**Moisture** - Sufficient moisture helps for quicker decomposition because it is essential for micro-organisms to be active. Excess water causes rotting of the materials and creates a bad smell. Without enough moisture the decomposition process slows down and the materials will not be changed into compost. (ORBIT, 2006)

**Air** - When there is sufficient air, oxygen enters the compost heap. When there is enough oxygen, special bacteria can convert nitrogen into nitrate, the materials are decomposed properly and there is a good smell. But if there is not enough air and too much water, the nitrogen is converted into ammonia. The ammonia escapes into the air removing nitrogen from the compost and making it smell bad. If there is excess air and too little water, the materials dry up and do not decompose to become compost. (ORBIT, 2006)

### 2.7.3 Dry and Green Plant Materials

- Dry materials give structure to the compost making process. They provide space for air to circulate so that the micro organisms can be active and make heat. (Sue Edwards and Hailu Araya, 2010)
- Green plant materials provide moisture for compost making, they give water and nutrients to the micro organisms so that they multiply and break down the organic materials into humus. (Sue Edwards and Hailu Araya, 2010)

### 2.7.4 Micro and Macro organisms

- The production of good quality mature compost depends on the number and types of micro and macro organisms living in the soil. These are living organisms that require air, moisture and heat in the compost heap so that they can live, work and multiply or reproduce.

- Compost materials supply food and energy like starch, soluble sugars, carbohydrates, amino acids for the micro organisms. In the presence of air supplying oxygen and moisture, the micro organisms convert the available food into humus and soluble plant nutrients, which stay in the compost heap, and carbon dioxide, which diffuses out into the atmosphere. Most of the carbon in compost materials stays in the humus and only a small amount leaves as carbon dioxide. As the micro organisms grow and multiply, they produce heat which speeds up the compost making process. (Sue Edwards and Hailu Araya,2010)

## 2.8 Compost Analysis and Quality

Depending on end-use, cured compost should be analyzed for stability, nutrient value and potential contaminants. Leaf and yard waste compost has been found to be a safe and valuable soil amendment. Contaminants should not be a problem; however, testing for them can be used as an extra safety measure especially if the compost is to be distributed to the public or marketed. Insuring stability is important if the compost is to be used as a growing medium. Tests for stability include organic content , carbon to nitrogen ratio, moisture, and pH .If the compost is to be sold, then the nutrient content of the end product should be analyzed to determine the percentage of nitrogen, phosphorous and potassium (N:P:K) present in the compost. This information indicates the fertilizer value, which is important to consumers of the product and is useful in marketing the compost (William F. Brinton, 2000). Leaf and yard waste may contain trace levels of certain heavy metals, such as lead or cadmium. Heavy metals do not degrade in the composting process. However, the level of heavy metals has been found to be very low in leaf and yard waste compost. These levels are well below the strictest state and federal standards for land application of organic materials and are comparable to background soil levels. Therefore, heavy metals should not be of concern. [Zhongxiang Gao, 2012]

Table 2.4 Heavy metals limit comparison of EU verses USA in mg/kg (William F. Brinton, 1998)

| Metal | Cadmium (Cd) | Chromium ( Cr) | Copper (Cu) | Mercury (Hg) | Nickel (Ni) | Zinc ( Zn) |
|---|---|---|---|---|---|---|
| EU-range | 0.7-10 | 39 | 70-600 | 0.7-10 | 20-200 | 210-4000 |
| USA Bio- solids | 70-200 | 1200 | 1500 | 17 | 420 | 2800 |

### 2.8.1 Functions of Nutrients and PH

- **Nitrogen** - in biological life there is an electrolyte. As an electrolyte in the soil, nitrogen functions very much like a metal carrying an electrical charge. It is the element that ionizes the water in the soil and makes it possible for the minerals to get into the plant. Without nitrogen in the soil, the electrical currents could not flow and the process of ionization, by which plants are built, could not take place.

- **Phosphate** - is the factor that determines the mineral content in any plant. The higher the water soluble phosphate the greater the mineral content. In order to get the maximum crop yields, the proper amount of phosphate is necessary.

- **Potash** - determines three basic things in a plant. i) It determines the thickness of the leaf and the thickness of the stem. ii) it determines the number of fruit or vegetable sets on a plant, and is the binder that holds the fruit or vegetable to the stem. iii) It determines the size of the vegetable or fruit.

- **Humic Acid** - helps maintain organic matter in the soil as active humus rather than inactive humin. It also acts as a growth stimulant, a catalyst, chelating agent, and a buffer against harsh materials put in the soil or harsh conditions in the soil that might affect the plant. Humic acid unlocks and chelates major and minor nutrients for plant uptake. As a catalyst, it acts much like a train carrying the chelated nutrients up into the plants.

According to leaf and yard waste composting guidance document, during the composting process, the material will become slightly acidic and then return to near neutral conditions as stability is approached. Decomposition is most efficient between a pH of 6.0 and 8.0. If the pH is too high, nitrogen is driven off as ammonia. If the pH drops below 6.0, the microorganisms begin to die off and the decomposition process slows.

### 2.9 Equipments Used in Windrow Composting

Operations may include Front - End Loaders, windrow turning machines, Shredding and Screening equipment, and bonded pads for windrow placement. Each of these components of the system may contribute to the GHG emissions from a facility during their construction and while they are operated in the management of the composting facility. (Gian Andrea Blengini, 2008)

Fig 2.2 Some of the machineries used for compost processing (Gian Andrea Blengini, 2008)

### 2.10 Compost and GHG

- Greenhouse effect - a buildup of greenhouse gases (GHG), mainly carbon dioxide ($CO_2$), methane ($CH_4$) and nitrous oxide ($N_2O$), in the atmosphere is causing temperature to rise due to the absorption of long-wave radiation re-transmitted by the earth surface by these gases.(Recycled Organics Unit, 2001b)

- Carbon sequestration - is the opposite of GHG emissions. Carbon is removed from the carbon cycle or from the atmosphere and added to a carbon sink. A carbon sink is a point in the carbon cycle where carbon is stored for a long period of time. While carbon is stored, it is not in the atmosphere contributing to the greenhouse effect. Examples of carbon sinks include soils, forests and oceans (Recycled Organics Unit, 2001b)

- $CO_2$ equivalent ($CO_2$ eq) - compares the impacts of various greenhouse gas emissions based upon their global warming potential. The $CO_2$ eq for a specific greenhouse gas is derived by multiplying the tons of that gas by its associated global warming potential. (Recycled Organics Unit, 2001b).

Poorly run compost piles may not be turned or agitated enough, leading to the development of anaerobic conditions in the pile. Under such conditions, the rate of composting slows, as organic material break down at a slower rate. Under anaerobic conditions methanogenic bacteria can potentially liberate methane during the decomposition of the organic fraction (Derikx et al., 1986). Although this is possible in poorly managed windrow systems, little evidence exists in the literature to suggest that methane cannot be produced under such conditions. Reports have suggested that the absence of methane in poorly managed windrow systems are because methanogenic microorganisms are strongly inhibited by ammonia released during the thermophilic phase of the composting process .In some studies; therefore the methane emissions from commercial composting facilities were not included, as they were considered to be negligible (Recycled Organics Unit, 2001b).

The approach to measuring GHG emissions from home composting was quite different than for the windrow composting system and involved a static flux chamber system attached on top of the composting units. As opposed to the measurements from windrow composting, the home composting units were covered entirely by the flux chamber and thus it will be easier to catch the entire flux of gases. As illustrated in Fig. 2.4, the composting apparatus consisted of a small reactor, a cap with a condensed-water trap, an aeration pump, an air-flow meter, a water trap, and a data logger connected to thermocouples. The reactor was covered with Styrofoam (30 mm) and supported with a plywood board to prevent heat loss

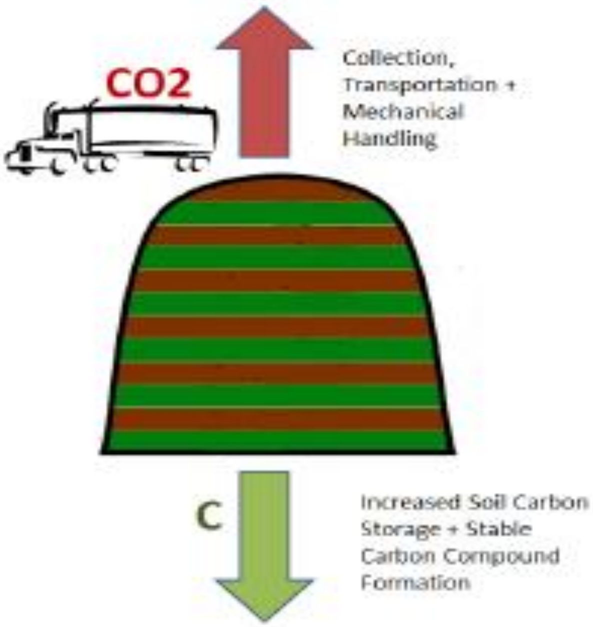
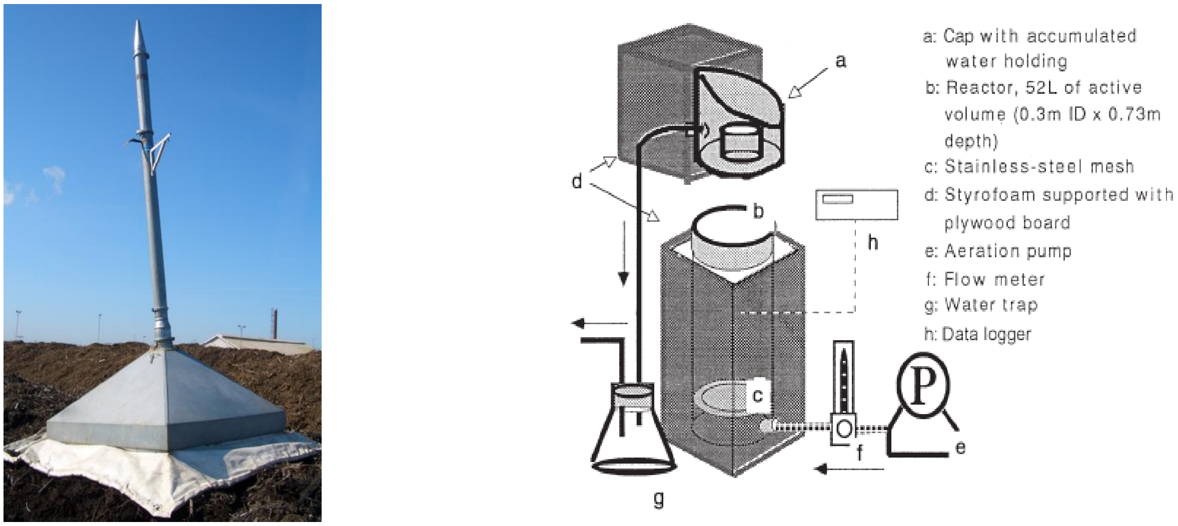


