ADDIS ABABA UNIVERSITY

FACULTY OF NATURAL SCIENCE

CENTER OF FOOD SCIENCE AND NUTRITION

Title of Project:- Food Waste management in some selected hotels at Addis Ababa, Ethiopia and their consequences.

By
Teferi Nemera

A Thesis Summited to graduate Studies program, Addis Ababa University in partial Fulfillment of the requirements for the degree of Master of Science in food Science and Nutrition

Major Advisor: Gulelat Desse Haki (Professor)
Co-advisor: Tilahun Bekele (Assistant Professor)

June, 2016
Addis Ababa, Ethiopia

DECLARATION

I, the undersigned, declared that this thesis is my original work and that all sources of materials used for the thesis have been correctly acknowledged.

Name: Teferi Nemera Bultum

Signature: _____

Date: _____

The thesis has been submitted with my approval as a supervisor.

Name: Professor Gulelat Desse Haki Signature: _____

Date: _____

Tilahun Bekele (Assistant Professor) Signature: _____

Date: _____

The thesis has been submitted with my approval as an examiner.

Name of external examiner: Dr. Majid Mohiuddin Signature: _____

Date: _____

Name of internal examiner: Dr. Ashagrie Zewdu Signature: _____

Date: _____

ACKNOWLEDGEMENT

First of all, I strongly desire to give my glory to God.

I would like to give my gratitude to my advisors Gulelat Desse Haki (Professor) and Tilahun Bekele (Ass.Professor) had been supporting me in any cases of my work, encouraging me to be strong and for their valuable discussion early from the beginning in developing my proposal till this end time.

It is also grateful to thank the Microbiology Department especially Ms Zenebech and Nigatu for their permission to use the microbiology laboratory facilities, and all the workers in that lab had been helping me while working with the food microbiological analysis.

I never forget the greatest contribution of my families, especially my wife, and my organization staff members also need to have so many thanks for their illimitable support.

Finally, I would like to acknowledge Food Science and Nutrition Center of Addis Ababa University for accept and training me in the program; and to all the staff members of the center for helping me in my effort to be fruitful.

Table of Contents

LIST OF ABREVIATIONS

ABT - Advanced Biological Treatment

AD - Anaerobic Digestion

ANOVA - Analysis of Variance

BOD – Biological Oxygen Demand

BOD_5 - 5-Day-Biological Oxygen Demand

CFU - Colony Forming Units

HgSO4 - Mercuric sulfate

CH_4 - Methane

C&I - Commercial and industrial

COD - Chemical oxygen demand

CO_2 – Carbon Dioxide

CV - Coefficient of variation

EU - European Union

G - Gram

GC - Gregorian calendar

IWMF - Integrated Waste Management Facility

Kg - Kilogram

KOH - Potassium Hydroxide

KWh - Kilo watt per hour

Log_{10} – Logarithm of ten

MBT - Mechanical Biological Treatment

Ml - Milliliter

Mm - Mili meter

MS - Municipal Solid

MSW - Municipal solid waste

NGOs – Non Governmental Organization

NWPP - National Waste Prevention Programs

OWTFs - Organic Waste Treatment Facilities

PDA – Potato Dextrose Agar

SPSS - Statistical Products and Service Solutions

TAD - Thermophilic Aerobic Digestion

TDS - Total Dissolved Solids

TKN - Total Kjeldhahl Nitrogen

TS - Total Solids

TSS - Total Suspended Solids

UK – United Kingdom

U.S – United State

VSS - Volatile Suspended Solid

WFD - Waste Framework Directive

^{0}C - Degree Celsius

^{o}F - Degree Fahrenheit

LIST OF FIGURES

LIST OF TABLES

LIST OF APPENDICES

Abstract

Background*: Food waste comprises a significant portion of waste stream hotels, contributing to ecological damages and nutritional losses. Guided by a systems approach, this study assesses, and characterizes food waste and also investigate microbial load in food waste from hotels in Addis Ababa, Ethiopia using 1978–2016 Publications, personal interviews and instruments.*
Method: *A total of 5 kg and 5 liter samples of food waste were aseptically collected from 12 points of a trigonaly disposed in a sterilized polyethylene bags from the randomly selected hotels in Addis Ababa And analyzed for their load of microbial groups using Gram staining KOH test microbiological method. The presence of Biological oxygen demand, Chemical oxygen demand and their physical parameters were also determined.*
Result: *About 66,600 tones of food waste were generated per a year from Addis Ababa city. Of all about 97% was generated during food preparation and 3% by consumers. But waste contains high amount of total solids, dissolved solids, and suspended solids, volatile solids, Total Kjeldahl nitrogen, Potassium, Phosphorus, sulphur, BOD and COD. Its microbial counts ranged from* $1.1x10^{23}$ *CFU/ml to* $1.3x10^{23}$ *CFU/ml and high amount of gram negative bacteria*
Conclusion*: The* 10^{7} *CFU/ml represents an index of spoilage and* 10^{8} *CFU/ml represents odour development. Therefore; the food waste did not fit for human consumption. And there is no any treatment; 100% of it was land filled. But it can be minimized to zero level or converted in to other products.*

KEY WORDS: Food waste, hotel, Addis Ababa, Microbial.

CHAPTER 1: INTRODUCTION

1.1 Background

Food wastes occur before, during or after food preparation in hotels, as well as food discarded too early manufacturing, distribution, retail and food service activities (Gustavsson et al., 2011). The food wastes from Addis Ababa city are directly disposed in to a land filed. This indicates that food waste management is poor and results in economic lose, environmental pollution and affects the health of its habitants.

The most important step in reducing food waste is to avoid its creation. The population should focus on real needs of nutrition and choose to avoid over-buying, over-ordering and over preparing food and thereby avoid dumping. Individuals, households and businesses should not waste precious food (Food, 2014).

An analysis of current food waste generation in any nation is a first step in the development of a national strategy on food waste. This includes an assessment of the adequacy of data reporting on food waste and efforts to ensure that definitions of food waste are clear and coherent. Food waste data reporting can be improved by establishing a common definition of food waste and by launching pilot studies on its measurement. The size and structure of the food sector may be taken into consideration along with the demographic factors such as the proportion of urban residents. Existing infrastructure to manage food waste and future needs should be considered alongside policy pressures on food waste management (Maxwell et al., 2011).

Reporting food waste separately provides a clear indicator of progress on prevention. Food waste that cannot be avoided should be recycled as much as possible. Successful food waste recycling requires the waste to first be separated from other types of municipal solid waste and then collected for delivery to recycling facilities. Food waste that has been mixed with other types of waste is contaminated and cannot be recycled. The separation and collection of food waste is therefore a critical aspect of any food waste recycling system (Food, 2014).

Turning food waste in to methane or biogas with biological technology is a mature solution to treat food waste for the dual purposes of solid waste management and generating energy. Biogas facilities to treat food waste are quite common in European countries such as England and

Germany. In the biggest city of China, Hong Kong, two Organic Waste Treatment Facilities turn food waste to biogas and compost (Nathao et al., 2013).

The other approach to valorize food waste developed is a bio-refinery process that can effectively convert food waste into valuable chemicals without carbon emission. This process utilizes enzymes and bacteria to convert food waste into succinic acid, which is a chemical widely applied to form the basis of many compounds for home and industrial uses. It is widely used as a flavoring agent by the food and beverage industry and as an ingredient to manufacture biodegradable plastics, textile and paints. The remaining solid biomass can be used as soil fertilizer. The bio-refinery process to produce succinic acid through the use of food waste should therefore be a feasible, and cost effective for environmental alternative (Zhang et al., 2013).

There are also recent cases in Japan of restructured pork production infrastructure that reuses and recycles food waste as feed in order to reduce CO_2 emission from incinerators (Maxwell et al., 2011).

There is no information on food waste generation and management particularly in hotels around Addis Ababa. The possible environmental hazard that these food wastes may cause and recycling opportunities are not documented. Therefore, the aim of this study was to survey and characterize the food wastes generated from selected hotels at Addis Ababa, Ethiopia and investigate the various parameters associated to food waste and the microbial load.

1.2 Statement of the problem

This study has addressed the following research questions around Addis Ababa hotels.

1) What contributions of food waste management practices?
2) What are the main consequences of food waste?
3) What is the microbial content of the food waste?

1.3 Objective Of The Study

1.3.1. General objective

The general objective of this project is to survey the food waste management practices at Addis Ababa Hotels and characterization of the waste generated.

1.3.2 Specific Objectives

1) Survey the food waste management practices and raw material handling of hotels

2) Characterize the waste generated in terms of total solids, dissolved solids, suspended solids, volatile solids, Total Kjeldahl nitrogen, Potassium, Phosphorus, sulphur, PH, Conductivity, BOD and COD

3) Investigate the microbial load of the waste generated

1.4 Significance of the Study

One can imagine how much food is lost due to food waste management problem at hotels that occur before, during or after food preparation, as well as food discarded too early manufacturing, distribution, retail and food service activities (Gustavsson et al., 2011).

The result of this study has contribution around Addis Ababa in:

1) Improving the food waste management problem.
2) Determining the consequences of the food waste.
3) Inspiring others to engage in finding other good food waste management practices

CHAPTER 2: LITRATURE REVIEW

2.1 What is a waste?

Under the Waste Framework Directive, the European Union defines waste as "an object that the holder discards, or intends to discard or is required to discard (Ragonig & Faist, 2009).

Municipal solid waste (MSW), commonly known as trash or garbage in the U.S. and as a refuse in the UK, is a waste type consisting of everyday items that are discarded by the public. "Garbage" can also refer specifically to food waste, as in a garbage disposal; the two are some times collected separately. The composition of municipal solid waste varies greatly from municipality to municipality (country to country) and changes significantly with time. In municipalities (countries) which have a well developed waste recycling system, the waste stream consists mainly of intractable wastes such as plastic film, and unrecyclable packaging materials(Chefetz, et, 1996).

At the start of the 20th century, the majority of domestic waste (53%) in the UK consisted of coal ash from open fires. In developed municipalities (countries) without significant recycling activity mainly includes food wastes, market wastes, yard wastes, plastic containers and product packaging materials, and other miscellaneous solid wastes from residential, commercial, institutional, and industrial sources(Knipe, 2005).