Fig. 2.3 Windrow compost emissions model (composting in WARM, US manual, 2012)

### 2.10.1 Global Warming Potential and GHG Emissions

By definition, the GWP of one kilogram of carbon dioxide is one, the so-called reference substance. The GWP of carbon dioxide, methane and nitrous oxide are summarized in the table 2.5 below. The GWP of gas emissions may be expressed in terms of delayed time (20, 100 or 500 years) after initial emission. Implicit in this notion is that the present is valued more highly than the future. Because shorter periods lead to large variance in data, a 100 year timeframe is most commonly used in LCA studies. Therefore, the same time frame is used in the current investigation. (White et al., 1995)

- **Carbon dioxide** - Studies have shown that carbon dioxide is the most significant gas released from composting (decomposition) processes. Other studies examining the composting of garden organics materials and pulp and paper mill sludge (e.g. Jackson and Line, 1997b;Riffaldi et al., and Jacobsen, 1994) have shown that carbon dioxide emissions after composting can range from 182.6 to 193.2 kg $CO_2$/ton (49.8 to 52.7 kg carbon/tone) of fresh feedstock.



(a) (b)

Fig.2.4 $CO_2$, $CH_4$, $N_20$ emissions analyzer (a) windrow composting (Anderson, 2010) (b) Laboratory scale composting (Takashi Osada ,2000)

- **Methane**-Although methane is a significant green house gas with a global warming potential 21 times greater than that of carbon dioxide, it is in most instances not produced by garden organics composting facilities [US EPA, 1998). This study investigated the GHG impacts of a number of waste processing technologies. In this study, methane emissions from commercial composting facilities were not included, as they were considered to be negligible. This assertion was based upon the information attained from experts at universities and the US Department of Agriculture. It was concluded well-managed compost operations usually do not generate methane because they typically maintain an aerobic environment with appropriate moisture content to encourage aerobic decomposition of the materials. The report also asserted that even if methane was generated in anaerobic pockets in the centre of infrequently turned compost pile, methane is most likely to be oxidized by microorganisms by the time it reaches the oxygen rich surface of the pile. Furthermore, anaerobic pockets are most likely to develop when too much water is added to the compost pile; however, this problem rarely occurs because compost piles are much more likely to be watered too little, rather than too much.

Table 2.5 Global warming potential of greenhouse gases based on 100 years measure (IPCC, 1996)

| Gas | Global Warming Potential | Atmospheric life time(years) |
|---|---|---|
| Carbon dioxide($CO_2$) | 1 | 50-200 |
| Methane($CH_4$) | 21 | 9-15 |
| Nitrous oxideN$_2$0) | 310 | 120 |

- **Oxides of Nitrogen**-Nitrous oxide ($N_2O$) generally results from the use of commercial and organic fertilizers and fossil fuel combustion, as well as from other sources such as the decomposition of nitrogen rich organic residuals. Nitrous oxide has a GWP 310 times greater than that of carbon dioxide. A study by Czepiel et al., (1996) indicated that nitrous oxide emissions could arise from the composting of waste water sludge and livestock manure. The study found emissions of 0.7 g of $N_2O$ (dry/kg) and 0.5 g of $N_2O$ (dry/kg) for sludge compost and the livestock manure compost respectively. These findings are not relevant to the composting of garden organics, as garden organics comprise low or negligible nitrogen content.

## 2.11 The Use of Compost

The end use of the compost provides some GHG benefits, both directly through sequestration and indirectly through improved soil health, reduced soil loss, increased water infiltration and storage, and reduction in the need for fertilizers, herbicide or fungicide and other inputs. (USCC fact sheet Composting and Carbon Credits, 2000)

## 2.12 Compost Emission Reductions (CER)

The greenhouse gas emission reduction benefits come from the agronomic use of compost and are calculated based on the finished compost product. The final reduction benefit is reported by converting the compost application benefit to units of initial organic feedstock. This analysis evaluates five benefits from a GHG perspective. [US EPA, 2008]

- Increased Soil Carbon Storage (CSb)
- Decreased Water Use (Wb)
- Decreased Soil Erosion (Eb)
- Reduced Fertilizer Use (Fb)
- Reduced Herbicide Use (Hb)

## 2.13 Synthetic Fertilizers Verses Compost

Application of synthetic fertilizers can be too much of a good thing. Studies have shown that a steady diet of synthetics will alter the ecosystem of the soil, resulting in the need for increasing amounts of chemical fertilizers and pesticides. It's a syndrome, also called "whiplash effect" and eventually the whole system goes downhill. For example, plant growth stimulated by high quantities of nutrients, especially nitrogen, can deplete the soil of other minerals. And the microbes that normally break down various soil nutrients stop activity when those nutrients are applied in high concentrations. [EOSTOFF Technical Support, 2013]

Though low in nitrogen, phosphorus, and potash compared to chemical fertilizers, compost produces tremendous growth response in plants. A soil rich in micro organisms and organic matter is basically well balanced. Studies have shown that compost substantially cuts the need for additional fertilizers, while still producing the same yields. Possible reasons include the anti leaching characteristics of compost, the slow release nature of its nutrients, and the optimum combination of macro and micro nutrients. [Bob Paulin, 2008]

## 2.14 Life Cycle Analysis /Assessment (LCA)

Life Cycle Analysis (LCA) or Life Cycle Assessment (LCA) is an important environmental risk analysis tool used in many industries to determine the environmental impact of a product or service during its entire life cycle. A LCA study involves an analysis and quantification of the various raw materials consumed or emissions released by the product or service at each of its life cycle stages.

Efforts have been made previously to develop methodologies and models and to conduct studies to assess the environmental impacts of waste management alternatives such as composting and anaerobic digestion using LCA methods quantified potential environmental effects from biological treatment, such as composting, AD, and combinations of both, for organic waste, found that diverting organics to AD would result in GHG reductions. Therefore, in light of these previous efforts attempting to evaluate the environmental impacts of waste management options using a LCA methodology and the increased interest and momentum to utilize organics outside of the landfill, a systematic LCA analysis of the true GHG impacts of potential organics management options including land filling, composting, and AD is warranted and valuable. For this purpose, an integrated LCA methodology was developed considering all aspects of organics management including transportation, materials handling, fugitive GHG emissions, land fill gas (LFG) capture or utilization, energy impacts, and carbon sequestration. It is worth-noting that a comprehensive LCA normally addresses 12 - 16 impact categories e.g. air, water, and groundwater quality, energy, ecological, economic, acidification, toxicity, global warming, human health, etc. (Recycled Organics Unit, 2007)

There are different approaches in conducting LCA indicated as follow;

- Cradle-to-grave LCA - is used to assess the environmental impact of a product throughout its life cycle, from manufacture until disposal
- Cradle-to-gate LCA - is used to assess the environmental impact of a product from its manufacture to its shipment or transportation to the end customer. In this type of LCA, the use and disposal phase are not considered
- Cradle-to-cradle LCA - is used to assess products that are recycled in their end of life stage and not disposed.

- Gate-to-gate LCA -considers only one value-added process in the entire life cycle of a product.

### 2.14.2 LCA Methodology

The technical framework of ISO 14040 (2004) has been used to conduct this LCA study. The major components of LCA are;

1. Goal and scope definition
2. Life cycle inventory analysis (LCI)
3. Life cycle impact assessment (LCIA) and
4. Interpretation phase

#### 2.14.2.1 Goal and Scope Definition

Here the goals of the LCA study, the functional unit and the boundaries of the product system will be identified. The functional unit defines the quantity or dimensions of the product and thus forms the basis of the LCA study. In addition to quantity and dimensions, the functional unit considered can also be the service delivered by the product. Functional unit defined as the reference to which input and output data are normalized or it is the function or service that a system provides for use as a reference point to make comparisons of environmental impacts. An appropriate functional unit for composting processes is the treatment of a specified amount of compostable organics over a specified period. [ISO 14040, 2004]

**The goal of the LCA** - is to quantify and to evaluate the environmental impact of the composting systems. Receival, processing, transportation and the application of composted products are the functions of the product system considered here.

A clear understanding of the following aspects is very important in the goal and scope definition phase of a LCA [ISO 14040, 2004]

- The functions of the product system (i.e. receival, processing, application)
- The functional unit (i.e. one ton of source separated organic mixture)
- The product system to be studied (the summary of the system as a whole)

- The product system boundaries (what is included and excluded)
- Allocation procedures (methods of allocating data to different processes in the system)
- Types of impact and methodology of impact assessment (the main environmental impacts considered in the study and how they are assessed)
- Data requirements (what data is required to identify the impacts of the system)
- Assumptions (assumptions made when creating system boundaries, using data sources/types etc.) and
- Limitations (any limitation associated with the overall approach used to identify the total environmental impact of a system).

#### 2.14.2.2 Life Cycle Inventory Analysis (LCI)

Life cycle inventory analysis (LCI) is a technical process that identifies and quantifies energy and resource consumption, and environmental releases to air, water and land throughout the life cycle of a product or system (ISO 14041, 2004). In LCI, the energy and resource use and emissions are considered for various processes in a system including;

- Acquisition of raw material from earth
- Processing and transformation of raw materials to final products
- Production and consumption of intermediate products
- Transportation of raw and finished products, and
- Final disposal of any waste produced during the processing period and at the end of the life of the product

An iterative process is used throughout the LCI, allowing for the refinement of system boundaries and life cycle stages or unit processes.

There are several phases to the LCI process;

- **Initial preparation** - The initial preparation phase requires that a very clear understanding of the studied system be established.

- **Data collection** - For the purpose of data collection, it is appropriate to view the system as a series of sub-systems or unit processes. Each unit process has energy and resource requirements. Likewise each unit process contributes to environmental emissions through different activities. These need to be clearly identified and documented. Once the components in the system have been identified, it is necessary to describe data collection techniques for each unit process. At this point, any special issues or irregularities in data requirements are documented. Inventory data for the system can be obtained from a number of sources including: Literature, Specific studies or reports, Laboratory investigations, Industry organizations, and Government bodies .Depending upon study data requirements (influenced by system boundary) and the accessibility of appropriate information, collecting data comprises a major part of the LCI process. The steps required for data collection may vary because of differences between individual unit processes. Therefore, LCI requires clear documentation of procedures used and associated reasons for their use.
- **Calculation procedures** - Data manipulation or calculation is a required step used to create inventory data during the LCI phase. Often data for different components or unit processes is obtained from a range of sources that may not be compatible with the functional unit(s) used in a study. Consequently, data needs to be modified to suit the purpose of the study. A simple example would have to change the units of measure of data if data is initially on a per kg basis, it may be necessary to convert it to a per ton basis, as may be used for the functional unit of the study. Similarly, measures of electricity may have to be converted from kWh to MJ or vice versa depending upon the standard measures used throughout the study. Data may also be aggregated where unit processes or functions.

#### 2.14.2.3 Life Cycle Impact Assessment (LCIA)

Is used to characterize and assess the effects of resource consumption and environmental loadings identified in the inventory stage. The following description on LCIA is based on the ISO 14042 (2004) .Impact Assessment is carried out in three different phases; Classification, Characterization, and Valuation.

Table 2.6 LCA for diesel fuel use for 1kg of diesel fuel (US EPA, 1998)

| Material | Carbon dioxide ($CO_2$) | Carbon monoxide (CO) | Nitrogen oxide ($NO_X$) | Nitrous oxide ($N_2O$) | Particulate matter ($PM_{10}$) | Methane ($CH_4$) | Sulphur dioxide ($SO_2$) | Hydrocarbons |
|---|---|---|---|---|---|---|---|---|
| Emission (kg) | 3.2843 | 0.0139 | 0.03874 | 8.265E-05 | 1.784E-03 | 1.827E-04 | 5.22E-03 | 3.698E-05 |

- **The classification phase** - requires the allocation of all resource inputs and environmental emissions (identified in the LCI) to a range of impact categories depending upon what type of environmental issues they contribute to. Internationally accepted impact categories typically include global warming, ozone depletion, photo-oxidants formation, eco-toxicity, eutrophication, energy, acidification, and human toxicity. Where possible impact categories are also based upon indicators of environmental health, as identified in the environmental indicators are physical, chemical, biological or socio-economic measures that best represent key elements of complex ecosystems or environmental issues (Hamblin, 1998). The use of nationally accepted environmental indicators and associated terminology will facilitate comprehension of issues presented in the LCA.
- **The characterization phase** - is a quantitative process where the contribution of each type of emission and resource consumption to different impact categories is determined. The calculation involves the conversion of LCI results to common units and the aggregation of the converted results within the impact category. This conversion uses characterization or equivalency factors. Characterization or equivalency factors have been developed within the LCA framework to identify how much a substance contributes to a particular environmental impact category compared with a reference substance. For example, nitrous oxide contributes 310 times more to global warming than carbon dioxide. Thus the quantity of nitrous oxide released by a system is multiplied by 310 to derive a carbon dioxide equivalent global warming figure. Carbon dioxide is used as a reference substance for GWP.

- **Valuation or weighting** - is the last stage of LCIA phase and involves converting impact category results using numerical factors based on value choices. Weighting is achieved by Converting impact category results or normalized results with selected weighting factors; or Aggregating these converted results or normalized results across impact categories. Weighting is used to facilitate decision-making processes by aiding with comparisons of overall impacts of products or systems studied. The weighting process is, however, not widely used in LCA methodology due to problems associated with weighting factors. Assigning weighting factors is a subjective process and varies with geographical location, and the extent and type of environmental problem.

#### 2.14.2.4 Interpretation Phase

The objectives of the life cycle interpretation phase are to analyze results, reach conclusions, explain limitations and provide recommendations based on the findings of the preceding phases and to report the results of the life cycle interpretation in a transparent manner (ISO 14043, 2004). The following steps are usually taken to determine and to enhance the confidence and the reliability of the results of the study including any significant issues identified (ISO 14043, 2004)

- **Completeness check –** ensures that all relevant information and data needed for the interpretation are available and complete.
- **Sensitivity check –** assesses the reliability of the final results and conclusions by determining whether they are affected by uncertainties in the data, allocation methods or calculations of impact category results.
- **Consistency check –** determines whether assumptions, methods and data are consistent with the goal and scope of the study.

# 3. Materials and Methods

## 3.1. Materials

Major equipments used for conducting compost and soil samples were Oven, Furnace, Digital balance, Nitrogen digester, Hot plate, UV Visible Spectrophotometer, Atomic Absorption Spectrometer (AAS). And Major equipments used for Compost gas emission collection and analysis were Aerobic Digester (as a reactor ), Flow Meter (to measure the atmospheric gas flow in to the aerobic digester in l/min), Aeration Pump (to suck the air from the atmosphere in to the aerobic digester ), pH meter (to measure the alkalinity of the samples), Digital Gas Analyzer (to detect and measure the mass % of $CH_4$ & $CO_2$ )

## 3.2 .Methodology

The proposed methodology in this study was a life cycle analysis (LCA). Both the environmental impacts of compost processing from floriculture waste and the emission reduction from using compost as a soil amendment were evaluated. More precisely, the LCA study is used to quantify and evaluate the total environmental impacts of composting systems from cradle to grave.

Fig 3.1 flow diagram of the process

The technical framework of ISO 14040 (2004) is used to conduct this LCA study which is shown in Figure 3.2 and the major components of LCA are

- Goal and scope definition
- Life cycle inventory analysis (LCI)
- Life cycle impact assessment (LCIA) and
- Interpretation phase

### 3.2.1 Goal and Scope Definition

#### 3.2.1.1 Goal Definition

As the "Cradle" to "grave" perspective is used, the goal of LCA in this study was to analyze the environmental impacts and to have quantitative and qualitative information on environmental emissions and benefits of the composting system from floriculture waste so that to help decision makers about the environmental impact of the system.

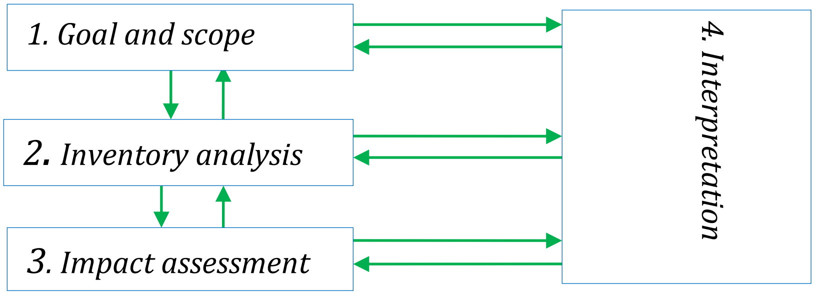


Fig 3.2 Lifecycle analysis frame work (ISO 14040, 2004)

#### 3.2.1.2 Scope Definition

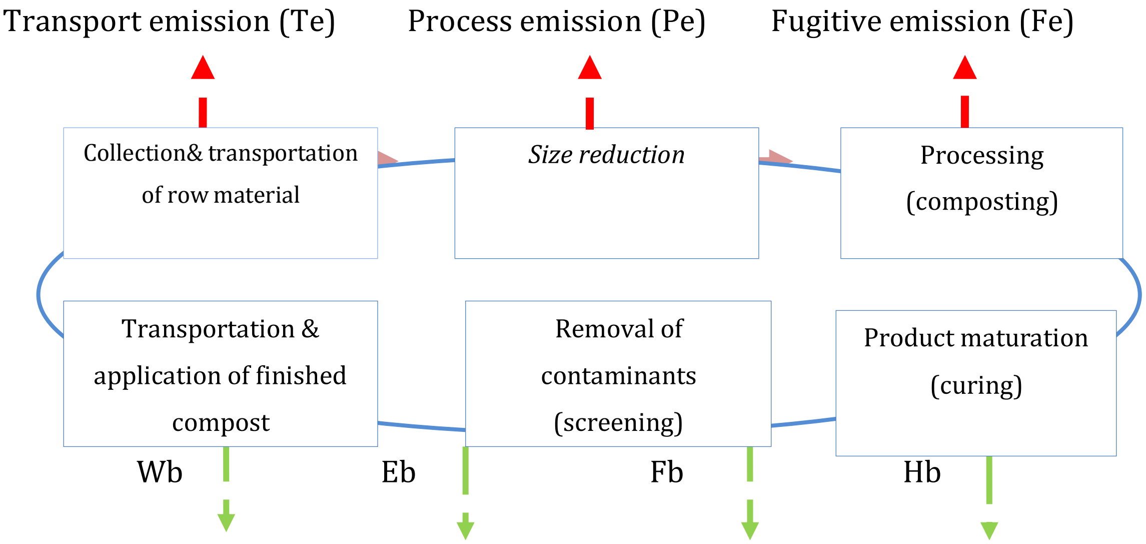


Fig 3.3 Scope and boundary of the LCA

Where:

Wb = Emission reductions due to decreased water use

Eb = Emission reduction associated with decreased soil erosion

Fb = Factor to account for the reduced fertilizer use

Hb = Factor to account for the reduced herbicide use

The system considered in this study includes receipt of source from the farm, transportation, production of mature compost both on site & in the laboratory, and application of compost to a soil for subsequent agricultural application.

a) Characterization of Compost Processing

In this study, the combination of floriculture waste as a green, caw manure as a manure, wheat straw as a brown, matured compost and inocculent as activator were used. The green which is the floriculture waste was found at Sher Ethiopia international farm. Both the caw manure and the wheat straw were found from the farmers around the soil and more commercial composting site. The matured compost and the inocculent (which are industrially processed sleep micro organisms) were found in the Soil & More Ethiopia which was processed commercially.