2.1.1 What is food waste?

Food waste is the food that is discarded or lost uneaten which include the followings:

1) Rotten fruit and vegetables
2) Fish and poultry organs and intestine,
3) meat scraps and residues
4) Fruit and vegetable peelings, and cores
5) Meat, fish, and bones
6) Food fats
7) Egg shells, cheeses, ice cream, yogurts
8) Tea leaves, and coffee grounds
9) Bread, cakes, biscuits, and jam

10) Cereals of all types e.g. rice, and maize
11) Plate scrapings and leftover of cooked food
12) Raw or cooked leftovers
13) Food past its use-by-date/expire date
14) Pet food, and but not limited (Food, 2014).

The causes of food waste are numerous, and occur at the stages of production, processing, retailing and consumption. It occurs at all stages of the food supply chain or value chain. In low-income countries, most loss occurs during production, while in developed countries much food about 100 kilograms per person per year is wasted at the consumption stage (Men et al., 2011).

Furthermore, food waste can be distinguished into avoidable and non-avoidable waste. The National Waste Prevention Programs (NWPP) report on household food and drink waste in the UK defines avoidable food waste as discarded edible food and drink, such as milk, lettuce, fruit juice, and meat (excluding bones, skin, etc.). Food and drink that some people eat and others do not, like bread crusts, or that can only be eaten when a food is prepared in a certain way, like potato skins, is not considered as avoidable. Unavoidable waste is then defined as waste, which is not edible under normal circumstances, such as meat bones or egg shells (Maxwell et al, 2011).

The 2008 European Union Waste Framework Directive defines bio-waste as "biodegradable garden and park waste, food and kitchen waste from hotels, households, restaurants, canteen, retail, and comparable waste from food processing plants". It excludes forestry residues, manure, natural textiles, paper and related products, as well as by-products of food production that never become waste. Food waste may be raw or cooked and includes edible materials such as decayed bread or Potato skins as well as inedible materials like banana skins or egg shells. Food waste may occur before; during or after meal preparation, as well as food discarded during manufacturing, distribution, retail and food service activities (Gustavsson et al., 2011)

2.1.2 What is waste water?

Waste water can be defined in terms of physical, chemical and biological characterization of the water. The major determinant of water quality parameters includes temperature, dissolved oxygen, pH, conductivity, biological oxygen demand (BOD), chemical oxygen demand (COD), and nutrients. Additional determinants include total solids, dissolved solids, suspended solids, volatile solids, Total Kjeldahl nitrogen, Potassium, Phosphorus, sulphur, PH, and Conductivity. In most water bodies, various chemical parameters occur in low concentrations. This concentration level increases due to human activities, and lack of environmental regulation (Ukpaka, 2013).

2.2 Food Waste Avoidance The most important step in reducing food waste is to avoid creating it in the first place.

2.2.1 Community Mobilization

People need to rethink of their relationship with food. The main social mobilization of food-wise campaign is designed to stimulate the community, from individuals to households to commercial and industrial (C&I) operators, to avoid and reduce food waste at source (Food, 2014).

Food waste Prevention means measures taken before a substance, material or product has become desecrate, and buying only what is required and making the most of what is bought that reduces:

(1) The quantity of waste, including through the reuse of products or the extension of the life span of products;

(2) The adverse impacts of the generated waste on the environment or human health; or

(3) The content of harmful substances in materials or products.

2.2.2 Behavioral Change Approach to Food Waste Prevention

There are diverse causes of food waste that can often be linked to specific national circumstances, for example cultural norms about using leftovers or the acceptance of “doggie bags” from hotels, or climatic impacts on the generation of green waste. Conducting Municipal Solid level research on the causes of food waste can be a good starting point for the development of a national approach to food waste prevention.

Public authorities, businesses and citizens are all implicated in bringing the food waste prevention behavioral change. These suggests a sector-based approach to food waste prevention, with tools and policies targeted to the circumstances in which food waste arises to maximize efficiency and to bring together the key stakeholders in each area. The overall aim is to shift norms in the way food in particular is produced, distributed and managed to priorities resource efficiency (Maxwell et al, 2011).

The behavioral change approach can be explained in the following ways:

Motivate: begin by addressing the values that drive behaviors. Motivating values that mention an efficient use of resources have a more permanent and wide-reaching impact beyond the provision of information and incentives. "Values are seen as more central to the self, exceed objects and situations, and determine attitudes and behavior". Unselfishness and environmental identity, which arises from personal perception and interaction with the natural environment, are suggested as values that particularly motivate environmentally aware behavior. Awareness-raising, including demonstration of environmental impacts of current behavior and benefits of behavior change, can then be beginning. There are eight practical steps to concretely address and activate motivational values; examples include to "stress fundamental goals in environmental communications" or to "begin to set up a broader vocabulary of values in policy debates" (Maxwell et al, 2011).

Enable: provide the information, training, expertise, practical alternatives and infrastructure to make change possible.

Engage: involve people on a community level, develop pilot projects, and take advantage of existing networks, link experts, key stakeholders and thought leaders through discussion forums.

Exemplify: lead by example by demonstrating how resource efficiency works in practice in different levels of public administration, through green procurement, use of environmental management systems, etc. The sharing of best practices in different sectors can also be helpful here.

Encourage: stimulate resource efficient behavior through investment grants, economic incentives, price signals, taxation, penalties, benchmarking and competitive pressure. While

awareness-raising and the provision of information is crucial, food behaviors are often well-established at an early age, and an effective approach to behavior change will begin by targeting young populations. Thus, behavior change needs to be approached from a number of angles, as illustrated below. Establishing values that promote an efficient use of resources may inform behavior in a cross-cutting way and have broad potential environmental benefits. This is complemented by a practical, hands-on approach to the principle sectors where bio-waste and food waste in particular is generated (Maxwell et al., 2011).

2.2.3 Sector Based Approach to Food Waste Prevention

Food waste is generated during food production, the distribution and sale of food products, the preparation and serving of food in commercial and institutional environments, as well as in households through the discard of uneaten food.

The following key sectors can be identified for targeted action on food waste:

a) Food manufacturing (and processing);
b) Food distribution and retail;
c) The food service sector (hotels, catering, cafeterias);
d) Businesses and institutions (businesses, schools, hospitals, public administrations); and
e) Households (Maxwell et al, 2011).

2.2.4 Developing a food waste prevention program

An analysis of current food waste generation in any nation is a first step in the development of a national strategy on food waste. This includes an assessment of the adequacy of data reporting on food waste and efforts to ensure that definitions of food waste are clear and coherent. Food waste data reporting can be improved by establishing a common definition of food waste and by launching pilot studies on its measurement. The size and structure of the food sector may be taken into consideration along with the demographic factors such as the proportion of urban residents. Existing infrastructure to manage food waste and future needs should be considered alongside policy pressures on food waste management (Maxwell et al., 2011).

2.2.5 Approaches to Measurement

Reporting on the sectors enables Municipal Solid (MS) to track progress on sector-specific prevention measures and promotes benchmarking with other MS. When a clear definition and methodology for measuring food waste has been adopted through national study and pilot measurement projects, mandatory data reporting obligations for each sector may be considered, as some sectors may be unwilling to share this sort of information. Accurate measurement allows stakeholders and Member States to adapt their strategies when measures are not demonstrating expected results(Maxwell et al, 2011).

2.3. Separation and Collection of Food Waste

In the long run, food waste that cannot be avoided should be recycled as far as possible. Successful food waste recycling requires the waste to first be separated from other types of MSW and then collected for delivery to recycling facilities. Food waste that has been mixed with other types of waste is contaminated and cannot be recycled. The separation and collection of food waste is therefore a critical aspect of any food waste recycling system(Food, 2014).

There are two categories of food waste in general:

1. Pre-consumer food waste:

Waste from industrial food processing (vegetative and animal food waste).
Vegetative food waste (vegetable and fruit together, spoiled produce)
Animal food waste (fish, meat, diary)

2. Post-consumer food waste

Served food that has been left uneaten (plate scraping).
To recycle food waste it requires a three step strategy: separation, collection and recycling. Each step is a major operation in itself and then each of the steps needs to be properly aligned for good results (Food, 2014).

Step 1: Source Separation

Source separation is a vital for effective recycling of waste into useful resources. Waste generators should be responsible for separating their food waste. Thus, a food processing business, such as a factory making cakes or food sauces should put in place a system whereby the pre consumer food waste arising from its business is separated out for subsequent collection.

Likewise, a hotel can have a system whereby its pre-consumer and post-consumer food waste is also separated from other waste for collection (Food, 2014).

Voluntary or mandatory separation

Examples from abroad show there are successful cases in adopting the voluntary and mandatory approaches. Some authorities, such as South Korea, first adopted the voluntary approach to get society used to a new way to deal with food waste and to learn from the process before mandating food waste separation. After all, to be able to draft the appropriate legislation, it is necessary to clear how it is to be done. In the case of South Korea, legislation only came about 7 years after the system was started. The view is to take a similar approach to get the circle in motion on food separation and iron out the details step by step with the community first (Food, 2014).

Step 2: Collection and delivery

Transporting food waste requires special attention. Food waste collection vehicles are needed to ensure there is no leakage or odor. Thus, a new fleet of food waste vehicles will need to be used or the existing fleet will need to be upgraded. Once food waste has been separated from other MSW, it can be collected and delivered to the food waste recycling facilities.

Step 3: Treatment and Recycling

From a treatment perspective, food waste is characterized by typical parameters that describe the nature of waste and its potential impact on the environment. These parameters can be divided into physical, chemical and biological, mainly including temperature, PH and concentrations of dissolved oxygen, oil and grease, sulphur, nutrients (nitrogen and phosphorous), biochemical oxygen demand, and chemical oxygen demand (Chen, 1996).

Temperature

Temperature of the wastewater determines its thermal impact on the receiving water. In a receiving water body that supports a biological community, temperature needs to be maintained within a certain range. For example, direct discharge of cooling water to streams that support cold water fish species will cause elevated temperature of the stream and adversely impact the

fish. Another important aspect of temperature is its impact on decay of waste material in the wastewater. The higher the temperature, the faster the decay rate will be.

Solids

Solids concentration represents the amount of material contained in water, usually expressed as milligrams of dry weight per litre of water sample. Several terms are typically used for characterizing solids. For example, the total solids represent the amount of residue resulting from evaporation of a wastewater sample at 103 to 105^0C. The total solids can be further divided according to particle size into total dissolved solids (TDS) and total suspended solids (TSS). In wastewater analysis, this separation is made by using a filter pad with a pore size of about 2 microns. The dry weight of the residue contained in the water sample that passed through the filter is called TDS, whereas the dry weight of the solids retained on the filter is called TSS. Another commonly used term related to solids is settleable solids, which refers to wastewater solids that settle to the bottom within 1 hour, as measured using a graduated Inhoff cone.