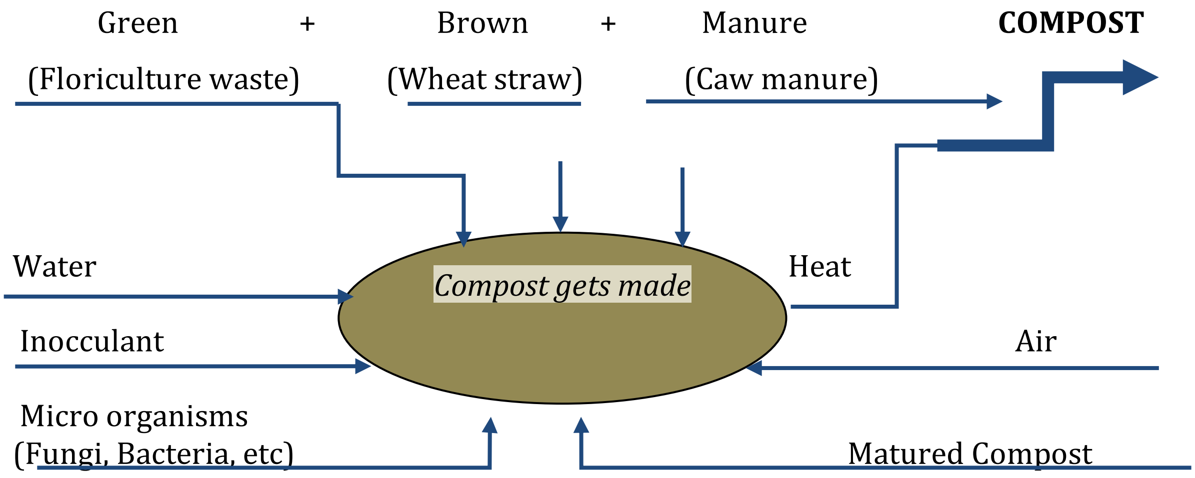


Fig 3.4 Components of compos processes

### b) Activity Flow and Description of the Study

The feedstock from Sher Ethiopia International flower farm (Ziway) were loaded and transported for 4 to 5 kilo meters by Isuzu vehicle in to the nearby soil & more commercial composting area. Then matured compost was produced after 10 weeks decomposition of the row materials and here the emission due to energy used for transportation (transport emission) was calculated. It was planned to take gas sampling weekly for a total of 10 times at the composting facility area (on site) but due to technology limitations it became difficult to make it practical. So that emissions due to decomposition of the feedstock (fugitive emission) analysis was conducted at Addis Ababa Institute of Technology Environmental Lab.

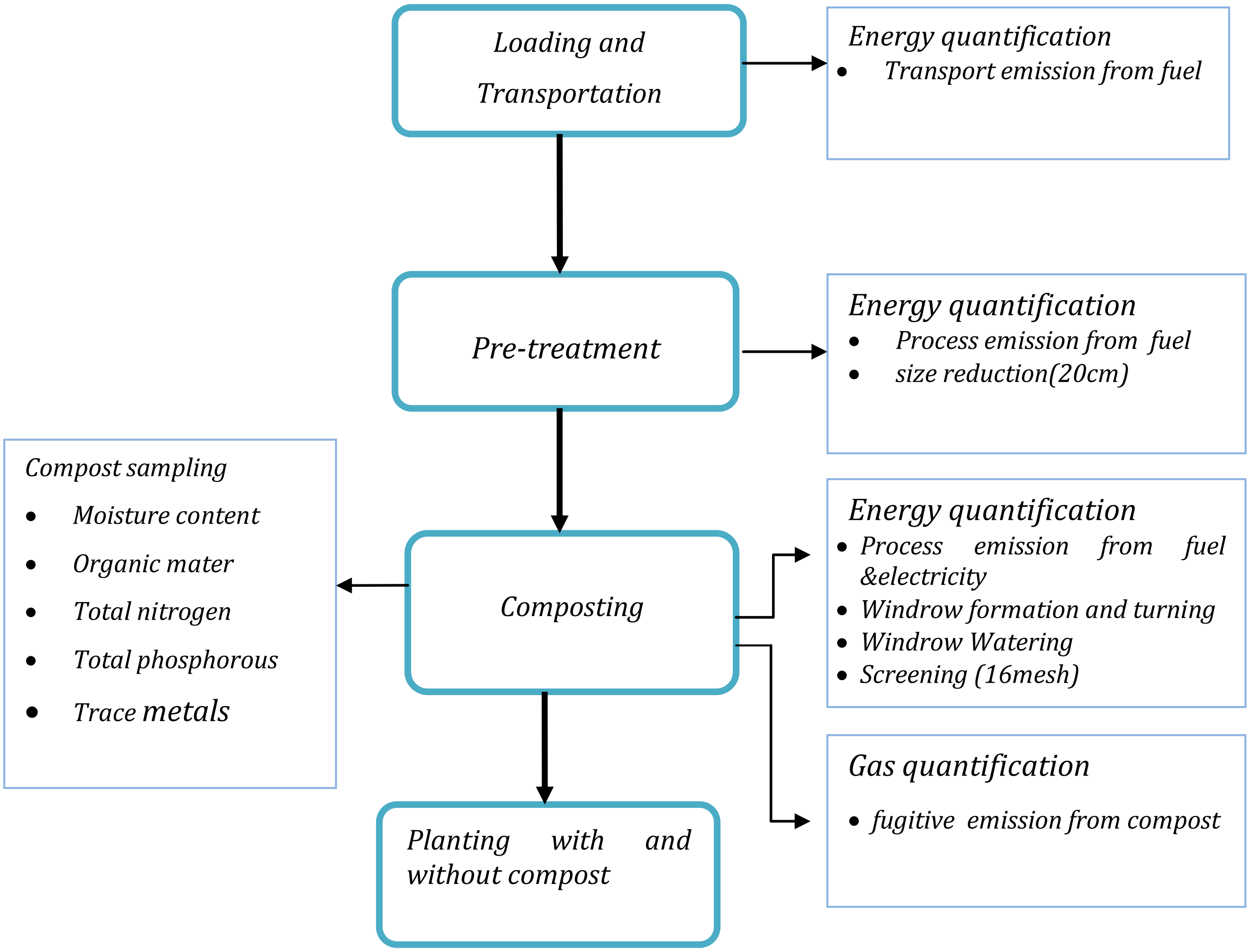


Fig3.5 Activity flow chart

### c) Windrow (on Site) Composting

Compost gets made after transporting the flower farm waste from the farm to the commercial composting site. A compost pile was built according to soil and more training manual (2013) with 3 meters base width in a three layers of green (the floriculture waste), brown (wheat straw), manure (caw dung) sequentially from base to top. Soil & More static compost starter (inocculant) and matured compost was added in layer to increase the biodiversity in the windrow and to speed up the breakdown process. At the end the windrow was compacted and forced in to a triangular shape at 1.5 meter height. There was totally 1ton of feedstock with composition as shown in the table 3.1. In addition 20 g of inocculent diluted in 10 liters of water was added. [Soil and more training manual, 2013]

Table 3.1 Row material composition of windrow compost making

| Raw material | Mass (kg ) |
|---|---|
| Floriculture waste | 600 |
| Wheat straw | 150 |
| Caw dung | 200 |
| Matured compost | 50 |

**Transport and process emissions** - In every stage of the compost making process energy and water required for the production of matured compost was quantified.

### d) Laboratory Scale Composting and Equipment Design

As illustrated in the figure 3.6 aerobic digester consisted of a small reactor (10 l) an aeration pump with an air flow meter (2 l/min), digital thermometer, turner for mixing the sample. Pvc Sieve was placed at 10cm above the base of the digester to facilitate aeration. The reactor was covered with Styrofoam with 25 mm thickness and supported with a cardboard to prevent heat loss.

An extension on the aerobic digester was made for the analysis of the gas that was emitted in the compost processing. As shown in figure 3.6 the upper part of the aerobic digester was connected with a flask for condensing the steam released in the process. Again a flask was connected with a sampling bag for temporary gas accumulation and to feed the gas sample in to the gas analyzer where the gases are being analyzed .Here all connections was done through hosepipe and Syringe of 50mm was used to sack and transfer the gases when it was necessary.

(a) (b)

Fig 3.6 Compost making and emitted gas collection in the laboratory (a) without Styrofoam (b) with Styrofoam

Major activities for composting the 3.125 kg sample in the laboratory was as follows

- Size reduction of the feedstock(20 cm long )
- The mixing of
  - 0.125 kg of brown (wheat straw)
  - 2 kg of green ( floriculture farm waste)
  - 0.8 kg of caw manure
  - 0.2 kg of matured compost ( conditioner)
  - The addition of 0.002 kg of inocculant diluted in a little of water
- Forced aeration of the sample( 2 l/min )

- The weekly turning of the sample for mixing &
- Natural drying and screening of the matured compost

**Fugitive emission analysis** - sample from the collected exhaust gases was taken every week for nine weeks beginning from the start of composting. $CO_2$, $CH_4$ and $N_2O$ were the targeted gases to be determined by the gas analyzer. Parallel to that the pH at the specific temperature was measured.