All the solids portions described above can be further characterized as fixed residue or volatile residue. Fixed residue is the ash component produced after the solids material is burned in a muffle furnace at 550^0C for 15 to 30 minutes, where the volatile residue is the portion of solids that disappeared during the burning process. Thus, Volatile residue is often interpreted as the organic component of the solids, and fixed residue as the oxidized inorganic matter.

Solids in wastewater have various environmental impacts. High TDS increases the salinity of the receiving water. High volatile solids concentration means high organic loading to the receiving water. High TSS concentration increases the turbidity of the receiving water. Higher turbidity in water reduces light transmittance of the water column. Additionally, discharging the wastewater with a high TSS concentration can also alter the habitat of the receiving water due to the deposition of the solids.

PH

The PH is related to the hydrogen ion concentration in the wastewater, thus the wastewaters acidity. Most bacterial and biological life can survive only within a certain pH range. Thus, the waste water's pH represents its impact on the receiving water's acidity. Environmental

regulations for discharge to the environment typically require that pH of the wastewater be within the range 6 to 9. Extreme waste water pH also adversely affects the performance of chemical and biological wastewater treatment systems, and causes corrosion of equipment as well.

Dissolved Oxygen

Dissolved oxygen (DO) concentration in wastewater is a measure of oxygen availability in the wastewater. A variety of aquatic life and many types of aerobic bacteria rely on DO for proper function. Adequate DO is required in a water body to support aquatic life. Thus, DO is often the limiting factor in protecting the safety of an aquatic environment because of the competition for DO between different organisms.

Biochemical Oxygen Demand

Biochemical oxygen demand (BOD) is a parameter that describes the amount of biological degradable organic matter in wastewater. BDO is determined by measuring the amount of Do consumed in a wastewater sample for a given time period under a given temperature. For example, BDO_5 is typically used in environmental regulations for indicating the amount of DO required for the decay of organic constituents in the wastewater sample within five days at 20^0C.

Chemical Oxygen Demand

Chemical oxygen demand (COD) measures the amount of oxygen needed for chemical oxidization of organic material contained in the wastewater sample. COD represents the maximum impact of wastewater on the DO of the receiving water. COD analysis is conducted using a strong chemical oxidant, which is more rapid than BOD measurement. For specific wastewater, there may be a correlation between COD and BOD values

Oil and Grease

Oil and grease are sometimes called fats, oil, and grease. As the names implies, this parameter represents the amount of oil and grease in wastewater. The environmental impact of oil and grease can be noted in several aspects. First, the thin film of oil and grease on the water surface reduces the interchange of air with water, which reduces oxygen diffusion to the water.

Secondly, these hydrocarbons and related compounds require more oxygen per unit of weight than other organics to complete their oxidation and thus increase the oxygen demand. Oil and grease are typically less easily biodegradable.

Nitrogen

Nitrogen exists in different forms and is important to all forms of life. Transformation of nitrogen among different forms is governed by the nitrogen cycle. Most environmentally important nitrogen forms include ammonia, nitrate, nitrogen gas, and organic nitrogen, such as protein. In most food products, nitrogen exists in the form of protein. Decomposition of protein in food waste by bacteria converts the organic nitrogen to ammonia. In an aqueous solution, ammonia has two forms: NH3 an NH4. The equilibrium between these two species is determined by pH. The unionized ammonia from (NH3) is toxic to most aquatic life. Under aerobic conditions, ammonia is converted to nitrite, and then nitrate ($NO3^-$) by a group of bacteria called nitrifiers. Nitrate can be readily taken up by plants and converted to organic nitrogen. Nitrate is mobile in soil because of its negative charge. Excessive nitrate leaching to groundwater can cause health problems. High nitrate concentration in drinking water is toxic to humans, specially infants, and livestock. Under anaerobic conditions, nitrate is converted to nitrogen gas biologically through a process called denitrification. Some bacteria or plants can fix nitrogen from nitrogen gas to protein.

Another often used term in food processing wastewater is Total Kjeldhahl Nitrogen (TKN), which measures the concentration total of organic nitrogen and ammonia.

Organic nitrogen can be determined if ammonia is removed from the TKN analysis. The protein content of wastewater can be determined by the organic nitrogen content.

Phosphorous (P)

Phosphorous as phosphate (PO_4^2) is another essential element in many living organisms, and is often considered the growth limiting factor in numerous water bodies, such as rivers and lakes. Excess P input to receiving water can cause eutrophication in rivers and lakes, characterized by the abundant growth of algae and other aquatic plants, which during the respiration phase at

night can deplete the dissolved oxygen in water bodies, causing fish kill and other nuisance conditions.

Sulphur

Sulphur compounds in wastewater are a major problem for some food processors. The use of sulphur dioxide in pre-treatment of fruits or sodium bisulphide in processing may result in sulphur content in wastewater. Sulphur compounds exist in water primarily as sulphide and sulphate ions or precipitates. Hydrogen sulphide, a product of anaerobic processes, can cause bad odor problems.

2.4 Treatment and Recycling of Food Waste

2.4.1 Turning food waste in to methane

Turning food waste in to methane or biogas with biological technology is a mature solution to treat food waste for the dual purposes of solid waste management and generating energy. Biogas facilities to treat food waste are quite common in European countries such as England and Germany. In Hong Kong, two Organic Waste Treatment Facilities has planned to establish to turn food waste to biogas and compost. One of the facilities is to be located at Siu Ho Wan (Phase I) and another one at Shaling (Phase II). When both facilities are in full operation in the future, the total treatment capacity is 400 to 500 tons of food waste per day. The Siu Ho Wan facility is scheduled to begin construction in March 2014 and in operation by June 2016 (Nathao et al., 2013).

It is possible to turn food waste to a high concentration of methane. Furthermore, if the methane from the 1.3 million tons of food waste generated each year in Hong Kong is fed into gas turbines to generate electricity, it is estimated that the energy output is enough to provide about 1-2% of Hong Kong's electricity consumption (i.e. around 0.4-0.8 billion kWh). Even though the output remains a small percentage of our energy consumption, this treatment technology serves three important purposes: (1) it diverts food waste away from landfills to lessen their burden; (2) the electricity produced can reduce the use of fossil fuels; and (3), the reduced consumption of fossil fuels in essence lowers the carbon emission (Dearman et al., 2006).

2.4.2 Turning Vegetable oil waste into fuel oil

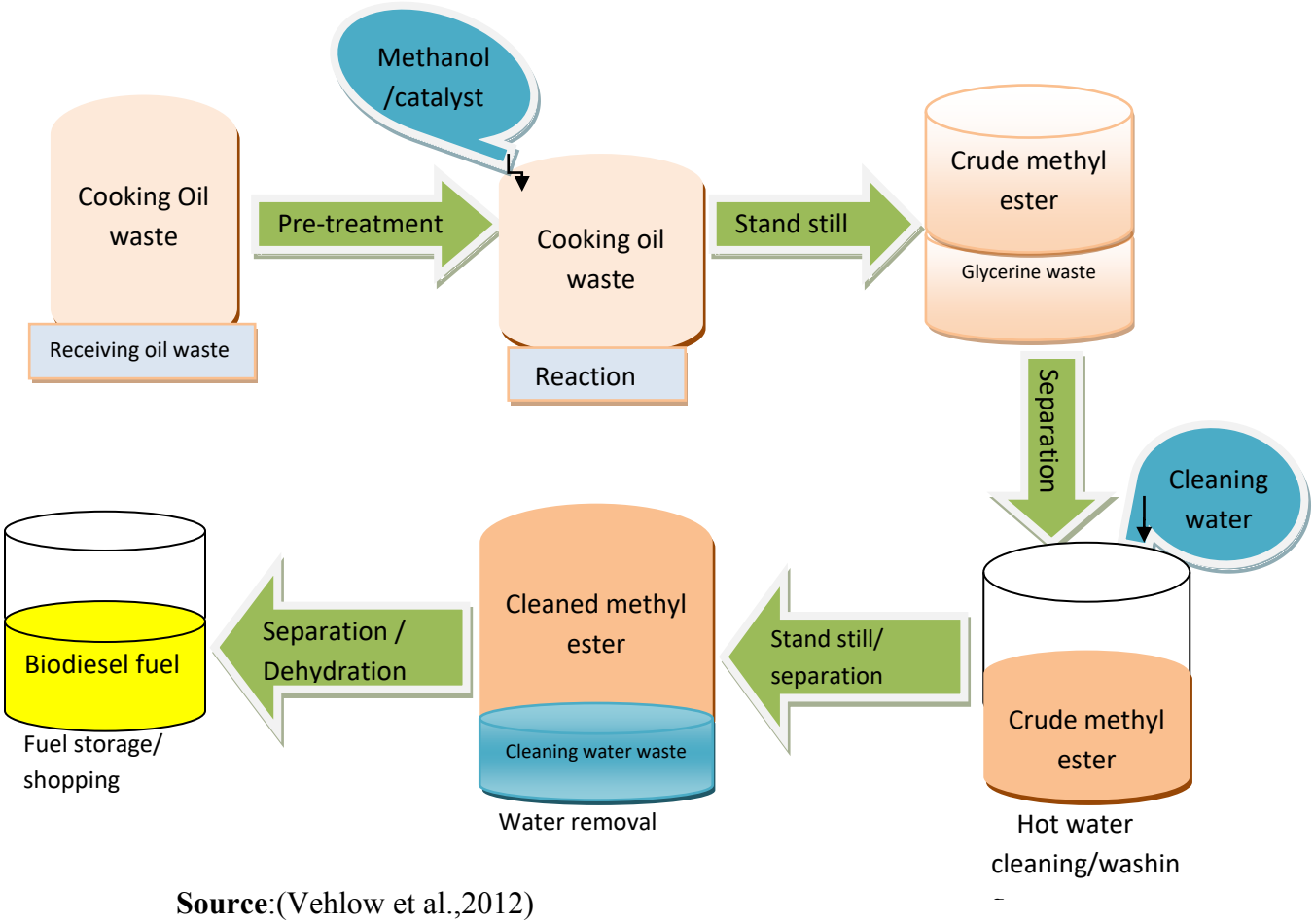
Cooking oil waste recovery system is structured to manufacture fuel oil, which is used as fuel for city-operated buses and garbage collection trucks that indicated in figure 1 below.

(1) Treatment capacity: Vegetable oil waste - approximately 5tone/day

(2) Treatment method: Fatty acid methyl ester

(3) Biodiesel fuel production: 5,000liter/day

Figure 1: Biodiesel Production process



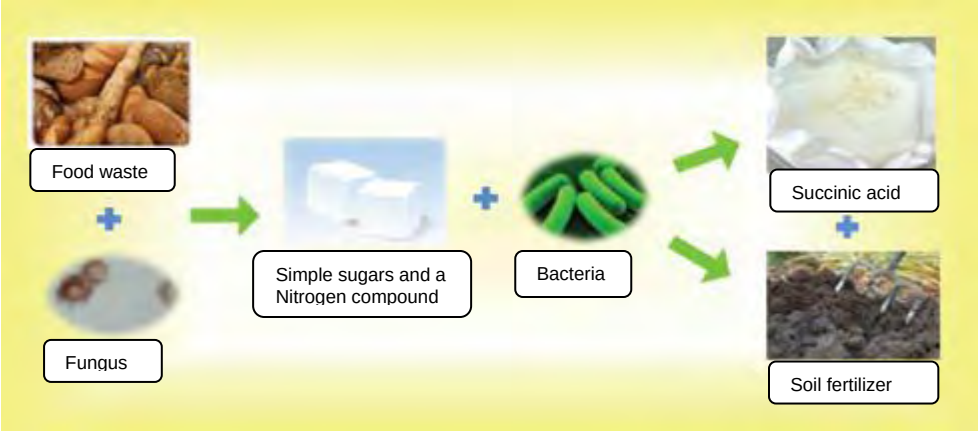
Source:(Vehlow et al.,2012)

2.4.3 Turning food waste in to succinic acid

A “bio-refinery” process can effectively convert food waste into valuable chemicals without carbon emission. This process utilizes enzymes and bacteria to convert food waste into succinic acid, which is a chemical widely applied to form the basis of many compounds for home and industrial uses.

During the process, food waste is first blended with two kinds of enzymes-secreting fungus to break down the carbohydrates and proteins in food respectively into simple sugars and nitrogen compound. Then, bacteria are added to undergo fermentation utilizing the simple sugars and nitrogen compound to produce succinic acid, which is widely used as a flavoring agent by the food and beverage industry and as an ingredient to manufacture biodegradable plastics, fabrics, paints, etc. As an important “bonus”, the remaining solid biomass can be used as soil fertilizer figure 2 below. It is currently produced from petroleum, which is energy intensive and not sustainable. The biorefinery process to produce succinic acid through the use of food waste should therefore be a feasible, and cost effective for environmental alternative (Zhang et al., 2013).

Figure 2 schematic showing how food can be converted to succinic acid and fertilizer.



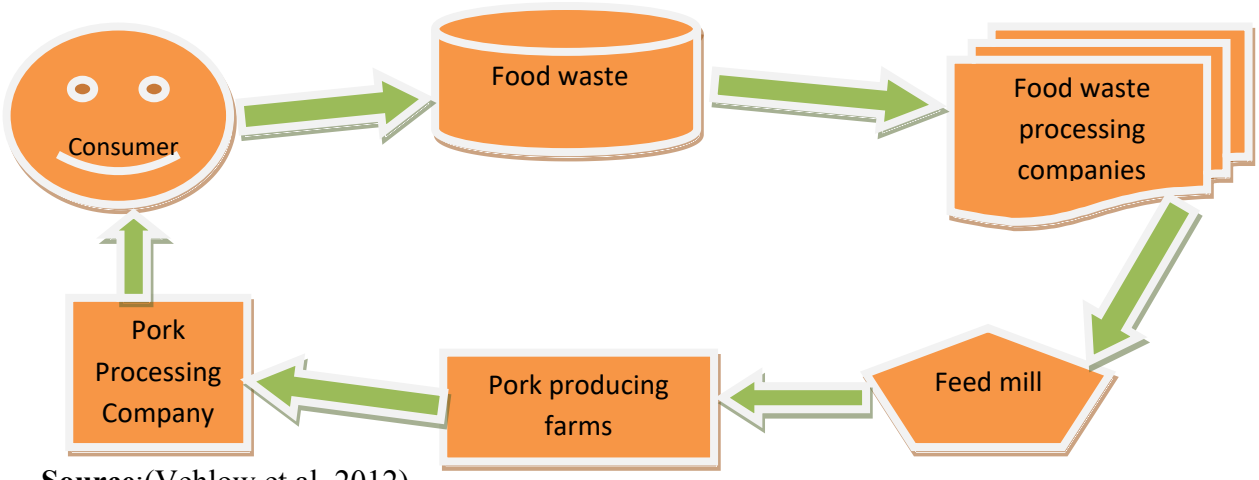
Source: (Zhang et al., 2013).

2.4.4 Concrete measures for food waste

In Japan, Fertilizer and feed producers, users, collection and transport companies cooperate to collect and treat two million tons of food waste annually as shown in figure 3 below. The waste is then recycled in to feed and fertilizer, or gas fuel by methane fermentation for power generation. There are recent cases in Japan of restructured pork production infrastructure that

reuses and recycles food waste as feed in order to reduce CO_2 emission from incinerators (Vehlow et al, 2012).

Figure 3: Structure a society where recycling is completed



Source:(Vehlow et al.,2012)

2.4.5 The "Leftovers" for Disposal

Despite every one's efforts, there will still be a considerable amount of food waste that are not separated and mixed with other waste that will be treated with other MSW. By 2022, about 3,000 tones of Hong Kong's MSW will be treated at a new Integrated Waste Management Facility (IWMF) each day, assuming it can be built in time. The rest will still have to be land filled (Food, 2014).

The Hong Kong's assumptions are motivated and bright but highly dependent on the successful mobilization of the community to separate waste, implementation of quantity-based development of an effective collection and delivery system for source separated food waste, and the continuous adding of OWTFs. Any change will increase the quantity of "leftover". So that citizens, organizations and the government can play their part to reduce, separate and recycle food waste (Food, 2014).

2.5 Food waste management options

2.5.1 Advanced Biological Treatment (ABT) Options

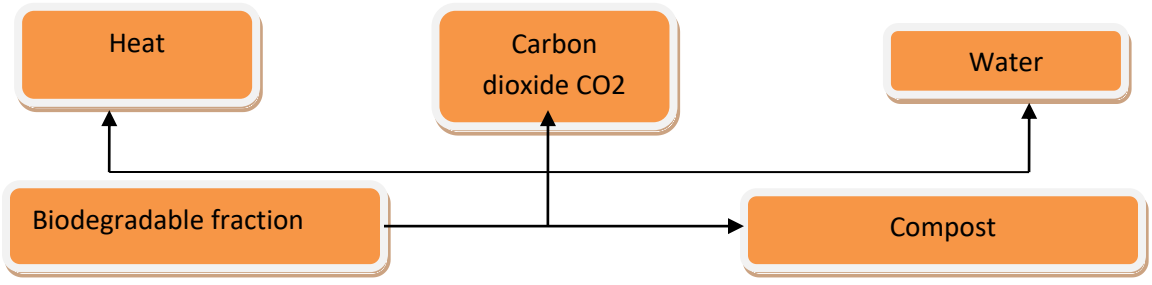
Advanced Biological Treatment is concerned with the use of relatively new technologies to treat biodegradable wastes using tightly controlled biological processes. Food and green wastes are suitable input materials for these ABT technologies. Other biodegradable material, such as card, paper and wood can be treated, however they take a longer time to degrade and input levels are limited to optimise the processing. Some ABT technologies have already been used in the UK for source segregated waste, green garden waste and food waste. ABT has also been used for sewage sludge treatment and in agriculture. There are two main types of conditions in which such microbes live, and therefore two main classes of biological processes used to treat biodegradable waste (Di Lonardo et al., 2012):

Aerobic – in the presence of oxygen; and Anaerobic – in the absence of oxygen (Di Lonardo et al., 2012).

Composting (Aerobic) Processes

During composting process, biodegradable material is decomposed into carbon dioxide (CO_2), water (H_20), and heat through microbial respiration in the presence of oxygen (figure 4 below) leaving a stabilised residual solid material, compost. If source segregated biodegradable material is treated, oxygen is often supplied passively through the presence of air or through mechanical turning. In MBT systems, air is usually blown or drawn through material, to speed up the drying and/or decomposition of the material (Di Lonardo et al., 2012).

Figure 4: Aerobic composting Process



Source: (Di Lonardo et al., 2012)

Aerobic processes are relatively dry and used for materials with high solids content (a moisture content of around 60% is considered optimal). These materials must have a good porous physical structure to allow the air to pass through the material. The right balance of carbon to nitrogen (and other mineral nutrients) is also required (Di Lonardo et al., 2012).

Accelerated composting processes require a net input of energy to supply the oxygen necessary. A large amount of biologically produced heat is created as microbes respire, and are associated with high processing temperatures of 60-70°C. High temperatures have the advantage of killing potentially pathogenic organisms in the waste (sanitization), and can also be used to dry material (Di Lonardo et al., 2012).

As the process progresses biodegradable material is converted into carbon dioxide, water, and heat, which are lost to the atmosphere. The material remaining consists of a mixture of non-biodegradable materials; unmanageable organics; microbes and microbial remains; and a complex of decomposition by-products called humus. This stabilized and dried mixture is known as compost (Di Lonardo et al., 2012).

Thermophilic Aerobic Digestion (TAD) technology is a type of in-vessel composting used in other industries (e.g. waste water treatment, agriculture) which has the potential to be utilised for food waste or other semi-solid liquids. It is a composting process that takes place under aerobic conditions within a digestion vessel. The vessel is heated to ensure that thermophilic (55-65^{o}C) temperatures are maintained, and similar to other In-Vessel Composting technologies is a net user of electricity. The residence time is relatively short under thermophilic Aerobic Digestion conditions (2–5 days), and the output may be de-watered and dried for use as a soil conditioner / compost. Whilst the technology has a track record in the other sectors it has limited application for municipal waste treatment to date (Di Lonardo et al., 2012).