**Functional Unit** - This unit provides a reference to which the inputs and outputs are related. One ton of raw material was used as a functional unit. Therefore the life cycle of the compost was calculated in relation to one ton of input materials.

### 3.2.2 Life Cycle Inventory

The collection of data for the LCA study was made in close reference to the various processes involved in each life cycle stage of the compost processing. Data sources used for the study include laboratory results, published journal articles, and data from similar processes. Data collection was specifically narrowed down to the system boundary identified in the case of this study.

#### 3.2.2.1 Compost Emission Reductions

This explains a life cycle method to quantify the greenhouse gas emission reductions from using compost and the greenhouse gas emissions associated with compost management. Compost application to agricultural fields increases soil health while providing multiple co-benefits. Compost application reduces the amount of synthetic fertilizer needed, reduces the amount of water used, decreases soil erosion, increases soil carbon storage and reduces the use of herbicides. Composting materials also cause greenhouse gas emissions during the collection of the initial feedstock and delivery of the compost, the use of energy and water to manage the compost pile and as microorganisms convert the initial feedstock to compost. [Composting in WARM, 2012]

Except reduced Fertilizer use (which is studied in a 10 years' time frame), all the compost emission reductions from using compost are calculated by US EPA (1998) in a 30 year's time frame after the application of compost to the plant. Similar studies were conducted by ICF International (2005).Even though these values are very site specific and also are influenced by soil characteristics, climate type, crops variability & soil management; results are used by different studies in different countries like Canada and Egypt for their further analysis. The same data was used in this study.

a) Increased Soil Carbon Storage (CSb)

The carbon that remains in the soil system is considered stored because it is not degrading and releasing $CO_2$ into the atmosphere. The active portion of carbon in compost follows a first-order decay pattern. According to US EPA (1998), the carbon content was forecasted to 30 years beyond the compost application to evaluate the decay pattern of carbon in compost. The upper and lower bounds of carbon storage were determined by evaluating the amount of carbon that decayed slowly or was passive.

b) Decreased Water Use (Wb)

Increases in porosity and surface area creates more binding spots for water, leading to higher water retention rates when compared to an amended soil. The compost application benefit in this case is the reduced energy needed to transport water to the compost-amended soil.

c) Decreased Soil Erosion (Eb)

This benefit was quantified by accounting for the emissions associated with replacing eroded soil with compost. The experimental plot values were extrapolated to represent a hectare of application and converted to a unit representative of soil saved per ton of compost. The emission factor represents the emissions associated with producing compost to replace the soil lost to erosion. The emission factor used for this production was generated from the emissions associated with the composting process.

d) Reduced Fertilizer Use (Fb)

The emission factor used for each fertilizer type (N, P, or K) was based on the avoided life cycle emissions from fertilizer production that would have occurred in the absence of compost use. The Nitrogen, Potassium and Phosphorous contents of fertilizer degrade more rapidly than carbon. A study indicated that nitrogen from compost is used over a 10 year time period. The study also assumed that nitrogen was "conserved" in the soil over time so the available nitrogen over a 10-year time period was actually greater than the initial nitrogen content.

e) Reduced Herbicide Use (Hb)

These benefits are limited and may last only one year, but allow for the reduced use or alleviation of herbicide use. Assuming a 100% replacement of herbicide by compost, the herbicide reduction value was multiplied by an emission factor that quantified the emissions associated with herbicide production.

f) Conversion Factor (Cuse)

The conversion factor is used to convert from tons of compost to tons of initial feedstock

$$\boxed{C_{use} = Fw/ Iw}$$

Where

Fw - Final weight of compost

Iw - Initial weight of compost

### 3.2.2.2 Compost Emission Sources

There are three main emission sources that occur during the composting process which are Transport Emission (Te), Processes Emission (Pe), and Fugitive Emission (Fe).

$$\boxed{\mathbf{E_{total}} = Te + Pe + Fe}$$

Where,

$E_{total}$ -Total emissions from composting (kg of CO2eq/ton of feedstock)

Te -Transportation emissions for composting (kg of CO2eq/ton of feedstock)

Pe -Process emissions for composting (kg of CO2eq/ton of feedstock)

Fe -Fugitive emissions from composting (kg of CO2eq/ton of feedstock

a) Transport emission (Te)

The total distance travelled by the Isuzu vehicle from the collection of the feedstock (Sher Ethiopia flower farm) and delivery of the finished compost to the farmers (inbound and outbound), in combination with an emission factor that indicates the amount of greenhouse gas emitted per distance travelled (kg $CO_2$/ km), and gives an approximation of the emissions for transportation.

$$\boxed{Te\ (kg) = \text{distance travelled}\ (km) * [CO_2\ (kg) * EC0_2 + CH_4\ (kg) * ECH_4 + N_2O\ (kg) * EN_2O]}$$

Isuzu vehicle with 4km/little of diesel consumption was used to transport floriculture waste from the farm to composting site (9 kms round trip). It was assumed that to distribute the finished compost from the composting site to the customers, the vehicle needs to travel 200 km radius. Totally, the vehicle is traveled 209 km to produce and deliver the finished compost. It implies that a total of 52.25 liters of diesel is used by the Isuzu vehicle.

b) Process Emission (Pe)

Process emissions from the composting process were from the energy required to grind the flower farm waste (diesel), turn and manage the compost pile (diesel) and the emissions associated with water use on the compost pile (electricity) and screening (diesel).

$$\text{Process Emissions (kg)} = \text{fuel used (kg)} * [CO_2\ \text{(kg)} * EC0_2 + CH_4\ \text{(kg)} *$$

c) Fugitive Emissions (Fe)

From the anaerobic decomposition of the composted materials fugitive emissions which arise during the composting process are Carbon dioxide ($CO_2$), Methane ($CH_4$) and Nitrous oxide ($N_2O$).

$$\text{Fugitive Emission (kg)} = CO_2\ \text{(kg)} * EC0_2 + CH_4\ \text{(kg)} * ECH_4 + N_2O\ \text{(kg)} * EN_2O$$

Where

$CO_2$(kg) -the amount of carbon dioxide in kilogram emitted in one liter of fuel used
$CH_4$(kg) -the amount of methane in kilogram emitted in one liter of fuel used
$NO_2$(kg) -the amount of nitrous oxide in kilogram emitted in one liter of fuel
E -the equivalency factor

3. 2.3 Life Cycle Impact Analysis

$CO_2$, $CH_4$, $N_20$ are the three targeted global warming gases that there impacts are analyzed. Emissions of these gases were converted to their ‘carbon dioxide equivalent and their Impact analysis was carried out in three different phase;

**Classification-** the environmental impact categories selected for the study is Global warming and all the emission is allocated to global warming impact

**Characterization**- One kg of carbon dioxide is equivalent to 21 kg of methane and 310kg of nitrous oxide

**Valuation or weighting**- the result is converted in to carbon dioxide equivalent and the impact is there for analyzed in terms of $CO_2$ equivalence ($CO_2$ eq).

### 3.2.4. Interpretation

Depending on the findings of the preceding phases and according to the objectives stated, results are analyzed, reach conclusions and limitations was explained.

## 3.3. Emission Reduction Factor Calculation

The compost emission reduction factor (CERF) is the sum of compost process emissions ($E_{total}$) ,

$$\boxed{CERF = B_{total} - E_{total}}$$

and compost application emission benefits ($B_{total}$) is

$$\boxed{B_{total} = CS_b + ((W_b + E_b + F_b + H_b) * C_{use})}$$

Where,

CERF -The compost emission reduction factor (kg of $CO_2$ eq/ton of feedstock)

CSb -Emission reductions associated with the increased carbon storage in soil (kg $CO_2$ eq /ton of feedstock)

Wb -Emission reductions due to decreased water use (kg $CO_2$ eq/ton of compost)

Eb -Emission reduction associated with decreased soil erosion (kg $CO_2$ eq/ton of compost)

Hb -Factor to account for the reduced herbicide use (kg $CO_2$ eq /ton of compost)

Cuse -Conversion factor used to convert from tons of compost to tons of feedstock

$E_{total}$ -Emissions due to the composting process (kg $CO_2$ eq /ton of feedstock)

## 3. 4. Fertility Potential Evaluation of Compost

Compost provides the food needed for a plant to grow after a seed has germinated in the soil. This food consists of plant nutrients and the most important of these nutrients are nitrogen (N), phosphorus (P) and potassium (K). There are also micronutrients or trace elements in small quantities, like copper (Cu), manganese (Mn), Zink (Zn) and others with a certain limit. The concentration of these nutrients in addition to C/N and organic matter are major quality parameters or fertility potential indicators of compost.

Two ways were used to evaluate the fertility potential of matured compost from floriculture waste. The first was for nutrients (phosphors, manganese and nitrogen) and trace metals (copper and Zinc) concentration .Matured Compost were analyzed for those nutrients and trace metals at Ethiopia EPA laboratory. So that the results were compared with the standard set by EU as there is no compost standard in Ethiopia. A quick comparison of compost standards of various countries shows Europe to be fairly well developed, while the rest of the world, including the United States (Woods End Research Laboratory Inc., 2000). The second way was planting a plant (cabbage) in a greenhouse from Addis Ababa university (since faculty) in two different pots in one replicate .In the first pot 2 kg of soil with no addition of compost (0%), in the second 1.5 kg of soil with 0.5 kg (25%) of compost was prepared by keeping the number of seeds constant. Then 300 ml of water was added in every week for 6 weeks but after the 6th week watering was interrupted and stopped purposely to see the effect on the plant growth. On the two bins, the plant (cabbage) was grown by watering 300 ml of water for 6 weeks..

# 4. Result and Discussion

## 4.1. Compost Emissions

Composting emissions were calculated in three different categories; emissions from transportation (transport emission), emissions from the process (process emission) and emissions from the compost making itself (fugitive emission).

### 4.1.1 Transport Emission (Te)

As shown in the table 4.1, the total emission of the three green house gases from transportation due to 52.25 liter of diesel consumption was 146.57 kg $CO_2$ eq. (Annex II)

Table 4.1 Global warming potential of transportation emission for composting floriculture waste

| | $CO_2$ (kg) | $CH_4$ (kg) | $N_20$ (kg) | Total $CO_2$ eq (kg) |
|---|---|---|---|---|
| Transport emission | 145.26 | $8.09*10^{-3}$ | $3.66*10^{-3}$ | |
| $CO_2$ eq (kg) | 145.26 | 0.17 | 1.14 | 146.57 |

### 4.1.2. Process Emission (pe)

Table 4.2 Global warming potential of process emission from composting floriculture waste

| Processing machineries | $CO_2$ (kg) | $CH_4$(kg) | $N_2O$ (kg) | Total $CO_2$ eq (kg) |
|---|---|---|---|---|
| Size reduction | 9.268 | 5.155E-4 | 2.33E-4 | 9.351045 |
| Windrow formation and turning | 0.336 | 2.12E-5 | 8.4E- 6 | 3.39E-01 |
| Windrow watering | 0 | 0 | 0 | 0 |
| Screening | 1.58 | $0.877*10^{-4}$ | 4.0E-5 | 1.58 |

As it is shown in table 4.2 emissions from compost processing machineries to process 1 ton of composting materials was 11.271 kg $CO_2$ eq. Here Within the scope of the LCA of this study windrow watering using electric water pump was assumed to be zero emission as hydropower is assumed to be emission free.

### 4.1.3 Fugitive Emission

Table 4.3 Laboratory gas emission test results from composting floriculture waste

| Time(Weeks) | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|---|
| Temp(°C) | | 25.10 | 26.60 | 27.00 | 29.00 | 30.00 | 29.00 | 22.50 | 21.50 | 21.20 |
| PH | | 5.80 | 6.00 | 6.60 | 6.90 | 7.10 | 7.10 | 7.00 | 7.00 | 7.00 |
| % Composition of Emitted Gas | $CH_4$ | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | $CO_2$ | 0.40 | 0.60 | 1.00 | 1.20 | 1.25 | 0.90 | 0.60 | 0.30 | 0.20 |

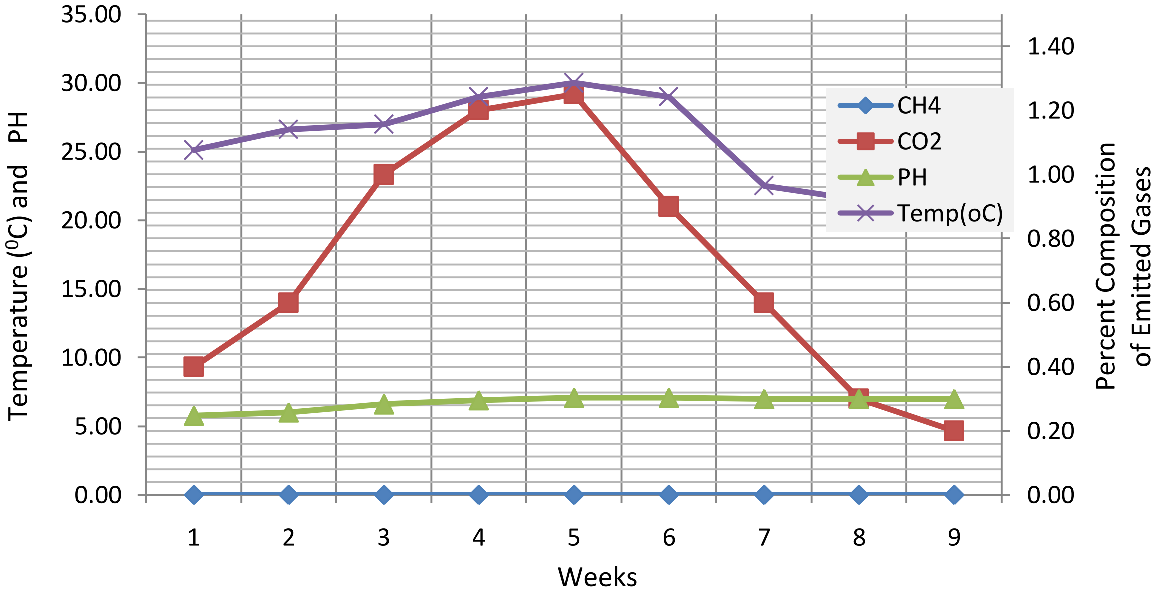


Fig. 4.1 Laboratory gas emission test results from composting floriculture waste

The experimental result indicate that after nine weeks of composting, the floriculture waste did not produce $CH_4$ since the reaction is aerobic, where as there is an appreciable level of $CO_2$ emission. Over a period of nine weeks the pH level exhibits a steady increase with an overall pH value changing from mildly acidic value of 5.8 to neutral of 7.0. The change in pH level to 7 is an indication for the end of composting as it is one among the quality parameterization of compost.

The temperature of the floriculture compost varied throughout the nine weeks period with a noticeable increase observed during the fifth week from an initial temperature of 25.1°c to 30.0 °c ( great change in temperature ) and gradually lowering to a value of 21.5 and 21.2 $^0$C at the eighth and ninth week respectively (minimum change in temperature) . All this change in temperature is due to the active microbial action .This minimum change for the last two weeks is an indication of the stabilization of the microbial activities and the composting materials too. (Andersen, 2009)

Because of the absence of the Gas Chromatograph equipped with an Electron Capture Detector (GC-ECD), $N_2O$ analysis in the laboratory was not conducted .But as, 2006 IPCC guidelines for National Greenhouse Gas Inventories and 2012 composting in WARM, in well managed compost piles the $CH_4$ and $N_2O$ emissions are typically negligible so good practice in the Waste Sector does not require their estimation. As it is known from the laboratory results (Table 4.3), the value of $CH_4$ is zero also it is considered that the value of $N_2O$ in this study is negligible.

In general from the graph ploted above ,when the composting temperature inside the aerobic digester increases due to active microbial activity, the concentration of the carbon dioxide emission increases .Specifically from the graph,as the temperature increases segnificantly from 25.1°C to the peack 30°C,the concentration of $CO_2$ emitted rises from 0.4 to 1.25 % by mass . At this point, the composting temperatures and more importantly, the production of carbon dioxide has begun to decline from their picks .As maturation progresses, the core temperature of the composting pile continues to decline and will eventually reach ambient temperatures which was 21.2°C .

Therefore fugitive emission (total concentration of $CO_2$ emission) within the nine weeks time frame of compost processing became 0.2836kg of $CO_2$eq (Annex II), that means at least a total of 90.752 kg of $CO_2$ is emitted in 1 ton of compost.

Table 4.4 Compost emission categories with their carbon dioxide equivalence percentage contribution

| Emission category | $CO_2$(kg) | $CH_4$(kg) | $N_2O$(kg) | Total $CO_2$ eq (kg) | % Contribution of the $CO_2$ eq |
|---|---|---|---|---|---|
| Te | 145.26 | 8.09E-3 | 3.66E-3 | 146.57 | 58.77 |
| Pe | 11.184 | 6.244 E-4 | 2.873 E-3 | 12.083 | 4.845 |
| Fe | 90.752 | 0 | 0 | 12.083 | 36.39 |
| Total | 247.196 | 8.7144 E-3 | 6.533 E-3 | 249.403 | |

Results on the three dominant types of emissions and the three primary forms of contributed to greenhouse gases are presented in Table 4.4. The experimental results for $CO_2$, $CH_4$, and the determined value for $N_2O$ are tabulated in kilograms per ton of waste and so as $CO_2$ equivalent in kilograms per ton of waste. The percentage contribution of the most significant of the three gases, $CO_2$ equivalent is also included in the table to provide a better quantitative comparison for the analysis.

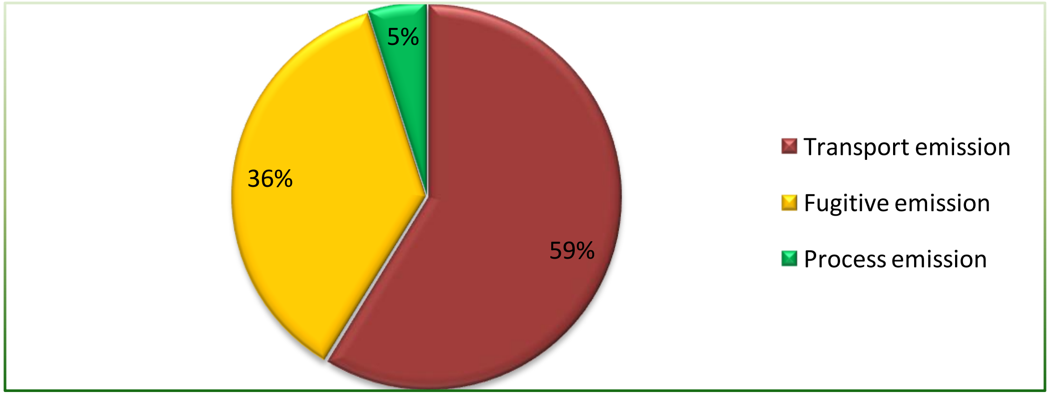


Fig 4.2 Relative contribution of each life cycle stage of compost from floriculture waste towards the total environmental burden

The results indicate that $CO_2$ is the most significant contributor in all three emission categories with values of 145.26 kg/tone for transport emissions, 90.75 kg/tone for fugitive emissions, and 11.18 kg/tone for process emissions. Compared to $CO_2$ the contributions of $CH_4$ and $N_2O$ are insignificant with values running from 0 to 8.09E-03 for $CH_4$ and 0 to 3.66E-03 for $N_2O$.

As in the fig. 4.1 the result demonstrates that from the three emission categories, transportation is the highest emitter with 59% $CO_2$ eq than fugitive and process emissions.