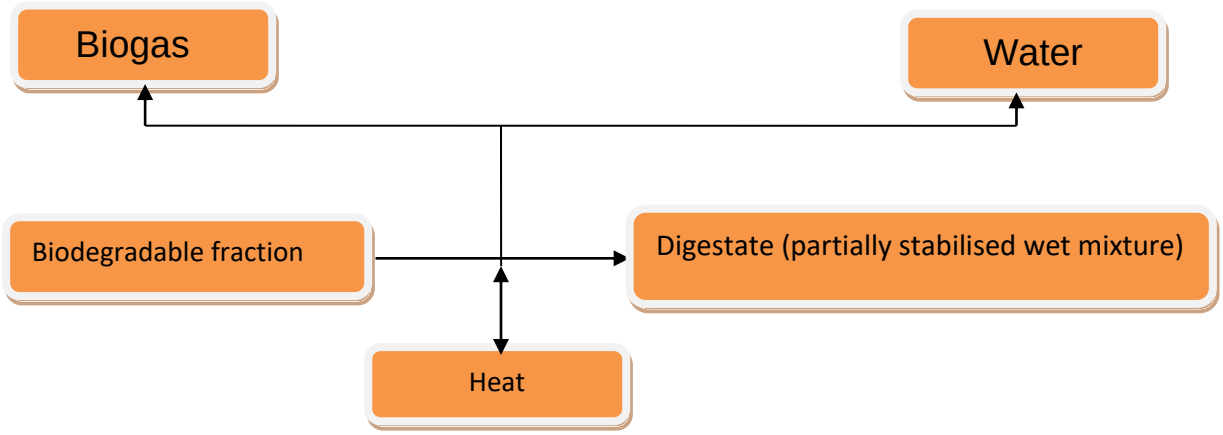
Anaerobic Digestion (Biogas) Processes

During Anaerobic Digestion (AD) biodegradable material is converted into methane (CH_4) and carbon dioxide (together known as biogas), and water, through microbial fermentation in the absence of oxygen (Figure 5), leaving a partially stabilized wet organic mixture (Di Lonardo et al., 2012).

AD is either a 'wet' process used for materials with moisture contents more than 85% or a 'dry' process used for materials with moisture contents less than 80%. Anaerobic processes require less energy input than aerobic composting and create much lower amounts of biologically produced heat. Additional heat may be required to maintain optimal temperatures but the biogas produced contains more energy than is required i.e. the process is a net producer of energy (Di Lonardo et al., 2012).

As the process progresses biodegradable material is converted into a combustible gas known as 'biogas' primarily consisting of a mixture of methane and carbon dioxide. Biogas can be burned for heat and/or electricity production, or cleaned for use as a fuel or injection into the national grid. The material remaining consists of a wet solid or liquid suspension of non-biodegradable materials; unmanageable organics; microbes (biomass) and microbial remains; and decomposition by-products. This partially stabilized wet mixture is known as 'digestate'. This wet mixture can be de-watered into its solid and liquid fractions. Sometimes these two fractions may both be referred to as 'digestate', but for clarity they would be referred to as digestate (solid) and liquor (liquid) (Di Lonardo et al., 2012).

Figure 5 Anaerobic digestion (biogas) processes



Source: (Di Lonardo et al., 2012).

2.6 Policy issues on food waste management

The 2008 European Union Waste Framework Directive (WFD) sets waste prevention at the top of the 'waste hierarchy' and requires MS to develop National Waste Prevention Programs by 2013. MS are also required to take measures to encourage the separate collection of bio-waste

with a view to the composting and digestion of bio-waste, but the Directive does not set prevention targets (Maxwell et al., 2011).

The 2010 Commission Communication on bio-waste identifies potential environmental and financial benefits of €4.1 billion through moderately ambitious bio-waste prevention policies. Around 29 million tones of CO_2 equivalent furthermore could be saved due to bio-waste prevention. Member States are developing the WFD-required National Waste Prevention Programs and may take advantage of this untapped potential of environmental and financial benefits by addressing food waste strategically as part of these programs (Maxwell et al., 2011.

The Landfill Directive sets diversion targets for biodegradable waste and requires MS to submit national strategies for biodegradable municipal waste management to the European Commission, describing how they will meet landfill diversion targets and improve biodegradable municipal waste management. The 2010 Commission Communication on future steps in bio-waste management in the European Union requires that MS draw up "waste management plans"Art. 28 of the WFD in line with the waste hierarchy (Art. 4 (1)) by December 2010. It underlines that MS must ensure separate collection and environmentally safe treatment of bio-waste (Maxwell et al., 2011).

2.6.1 Policy Implementation and Enforcement

Implementation

Early involvement of stakeholders in the development and implementation of the food waste prevention program is important in order to secure stakeholder ownership and engagement in the long-term. The establishment of a National Waste Prevention Committee can be an effective means to oversee the implementation of a National Waste Prevention Program and a national food waste prevention strategy. This body may exist within the Member State's Environment or Waste Agency and may comprise representatives from government ministries (environment, agriculture, and industry), relevant trade associations, waste management associations, and environmental NGOs. In addition to a coordinating role, the Committee's board membership will seek to assure active engagement and high-level commitment from key food waste generating sectors (Maxwell et al, 2011)

Monitoring

A National Waste Prevention Committee may track how the food waste prevention strategy is working. The Committee or independent body may be responsible for centralizing national food waste data and sub-sector data if possible. It is thus well placed to monitor progress towards targets and can contribute to adjustments of the food waste prevention strategy to build on successes achieved and address any failing areas. Further research may also be commissioned and overseen by the implementing body. Waste characterization and consumer behavior regarding food waste are two notable areas for further study. An independent body may also be considered to assess progress towards targets, in order to ensure objective assessment and decouple implementation from monitoring (Maxwell et al, 2011)

Enforcement

Many measures to prevent food waste are non-regulatory (awareness-raising, information sharing, benchmarking). However there may be opportunities to link funding to prevention targets or impose penalties on sectors that fail to meet targets. A National Waste Prevention Committee can play a role in both monitoring and enforcement, assuring the overall success of the program (Maxwell et al, 2011).

2.7 Strategy to food waste management

The strategy for food waste management (figure 7) has the following four main components:

1. **Mobilize the community**

Prevent and reduce food waste at source through strong and sustained public communication (That is before food become waste); or donate remaining food to people.

2. **Promote food waste separation**

Incentivize separation

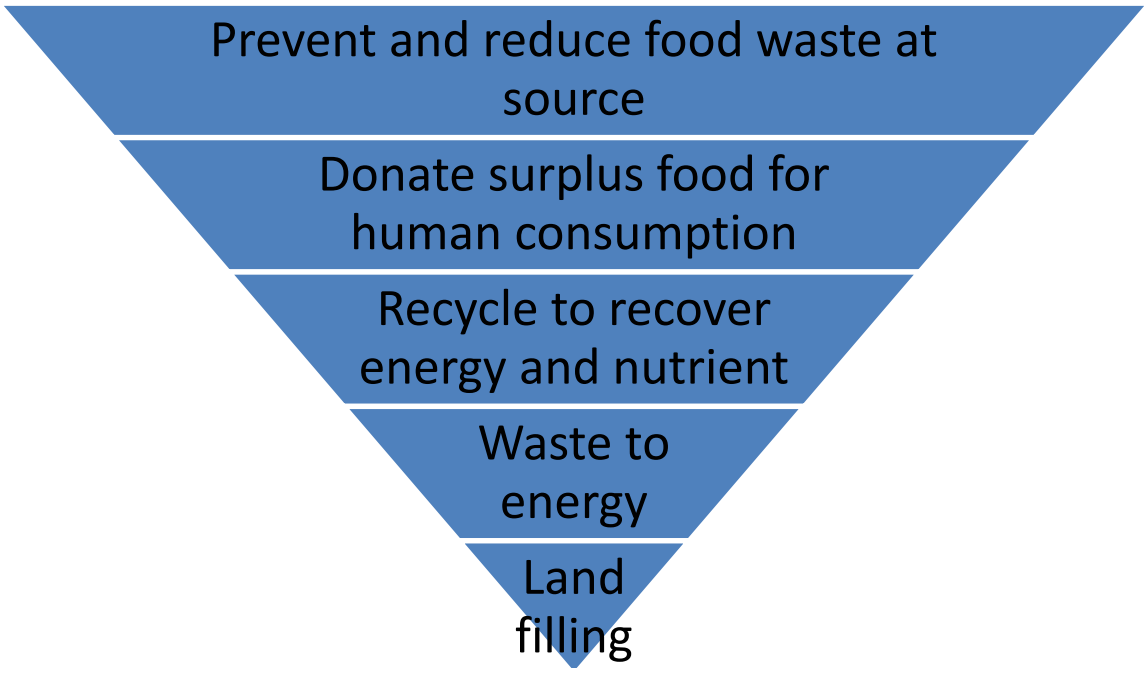
3. **Recycle and treat separated food waste**

Turn food waste into renewable energy; and convert food waste residue to compost to create a soil supplement

4. **Treat non-separated food waste and final disposal**

Provide MSW waste-to-energy treatment that includes non-separated food waste for recovery of energy; and disposal as last resort at landfills

Figure 6: Food waste management strategy hierarchy from most to least preferred



Source: (Food, 2014).

2.8 Food Waste, management and hotels in Ethiopia

City of Addis Ababa generates a solid waste of 0.4kg per capita per day. About 550tones/day, and 80% of the total waste was collected. More than 200,000 tones are collected each year. Among these 33.3% that is 66,600 tones was food waste. The municipality increased the collection rate from 60% to 80%. Sources of waste generated are 76% households, 18% institutions, commercial, factories, hotels, and 6% was street sweeping(Tessema, 2010).

There is currently one open dumpsite where all collected waste is disposed off. It has been established 47 years ago. The site is known as "Rappi" or "Koshe"(figure 9) which was south west part of the city located 13 km away from the city center. It has a surface area of 25 hectares. The present method of disposal is crude open dumping: transport the hotel waste by especial truck (figure 8), spreading, leveling and compressing it by bulldozer (figure 9) (Tessema, 2010).

Figure 7: Hotel's waste disposal truck

Source:(Vehlow et al.,2012)

Figure 8: Reppi Solid Wste Disposal Site, Addis Ababa, Ethiopia

Source: (Tessema, 2010)

2.8.1 Challenges and Opportunities

Challenges: The major challenges associated with the disposal site are:

1 The site is getting full.

2 It was surrounded by housing areas and institutions.

3 Nuisance and health hazard for people living nearby.

4 More than 200-300 waste pickers per day work continuously and obviously living nearby the site and interfering the operation of the work for collection of retrieve materials such as wood, scrap metals and discarded food.

5 No daily cover with soil.

6 No treatment.

7 No rainwater drain-off.

8 No odor or vector control.

9 No appropriate fence.

10 No weigh bridge, inaccurate weighing of waste.

Opportunity: The major opportunity in Addis Ababa city food waste management was establishing the methane gas production company at Rappi solid waste disposal site for the first time in Addis Ababa, Ethiopia (Regassa et al., 2011).