## 4.2. Compost Emission Reductions

### 4.2.1 Increased Soil Carbon Storage (CSb)

The carbon storage value obtained for the passive carbon phase was 0.183 $CO_2$eq/ton of feedstock. Combined together the overall carbon storage value was 0.256 t $CO_2$eq/ton of feedstock. The results indicated that the carbon storage of the active carbon phase due to compost application was 0.073 t $CO_2$ eq /ton of feedstock

### 4.2.2 Decreased Water Use (Wb)

Over 30 years, this equates to a benefit of 3550 and 13000 gallons/tone of compost for the fire affected and construction sites, respectively. Converting gallons per ton of compost to AF and multiplying by the water use emission factor (1.5 $CO_2$eq/AF) leads to a range of 0.015-0.065 t CO2eq/tone of compost and an average of 0.04 t $CO_2$ eq/tone of compost

### 4.2.3 Decreased Soil Erosion (Eb)

The emission factor for replacing one ton of eroded soil was 0.114 t $CO_2$ eq/ton of feedstock. Compost applied to the fire affected site and construction site reduced soil erosion by 91 and 328 lbs/ton of compost on a 1 - year timescale, respectively. This corresponds to a 30 year soil retention benefit of 1750 and 6300 lbs of soil/ton of compost for the fire affected and Construction sites.The emission factor is 0.119 t $CO_2$ eq/ton of soil, which equates to an average savings of 0.25 t $CO_2$ eq/ton of compost and a range of 0.1 - 0.39 t $CO_2$ eq/ton of compost (after being multiplied by the pounds of soil saved) over a 30-year time period.

### 4.2.4 Reduced Fertilizer Use (Fb)

The emission factors for N, P, and K are 8.9, 1.8 and 0.96 kg $CO_2$ eq/kg respectively. The results from this method compare well with existing literature studies. The average fertilizer benefit from these studies was 0.17 t $CO_2$ eq/ton of compost with a range of 0.14-0.32 t CO2eq/ton of compost.

### 4.2.5 Reduced Herbicide Use (Hb)

This produces a measurable but highly uncertain greenhouse gas benefit which is < 0.001 t $CO_2$ eq/ton of compost due to the large amount of compost needed to achieve the same benefit as a small amount of herbicide. In terms of the overall contribution to the CERF, this benefit is negligible.

Except increased soil carbon storage (CSb) which was measured in terms of kg $CO_2$ eq in one ton of the row material (feedstock), the benefits of all were measured in terms of kg $CO_2$ eq in one ton of the product which is compost.As shown from table 4.5 the result of application of composted products have positive values meaning negative GWP.

Table 4.5: summary of compost application emission benefits

| Compost application emission benefits | Emission Reduction ($B_{total}$) | |
|---|---|---|
| | Kg $CO_2$ eq/ ton of feedstock | kg $CO_2$ eq/ton of compost |
| Increased soil carbon storage (CSb) | 256 | - |
| Decreased water use (Wb) | - | 40 |
| Decreased soil erosion (Eb) | - | 250 |
| Reduced fertilizer use (Fb) | - | 170 |

### 4.3. Compost Emission Reductions Factor (CERF)

In general the benefit of post application impact ($B_{total}$) and the Compost Emission Reduction Factor (CERF) became 653.44 kg $CO_2$eq and 404.037 CO2eq per ton of feedstock respectively. [Annex II]

All the results show that production and application of compost products produced negative GWP, representing a net environmental benefit or beneficial environmental impact. The reason is being that post application benefits of compost products reduce requirements for energy, fertilizers, and herbicides and increase carbon sequestration. These benefits reduce the release of greenhouse gases involved in the production and use of these items for agriculture resulting in net reduction in GWP.

### 4.4 Fertility Potential Evaluation of Compost

#### 4.4.1Nutrient and Trace Metal Evaluation

The laboratory result of the matured compost for the nutrients and trace metals compared with the standards sated by the EU for trace metals is given in the table shown below.

Table 4.6: Laboratory result of compost from floriculture waste to evaluate its fertility potential

| Parameters | N (%) | P (ppm ) | K (ppm ) | Mn (ppm ) | Zn ( ppm ) | CU (ppm ) | C/N | Organic matter (%) |
|---|---|---|---|---|---|---|---|---|
| Compost | 0.406 | 34 | 14840 | 602.5 | 940.91 | 1484 | 18 | 18 |
| Soil | 0.046 | 14 | 25.4 | 512.3 | - | - | - | - |
| EU-Standard of compost | - | - | - | - | 280-4000 | 100 - 1750 | 10 - 30 | 50 - 70 |

As shown in table 4.6, when comparing the laboratory results for the trace metals of compost from floriculture waste with the EU standard, the concentration of Zn, CU, C/N and organic matter lies within the range. In addition the nutrient concentrations (N, P and K) of the soil became very low when it is compared with the N, P and K of the compost. It implies that the floriculture waste compost was richer in nutrients and increases the soil's ability to hold plant's available nutrients by creating high quality healthy soil.

### 4.4.2 Planting Evaluation

Varying the concentration of compost by keeping the number of seeds constant on the two bins, the plant (cabbage) was grown by watering 300ml of water for 6 weeks .But after the 6th week watering was interrupted and stopped purposely to see the effect on the plant growth. Its effect is as shown in the fig below.

Fig4.2 Evaluating fertility potential of compost (a)25% compost added bin before the 6th week (left) after the 6th week (right) (b) 0% compost added bin before the 6th week (left) after the 6th week (right)

i.

(b)

As in the fig 4.2 (a) & (b) left the result at 25% composted bin was appreciable than the 0%. Again as in the fig (b) (right) after the 6th week the soil became dried and went cracked due to the scarcity of water, as the result, the growth of the cabbage became interrupted and went to die .To the opposite, on the 25% composted bin, there was no significant negative effect on the growth of the cabbage rather its soil kept moist.

The above planting analysis shows the benefit from application of compost to boost plant health and the potential to reduce irrigation water producing a net environmental benefit in terms of water conservation. As it is already known majority of farming culture of Ethiopia is based on seasonal rain so in case of interruption of seasonal rain, crops can die at pre-maturity stage .the use of organic compost can solve this problem to certain degree.

From the above evaluations, Compost therefore has the potential to supply a significant proportion of a crop’s total nutrient needs ,increasing soil organic matter, improves soil structure, water infiltration, soil aeration, combats compaction and increases the soil’s water-holding capacity, increases soil health, fertility and productivity.

## 5. Conclusion and Recommendation

### 5.1 conclusion

- The results of this study indicates that $CO_2$ is the most significant contributor in all three emission categories with values of 145.26 kg/ton $CO_2$eq for transport emissions, 90.75 kg/ton $CO_2$eq for fugitive emissions, and 11.18 kg/ton $CO_2$eq for process emissions. From the three emission categories, transportation is the highest emitter (59% $CO_2$ eq ) than fugitive and process emissions. Planting a plant (cabbage) in addition to characterizing compost for nutrients and trace metals concentration was made to evaluate the fertility potential of compost from floriculture waste.

- The results of all show that production and application of composted products produced negative GWP, representing a net environmental benefit or beneficial environmental impact. The reason is being that post application benefits of composted products reduce requirements for energy, fertilizers, and herbicides and increase carbon sequestration. These benefits reduce the release of greenhouse gases involved in the production and use of these items for agriculture resulting in net reduction in GWP.

- The results can be used for the elaboration of a greenhouse gasses emissions inventory from floriculture waste in Ethiopia The great benefit of conducting this study is the incremental establishment of data to support future comparative studies on the basis of total environmental impact so that to Support decision makers about the environmental impact of composting system in the country. However, further research is required to quantify emission reduction benefits from using floriculture compost using LCA.

## 5.2 Recommendations

- It is known that the government of Ethiopia has initiated a Climate-Resilient Green Economy (CRGE) initiative to protect the country from the adverse effects of climate change and to build a green economy. In addition to this, currently, the horticulture sector has shown a very dramatic growth in the country. By considering the huge generation of solid waste from the sector as a good opportunity, the country can save currency from importing artificial fertilizers at the same time adhering with the idea of CRGE .

- The horticultural sector can make their own compost to save their currency in addition to saving the environment from using vast amount of artificial fertilizer.
- As a country and as the economy of a country is based on agriculture, there should be compost standard in Ethiopia.

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# Annex

## ANNEX I – Pictures on Windrow and Laboratory Experiment

(A) (B) (C) (D)

Fig. 1 (A) Transportation and disposal of waste (B) waste separation (C) preparation and weighing the row materials for compost making (D) compost making

**A) (B) ( C)**

Fig.2 ( a) finished compost (c) weaighing compost and soil ( b ) mixing compost and soil in different proportion to plant a cabbaje for the analysis