CHAPTER 3: MATERIAL AND METHODS

3.1. Location of the study site

The study was conducted in Addis Ababa the capital city of Ethiopia, with a population of 3,384,569 according to the 2007 population census with annual growth rate of 3.8% percent. Its geographical locations were 9°1′48″North 38°44′24″ East.

3.2. Sampling techniques

A total of 5 kg and 5 liter samples of food waste were aseptically collected from 12 points of trigonaly disposed on June 16 and 17, 2015 in a sterilized polyethylene bags from all the randomly selected hotels. And transported to Addis Ababa University food science and nutrition centre research laboratory. And Microbiology department; and JIJE analytical testing service laboratory in Addis Ababa.

The questionnaires were prepared originally in English and then translated into Amharic in order to obtain content validity (Attached in Appendix). Finally the questionnaires results were administered in English from the selected hotels that were coded by four digits.

3.3 Microbiological Investigation Method

3.3.1 Gram staining

For microbiological analyses, 25g of sample was aseptically taken from each sample using a sterile spoon and vigorously shaken in 225ml of sterile flask with 0.1 % bacteriological peptone water (oxoid) for three minutes. Then, the homogenized sample was taken for further dilution. Following, serial 10 fold dilutions (10^{-1}, 10^{-2}, 10^{-3}, 10^{-4}, 10^{-5}, and 10^{-6}) were made by transferring 1 ml of the homogenized sample to 9 ml diluents. Appropriate dilutions were 10^{-3} and 10^{-4} spread plated in duplicate on various media (Nutrient agar, Sabourd dextrose agar, and Potato Dextrose agar PDA) for inventory of microbial load. The prepared test sample dilution was transferred separately in to sterile petri dishes in duplicate using sterile graduate pipette with sterile plastic tips and spread plate in duplicates on pre dried surface of plate count agar plates. The culture media were incubated at 34-37^{0}C for 48 hours were Parallel to that, control plates were also prepared using similar medium (15-20 ml) to check the sterility of media. The dishes containing more than 30 and /or fewer than 300 colonies were selected and counted using colony counter (Gregersen, 1978).

Aerobic mesophilic bacteria were counted using plate count Agar (oxoid) plates incubated at 30^{o}c for 72 hours. For Enterobacteriaceae, Violet Red Bile Glucose Agar (oxoid) was used and plates were incubated at 30^{o}c for 72 hours. All purple colonies were counted as members of Enterobacteriaceae. Coliforms were counted on Violet Red Bile Agar (oxoid) after incubating the plates. Red to pink colonies, surrounded by precipitated were counted as coliforms. Counts of yeasts were determined on chloramphenolicol Bromophenol Blue Agar plates incubated at 25-28 ^{o}C for three to five days. Non-hairy colonies were counted as yeasts. Microbial counts were transformed to cfu/ml.

The individual dilution factor for each tube was obtained by using the formula:

$$\text{Individual Dilution Factor (IDF)} = \frac{\text{Amount transferred}}{\text{amount transferred} + \text{Amount already in tube}}$$

For Tube A, the $(IDF_A) = \frac{1}{1+9} = \frac{1}{10} = 0.1 = 1o^{-1}$

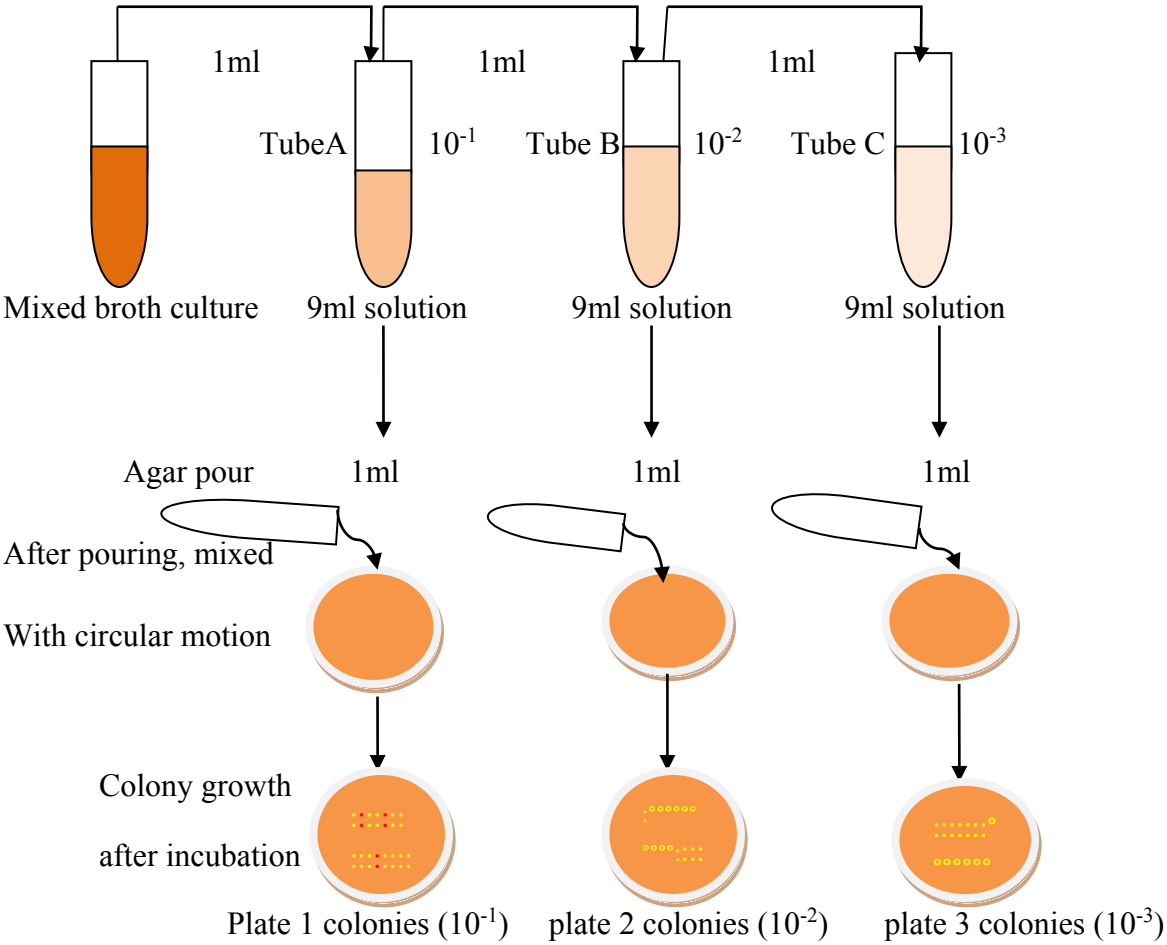
Likely for individual tube B, C, D, E,and F respectively results were as follows:

$IDF_B = 10^{-2}$, $IDF_C = 10^{-3}$, $IDF_D = 10^{-4}$, $IDF_E = 10^{-5}$ and $IDF_F = 10^{-6}$

Total Dilution Factor (TDF) = $(IDF_A)(IDF_B)(IDF_C)(IDF_D)(IDF_E)(IDF_F)$

$= (10^{-1})(10^{-2})(10^{-3})(10^{-4})(10^{-5})(10^{-6}) = 10^{-21}$

Figure 9: Microbial plate counting



The number of bacteria (CFU) per millilitre of sample was obtained by dividing the number of colonies to the dilution factor.

$$\text{Bacteria/ml} = \frac{\text{number of colonies per ml plated}}{\text{Individual dilution factor}}$$

a) For tube C, the plate of the 10^{-3} dilution yielded a count of 130 colonies. Then, the number of bacteria in 1 ml of the original sample was calculated as follows:

Bacteria/ml = $(130)/10^{-3} = 130X10^{3} = 130{,}000 = 1.3 \times 10^{5}$

b) For tube D, the plate of the 10^{-4} dilution yielded a count of 110 colonies. Then, the number of bacteria in 1 ml of the original sample was:

Bacteria/ml = $(110)/10^{-4} = 110{,}000 = 1.1 \times 10^{5}$

We can assume that each colony of bacteria arose from one living cell immobilized on an agar plate. Thus each colony was a clone of cells. We can now determine the number of live bacteria (or Colony Forming Units [CFU]) per ml of original culture by using the formula:

$$\text{CFU/ml} = \frac{\text{number of colonies per ml plated}}{\text{Total dilution factor}}$$

c) As plate C have 130 colonies, in the original culture, the number of live bacteria (or Colony Forming Units [CFU]) per ml of original culture was:

The CFU/ml = 130 colonies per ml plated/$10^{-21} = 130x10^{21} = 1.3 \times 10^{23}$ CFU/ml.

d) As plate D have 110 colonies, in the original culture, the number of live bacteria (or Colony Forming Units [CFU]) per ml of original culture was:

The CFU/ml = 110 colonies per ml plated/$10^{-21} = 110x10^{21} = 1.1 \times 10^{23}$ CFU/ml.

3.3.2 KOH Test

KOH Test was done according to (Gregersen, 1978). One drop of 3% KOH solution was placed on a clean microscope slide. A colony was picked with a sterile bacteriological wire loop and stirred in the KOH solution for 5 to 10 seconds and the inoculating loop was then raised slowly from the mess. When KOH solution becomes viscous, the thread of slime followed the loop for 0.5 to 2 cm or more. This was a positive reaction and it was observed in Gram negative bacteria. In case of no slime, but the watery suspension that did not follow the loop, the reaction was negative. And this was seen in Gram-positive bacteria.

3.4 Analytical Methods

For quality control (error minimization) and quality assurance (machines and equipments calibration) purposes it was checked 3 times by the known sample. And others were done at the recognized JIJE Analytical Testing Service Laboratory. The chemicals used were valid and the instruments were calibrated.

3.4.1. Total Solids (TS)

A well-mixed sample was evaporated in a weighed dish and dried to constant weight in an oven at 105°C. The increase in weight over that of the empty dish represents the total solids. The results may not represent the weight of actual dissolved and suspended solids in waste water samples. A volatile solids were measured ignite clean evaporating dish at 550°C for 1 hour in a muffle furnace. The total solids were measured, heated and cleaned dishes to103-105°C for 1 hour. Stored and cooled the dishes in desiccators and weighed immediately.

In a drying oven evaporated to dryness. During transfer stirred with a magnetic stirrer. After evaporating in a drying oven, the temperature was lowered to 2°C below boiling to prevent splattering. The evaporated samples were dried for at least 1 hour in an oven at 103 to 105°C. Cooled the dish in desiccators to balance temperature, and weighed. The cycle of drying was repeated, cooled, desiccating, and weighing until a constant weight was obtained until weight change was less than 4% of previous weight, whichever was less. When weighed the dried sample, alert was taken to control change in weight due to air exposure and/or sample degradation. And all samples were analyzed in duplicate. The duplicate determinations were agreed within 5% of their average weight using the formula:

$$\text{Total solids mg /L} = \frac{(A - B)\ \text{X}\ 1000}{\text{sample volume, mL}}$$

Where:
A = weight of dried residue + dish, mg, and
B = weight of dish, mg.

3.4.2 Total Dissolved Solids (TDS)

Disk was inserted with wrinkled side up into filtration apparatus. Vacuum was applied and the disk was washed with three successive 20-mL volumes of reagent-grade water. It was continued to remove all traces of water.

The volatile solids were measured, ignite cleaned evaporated dish at 550°C for 1 hour in a muffle furnace. The total dissolved solids were measured, heated, cleaned dish to 180 ±2°C for 1 hour in an oven. Stored in desiccators and weighed immediately.

Sample was stirred with a magnetic stirrer and pipet a measured volume onto a glass-fiber and filtered with applied vacuum. Washed with three successive 10-mL volumes of reagent-grade water, allowing complete drainage between washings, and continue suction for about 3 min after filtration was completed. Total filtrate was transfer (with washings) to a weighed evaporating dish and evaporates to dryness on a steam bath or in a drying oven. Evaporated sample was dried for 1 hour in an oven at 180 ± 2°C, cooled in a desiccator to balance temperature, and weighed. Drying cycle was repeated, cooled, desiccating, and weighing until a constant weight was obtained until weight change was less than 4% of previous weight. Duplicate determinations were agreed within 5% of their average using the formula(Wilson et al., 2013):

Total dissolved solids mg /L = (A-B) × 1000 / sample volume, ml.

Where:
A = weight of dried residue + dish, mg, and
B = weight of dish, mg.

3.4.3 Total Suspended Solids (TSS)

A well- mixed sample was filtered through a weighed standard glass-fibber filter and the residue retained on the filter was dried to a constant weight at 103 to 105°C. The increase in weight of the filter represents the total suspended solids. The difference between the total solids and the total dissolved solids provide an estimate of the total suspended solids.(Beck et al., 2012)

Disk was inserted with wrinkled side up into filtration apparatus. Vacuum was applied and the disk was washed with three successive 20-mL volumes of reagent-grade water. It was continued to remove all traces of water, and discarded washings. Filtration apparatus was removed and transferred to an inert aluminium-weighing dish. Filter material that sticks to the dish was added to the filter to avoid error. Dry in an oven at 103 to 105°C for 1 hour. When volatile solids were measured and ignited at 550°C for 15 min in a muffle furnace. Cooled in a desiccator to balance temperature and weighed. The cycle of drying or igniting was repeated, cooled, desiccated, and weighed until a constant weight was obtained until weight change was less than 4% of the previously weighed and store in desiccators.

Sample was stirred with a magnetic stirrer and pipet a measured volume onto a glass-fibber and filtered with applied vacuum. Washed with three successive 10-mL volumes of reagent-grade water, allowing complete drainage between washings, and continue suction for about 3 min after filtration was completed. Total filtrate was transfer (with washings) to a weighed evaporating dish and evaporates to dryness on a steam bath or in a drying oven. Evaporated sample was dried for 1 hour in an oven at 180 ± 2°C, cooled in desiccators to balance temperature, and weighed. Drying cycle was repeated, cooled, desiccating, and weighing until a constant weight was obtained until weight change was less than 4% of previous weight. Duplicate determinations were agreed within 5% of their average using the formula:
Total suspended solids mg /L= (A-B) × 1000 /sample volume, ml.

Where:
A = weight of filter + dried residue, mg, and
B = weight of the filter, mg.

3.4.4 Volatile Suspended Solid (VSS)

The residue from TS, TDS or TSS was ignited to constant weight at 550°C. The remaining solids represent the fixed total, dissolved, or suspended solids while the weight lost on ignition was the volatile solids.(Sosnowski et al., 2003)

Ignited residue was produced by TS, TDS or TSS to constant weight in a muffle furnace at a temperature of 550°C. The 15 min ignition was required for 200 mg residue. It transferred to desiccators for final cooling in a dry atmosphere. Desiccators were done not over load. The

dish was weighted as soon as it had been cooled to balance temperature. The cycle of igniting was repeated, cooled, desiccated, and weighed until a constant weight was obtained; and until weight change was less than 4% or 0.5 mg, Duplicate determinations was agreed within 5% of their average using the formula:

Volatile solids mg /L = (A-B) × 1000 /sample volume, ml.
Fixed solids mg /L = (A-B) × 1000 / sample volume, ml.

Where:
A = weight of residue + dish before ignition, mg.
B = weight of residue + dish or filter after ignition, mg, and
C = weight of dish or filter, mg.

3.4.5 Biochemical Oxygen Demand (BOD) - 5-Day BOD Test

The method consists of filling with sample, to overflowing, an airtight bottle of the specified size and incubating it at the specified temperature for 5 days. Dissolved oxygen was measured initially and after incubation, and the BOD was computed from the difference between initial and final DO. Because the initial DO was determined shortly after the dilution was made, all oxygen uptakes occurred after that measurement was included in the BOD measurement(Latif & Dickert, 2015)

Due to samples for BOD analysis degrade significantly during storage between collection and analysis, resulting in low BOD values; reduction of BOD minimized by analyzing sample promptly or by cooling it to near-freezing temperature during storage. The chilled samples were Warmed to 20 ± 3°C before analysis; The analysis was begun within 6 hour of collection(Latif & Dickert, 2015)

Incubation bottles: Glass bottles were used having 60 mL having a ground glass stopper and a flared mouth. Bottles were cleaned with a detergent, rinsed thoroughly, and drained before use. A plastic cup was placed over flared mouth of bottle to reduce evaporation of the water seal during incubation..

Preparation of dilution water: A desired volume of water was placed in a suitable bottle and added 1 mL each of phosphate buffer, $MgSO_4$, $CaCl_2$, and $FeCl_3$ solutions/L of water.

Before used it was diluted the water temperature to 20°C. It was saturated with DO by shaking in a partially filled bottle. It was Stored in cotton-plugged bottles long enough for water to become saturated with DO. Water quality was protected by using clean glassware, tubing, and bottles.

For each test bottle meeting the 2.0-mg/L minimum DO depletion and the 1.0-mg/L residual DO, BOD5 was calculated as: Where:
D1 = DO of diluted sample immediately after preparation, mg/L,
D2 = DO of diluted sample after 5 d incubation at 20oC, mg/L,
P = decimal volumetric fraction of sample used,

3.4.6 Chemical oxygen demand (COD) - Closed Reflux, Titrimetric method

Samples were homogenized containing solids to assure representative sample. The measurement was done soon after the collection of the samples. Samples treated with sulphuric acid to a pH of less than 2 (2ml per litre) and refrigerated at 4°C was stored up to 28 days.

2.8 ml of the dichromate reagent + 36 mg mercuric sulphate (HgSO4) salt, then 2 ml Sample was added, digested in COD reactor for two hours at temperature of 160°C. Cooled then measured at 620 nm for high range (0-1500mg/lit) samples and calculated using:

3.4.7 P^H

The pH value of a sample was determined by using potentiometric measurement of hydrogen ions activity using a sensing electrode and a reference electrode.

3.4.8 Determination of total nitrogen by Kjeldahl method

The sample was heated with sulphuric acid, which decomposes the food waste by oxidation to liberate the reduced nitrogen as ammonium sulphate. Potassium sulphate was added to increase the boiling point of the medium. Chemical decomposition of the sample was completed when the initially very dark-coloured medium was become clear and colourless. Then distilled with a small quantity of sodium hydroxide, and determined by back titration. The end of the condenser was dipped into a solution of boric acid. The ammonia reacts with the acid and the remainder of

the acid was then titrated with a sodium carbonate solution by way of a methyl orange pH indicator.

3.4.9 Determination of minerals (S, P and K)

To determine the minerals, firstly Ash Content was determined as follows. Porcelain dishes were placed in a muffle furnace for 30min at 550^{o}C. The dishes was cooled in desiccators (with granular silica gel) for about 30 minutes at room temperature and weighed to the nearest milligram (m1). About 2.5000g of fresh sample was placed in dish and weighed (m2). Dishes were placed on a hot plate under a fume-hood and the temperature was slowly increased until smoking ceases and the samples become thoroughly charred. The dishes with sample was placed inside the muffle furnace at 550^{o}C for 5 hours and cooled in desiccators for 1 hour. The ash was clean and white in appearance. When cooled to room temperature, each dish with ash was reweighed to the nearest milligram (m3).

$$\text{Total Ash (\%)} = \frac{M_3\text{-}M_1 * 100}{M2\text{-}M1}$$

Where:

(M2-M1) is sample mass in g on dry base and (M3-M1) mass of ash in gram.

Ash was obtained from dry ashing of food samples. The ash was wetted completely with 5ml of 6N HCl, and dried on a low temperature hot plate. 7ml of 3N HCl was added to the dried ash and heated on the hot plate until the solution just boils. The ash solution was cooled to room temperature in a hood and filtered into a 50ml graduated flask using a filter paper. 5ml of 3N HCl was added into each crucible dishes and heated until the solution just boils, cooled and filtered into the flask. The crucible dishes were again washed three times with deionized water; the washing was filtered into the flask. A 2.5ml of 10% lanthanum chloride solution was added into each graduated flask. Then, the solution was cooled and diluted to 50ml with deionized water. A blank which contains 12ml 3N HCl and deionized water in 50ml volumetric flask was also prepared.

Standard solutions: Four serious of working standard metal solution was prepared by appropriate dilution of the stock solution with deionized water containing 2.4ml 3N HCl in 10ml volumetric

flask. After manipulating the instrument operation procedure, calibration graph (concentration versus absorbance) for each element (S, P and K) using the prepared standard solution were prepared. The sample concentration was analyzed using Flame photometric for (K), Iodometric method for (S^{-2}), and phosphoric acid colorimetric method for (P). Sample blank solution was run with the sample solution. Single mineral hollow cathode lamps were used for each element.

$$\text{Mineral content (mg/100g)} = \frac{[(a-b)xV]}{10W}$$

Where:

W= weight (g) of samples

V= 50ml = volume (V) of extract

a= concentration (µg/ml) of sample solution

b= Concentration (µg/ml) of blank solution

3.5 Statistical Analysis

Data from the questionnaire were analyzed using SPSS for window (Version 20.0). Descriptive statistics was used to compute percentage and the mean. Microbial counts were determined by cfu/ml values. To see if there was significant variation in counts within samples in each type of food waste and waste water, coefficient of variation (CV) was calculated. CV indicated inconsistency in the level of microbial count and 10% level indicated significant variation in counts.