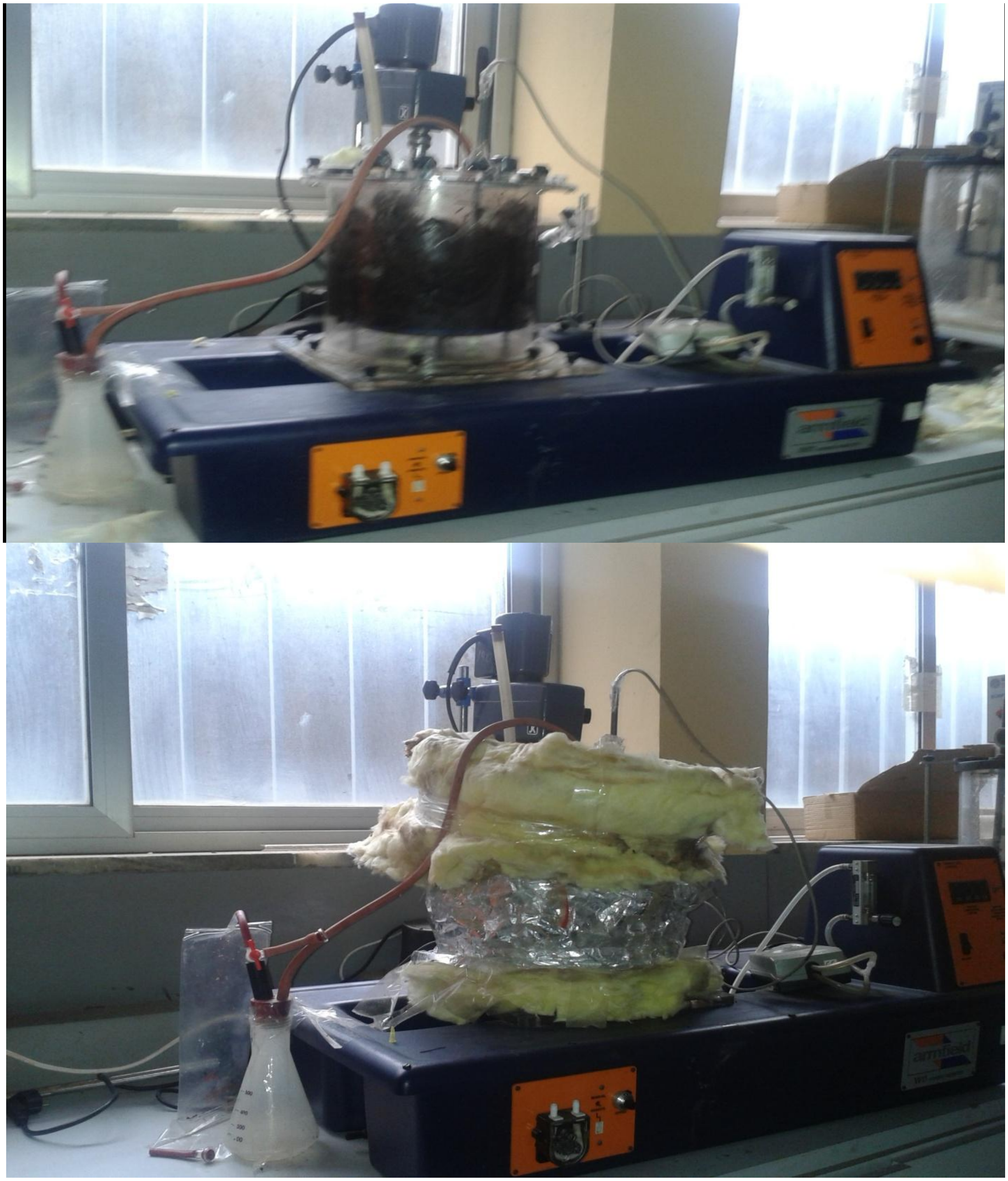

Fig. 3 Compost making and emission gas collection in the laboratory

# ANNEX II- Composting Emission ($E_{total}$) , Compost Emission Benefit ($B_{total}$) and Compost Emission Reduction Factor (CERF)

## 1. Transport Emission

Emission from one litter of diesel = $1.548*10^{-4}$ kg of $CH_4$

52.25 liters of diesel consumption emits =$8.09*10^{-3}$kg of $CH_4$

Emission in terms of $CO_2$eq =$21*(8.09*10^{-3})$kg=0.17kg of $CO_2$eq

**Transport emissions** (kg) = distance travelled (km) * [$CO_2$ (kg) * $EC0_2$ +$CH_4$ (kg) * $ECH_4$+ $N_2O$ (kg) * $EN_2O$]

Kg of diesel = little of diesel *specific gravity of diesel

One kg of diesel = One litter of diesel *0.845 liter/kg

*1kg of diesel=1.18 litter of diesel*

| Gas type | Emission(kg) |
|---|---|
| **$CO_2$** | 3.28425 |
| **$CH_4$** | 0.01392 |
| **$N_2O$** | 0.038715 |

Therefore

**$CO_2$ emission**

Emission from one litter of diesel =2.776 kg of $CO_2$

52.25 liters of diesel consumption emits =145.26 kg of $CO_2$

Emission in terms of $CO_2$eq =1*(145.26kg of $CO_2$) kg=145.26kg of $CO_2$ eq

**$CH_4$ emission**

From the above table and eq1,

**$N_20$ emission**

| | |
|---|---|
| Emission from one litter of diesel | $=7.0*10^{-5}$kg of $N_2O$ |
| 52.25 liters of diesel consumption emits | $=3.66*10^{-3}$kg of $N_2O$ |
| Emission in terms of $CO_2$eq | $=310*(3.66*10^{-3)}$ kg=1.14kg $CO_2$ eq |

2. Process Emission

***Process Emissions** (kg) = fuel used (kg) * [$CO_2$ (kg) * $ECO_2$ +$CH_4$ (kg) * $ECH_4$+ $N_2O$(kg) * $EN_2O$]*

Table1 Equipments Specification for Compost Processing (Recycled Organics Unit, 2007)

| Function | Equipment | Engine Capacity/Fuel Consumption | | | Quantity of Material | Duration of Hour |
|---|---|---|---|---|---|---|
| Size Reduction | Matilda MK grinder | | 1200hp | 200l/hr | 60tonn (density=309kg/m³) | 1hour |
| Windrow Formation and Turning | volvoL20 wheel loader | 165 kw | 224 hp | 15 l/hr | 250m³(density= 650 kg/m³) | 1hour |
| Windrow Watering | High volume low pressure, electric pumps | 4 kW | | | | Transfers water from feeder tanks to windrow 100 l/min |
| Screening | Chieftain 1200 power screen | | | 16 l/hr | 60m³ (density=650kg/m³) | 1hour |

**Size reduction**

Given

Diesel consumption of the grinder = 200 l/hr

Quantity of row material =60 tone

Duration to grind 60 tone =1 hour

Solution

To grind 1 tone of the feedstock needs 0.0167 hr

3.33liter is used to grind one tone of feedstock in 0.016 hr

Therefore the associated emission due to the 3.33 liters of diesel consumption is calculated as below

**$CO_2$ emission**

Emission in 3.33 litter of diesel = 9.268 kg of $C0_2$

Emission in terms of $CO_2$eq =1*9.268 kg $CO_2$ =9.268 kg of $CO_2$ eq

**$CH_4$ emission**

Emission in 3.33 litter of diesel = 5.155E-4 kg of $CH_4$

Emission in terms of $CO_2$eq =21*5.155E-4 kg of $CH_4$=0.010815kg $CO_2$eq

**$N_20$ emission**

Emission in 3.33 litter of diesel = 2.33E-4 kg of $N_20$

Emission in terms of $CO_2$eq =310*2.33E-4 kg of $N_20$=0.07223 kg $CO_2$eq

**Windrow formation and turning**

Given

Volume of sample =200 $m^3$

Density =650 $kg/m^3$

Duration =1 hour

Fuel consumption =15 l/hr

Solution

M= $\delta$*v=130 tone

1tone requires 0.008 hr

for windrow formation and turning 1 tone of feedstock requires 0.12 liter of diesel

Therefore the associated emission due to the 0.12 liter of diesel consumption is calculated as below

**$CO_2$ emission**

Emission in 0.12 litter of diesel = 0.336 kg of $C0_2$

Emission in terms of $CO_2$eq =1*0.336 kg $CO_2$=0.336 kg $CO_2$eq

**$CH_4$ emission**

Emission in 0.12 litter litter of diesel = 2.12E-5 kg of $CH_4$

Emission in terms of $CO_2$eq =21*2.12E-5kg of $CH_4$=4.452E-4 kg $CO_2$eq

**$N_20$ emission**

Emission in 0.12 litter of diesel = 8.4E- 6 kg of $N_20$

Emission in terms of $CO_2$eq =310*8.4E- 6 kg of $N_20$=2.6E-3 kg $CO_2$eq

### Screening

Given

Volume of sample =60 $m^3$

Density =650 kg/$m^3$

Duration =1 hour

Fuel consumption =16 l/hr

Solution

M= $\delta$*v=130 tone

1tone requires 0.03hr

To screen 1 tone of feedstock requires 0.48 liter of diesel

Therefore the associated emission due to the 0.48 liter of diesel consumption is calculated as below

**$CO_2$ emission**

Emission in 0.48 litter of diesel = 1.58kg of $CO_2$

Emission in terms of $CO_2$eq =1*1.58kg of $CO_2$=1.58 kg $CO_2$eq

**$CH_4$ emission**

Emission in 0.48litter of diesel = 0.877*$10^{-4}$kg of $CH_4$

Emission in terms of $CO_2$eq =21*0.877*$10^{-4}$kg of $CH_4$ =1.84*$10^{-3}$kg $CO_2$eq

**$N_2O$ emission**

Emission in 0.48 liter of diesel = 4.0E-5 kg of $N_20$

Emission in terms of $CO_2$eq =310*4.0E-5kg of $N_20$=1.24 E-2 kg $CO_2$eq

**Total diesel consumption due to processing**

Total diesel consumption due to = ( size reduction + Windrow formation and turning+ watering +screening )

= 3.33liter +0.12liter+0+0.48liter=**3.93liters**

Therefore total composting emissions became

**Etotal** **=** Te + Pe +Fe

= 146.57+12.083+12.083

=**249.403$CO_2$ eq** **. . . (1)**

$\mathbf{B}_{total}$ = $CS_b$+(($W_b$+$E_b$+$F_b$+$H_b$)*$C_{use}$)

Where,$\mathbf{C_{use}}$**=** Final weight/initial weight

Initial weight =3.125 kg sample &

Final weight =2.7kg of compost

i.e, $\mathbf{C_{use}}$ = 2.7kg/3.125kg = 0.864kg

=256+((40+250+170+0)*0.864)

=653.44kg of $CO_2$ eq/ton of feedstock **. . . (2)**

**CERF** **= $\mathbf{B_{total}}$ –$\mathbf{E_{total}}$**

=(653.44-249.403) kg of $CO_2$eq/ton of feedstock

=**404.037 $CO_2$eq/ton of feedstock**