CHAPTER 4: RESULT AND DISCUSSIONS

4.1 Hotels in Ethiopia

Based on the survey data collected, there were 516 hotels which are classified from basic to star level in Ethiopia (Table 4.1). Among this, thirty-eight (38) hotels in Addis Ababa were awarded five to one star, by the (Ethiopian Ministry of Culture and Tourism) collaborated with (World Tourism Organization, 2014). Of the 125 hotels eligible to the rating, 3 hotels got five stars, 11 hotels got four stars, 13 hotels got three stars, 10 hotels got two stars and one hotel awarded one star. Accordingly, the classification was made based on (12 international criteria) were Kitchen, restaurants, Bedrooms, bath rooms, rest rooms, guest room, sustainability of hotel service, security and employ treatment.

Table 1 Number of hotels from basic to star level in Ethiopia, 2014 (n=516)

S.N	list of hotels from basic to star level in Ethiopia	Total number of hotels
1	In Addis Ababa	125
2	In Amhara	124
3	‘’ South NNP	79
4	“ Oromiya	74
5	“ Tigray	38
6	“ Diredawa	19
7	“ Gambella	16
8	“ Somali	14
9	“ Benishangul Gumuz	13
10	“ Harari	7
11	“ Afar	5
Total		**516**

Source: Ethiopian Ministry of culture and Tourism, 2014

All the selected hotels (Table 1) used local and foreign raw materials to provide services for the customer to achieve their goals. The hotels had periodic physical examination and training plan for the food handlers, four times per year. Raw materials were handled in proper protective containers separately, monitored and inspected.

The hotels had kitchens with floor constructed. The cleanliness of floor in the kitchens was kept nice. The wall and ceiling of the kitchens were kept clean. It had kitchens with adequate lighting system. In all of it (Table 2) the food handlers wear appropriate overcoat.

Table 2: Food handlers practice in the selected hotels in Addis Ababa, Ethiopia, 2014

Practices	Number of randomly selected food handlers	Percent
Wear of appropriate over coat		
- yes	6	100
- no	0	0
Wear of appropriate hair cover		
- yes	5	83.3
- no	1	16.7
Over coat and visible body part		
- clean	5	83.3
- not clean	1	16.7
Short neat and cleaned nail		
- yes	6	100
- no	0	0
Wear of jewellery		
- yes	5	83.3
- no	1	16.7
Nail paint during visit		
- observed	1	16.7
- not observed	5	83.3
Washing of hands before work on day of interviewing	6	100
- yes	0	0
- no		

Refrigerators were available in all of the hotels for storage of perishable food. This was found to be a better condition when compared to other findings of (Gustavsson et al,. 2011) studies conducted. The refrigerators had fixed temperature reading, adjusted from 0 to 4ºC. Although

refrigerators were available in it, about 16.6% of perishable and non perishable foods were temporarily stored near together. But the (Knipe and AD, 2005) indicates that there is the possibility of cross-contamination between perishable and non perishable foods at storage. However, in 100% of the hotels cooked and raw foods were stored separately.

The dining rooms in all the hotels did not have cracks in which dirt can lodge. The wall of the dining rooms were maintained in good conditions and kept clean, having smooth and easily cleanable surfaces. As (Mena et al,.2011) the causes of food waste in the supplier–retailer interface: evidences from the UK and Spain, all of the hotels had a separate store rooms which were free from any insect during the visit. The hotels had water pipe installed connected with municipal services; and water storage "Rotto" tankers for shortage time.

Appropriate waste containers car "Ganda" were placed in the appropriate place in all of the hotels (Figure 7 and 8). But in one of them the container was not durable. Solid wastes generated from kitchens and other work areas (Vehlow et al., 2012) were collected and stored in proper container. According to (Tessema, 2010) the food waste containers should be easily lifted and transported. Similar to that the food wastes were transported to final disposal "Rappi/koshe" site before overfilling in all of the hotels. And in all the solid wastes were disposed by municipal services.

In all of the hotel industries, liquid waste disposing drainage system was installed. The type of drainage systems (Beck et al, 2012) were found to be closed which can collect all generated liquid wastes in open drain. In one of the centre kitchen, the liquid wastes were disposed to open dumping area but according to (Bersinger, et al,. 2015) it can aid breeding of flies and affect sanitary conditions of the centre and in turn cause contamination of foods by microbes.

The source of microbial (Maxwell et al., 2011) was originated from food handlers and from utensils previously contaminated. And the food handlers as observed from the (Table 2) were free from infectious diseases like, visible infected skin injury (boils, cuts), and discharges from ear, eye and nose should be pending from food handling and preparation until they become cured. The measure was to prevent food contamination and thereby the spread of infectious disease through the ingestion of contaminated food. All of them had washed their hands before

work on day of interviewing. In addition, it was found that none of the food handlers smokes cigarette.

Since source of food contamination (Table 2) were diversely controlled the overall sanitary condition of the hotels, health status of workers and raising the awareness of managers and food handlers had great roles in improving food handling and prevention of food borne illness and its transmission.

Food Waste characterization: From a treatment perspective and according to (Gupta, et al., 2012) food waste was characterized by typical parameters that describe the nature of waste and its potential impact on the environment. Therefore; these parameters were TS, TDS, TSS, VS, VSS, electrical conductivity, P^H, sulphur, nitrogen, phosphorous, potassium, biochemical oxygen demand BOD, and chemical oxygen demand COD as analyzed and described in (Table 3).

Table 3: Characteristics of food waste analytical test results

S.N		Parameters (mg/L)										
1	Waste water	TS	TDS	TSS	VSS	TN	TK	TP	(S^{2-})	BOD (mg/L)	COD (mg/L)	EC 3.2dS/m
		6610.00	5910.0	700.0	210.0	20.79	26.00	13.14	5.58	1127.52	6561.33	P^H 7.42

2	Food waste	Parameters mg/Kg							
		TS	Volatile Solid (VS)	TN	TK	TP	SO_4^{2-}	EC	pH
		966000.00	55.78	3.73	5875.00	3227.50	823.18	4.17 (dS/m)	4.46

The waste water samples, unlike water supplied for domestic and industrial purposes (Table 3), contains higher concentrations of inorganic suspended and dissolved materials (TS, TDS, TSS, and VSS), which can damage the soil and irrigated crops *(*ISO 16075-1&2). But the presence of nutrients (Nitrogen 20.79>10mg/L, Phosphorus, and Potassium were not limited) can become an advantage due to possible saving in fertilizers.

Waste water can be treated and used for various non-potable purposes. As (ISO 16075) stated that the dominant applications for the use of treated wastewater (recycled water) include

agricultural irrigation, industrial reuse, and ground water recharge. Agricultural irrigation was the largest reuse water consumer with recognized benefits and contribution to food security.

More recent and rapidly growing applications were for various urban uses, recreational and environmental uses, and indirect and direct potable reuse. Consequently, the public health and potential agronomic and environmental adverse impacts were to be considered as priority elements in the successful development of water reuse (ISO 16075-1&2). To prevent such potential adverse impacts, the development and application of international guidelines such as for the reuse of waste water was essential.

The solids concentration represents the amount of materials contained in water, usually expressed as milligrams of dry weight per litre of water sample. Several terms are typically used for characterizing solids. The (Hassanpour Aslani, et al.,2013) and (Beck et al, 2012) states that the total solids represent the amount of residue resulting from evaporation of a waste water sample at 103 to 105^0C. The total solids can be further divided according to particle size into total dissolved solids (TDS) and total suspended solids (TSS). In the waste water sample analysis, the separation was made by using a filter pad with a pore size of about 2 microns. The dry weight of the residue contained in the water sample that passed through the filter was TDS, whereas the dry weight of the solids retained on the filter was TSS.

All the solids portions described (Table 3) can be further characterized as fixed residue or volatile residue. Fixed residue was the ash component produced after the solids material was burned in a muffle furnace at 550^0C for 30 minutes, where the volatile residue was the portion of solids that disappeared during the burning process. Thus, Volatile residue was often interpreted as the organic component of the solids, and fixed residue as the inorganic matter. Solids (Bersinger et al, 2015) in the waste water samples have various environmental impacts. And according to *(*Hassanpour Aslani et al., 2013) high TDS increases the salinity of the receiving water. Fresh water river's TDS ranges from 100–1,000(mg/L). But this study indicates an appealing result of about 5910.00 mg/L. An appropriate concentration of salts was vital for aquatic plants and animals; salinity that was beyond the normal range of any species of organism was cause stress or even death to that organism. Salinity also affects the availability of nutrients

to plant roots. Water containing a TDS level of over 500 mg/L was unsuitable for irrigation of plants.

Therefore, it increases the amount of salinity in the receiving river. High volatile solids concentration means high organic loading to the receiving water. High TSS concentration increases the turbidity of the receiving water. Higher turbidity in water reduces light transmittance of the water column. Additionally, discharging the waste water with a high TSS concentration can also alter the habitat of the receiving water due to the deposition of the solids.

Nitrogen exists in different forms and was important to all forms of life. Transformations of nitrogen among different forms were governed by the nitrogen cycle. Most environmentally important nitrogen forms include ammonia, nitrate, nitrogen gas, and organic nitrogen, such as protein. In most food products, nitrogen exists in the form of protein. According to (Saha, et al., 2012*)* decomposition of protein in food waste by bacteria converts the organic nitrogen to ammonia. And in an aqueous solution, ammonia had two forms: NH3 an NH4. The equilibrium between these two species was determined by pH. The unionized ammonia from (NH3) was toxic to most aquatic life. Under aerobic conditions, ammonia was converted to nitrite, and then nitrate ($NO3^-$) by a group of bacteria called nitrifiers. Nitrate can be readily taken up by plants and converted to organic nitrogen. Nitrate was mobile in soil because of its negative charge. Excessive nitrate leaching to ground water can cause health problems. High nitrate concentration in drinking water was toxic to humans, specially infants, and livestock. Under anaerobic conditions, nitrate was converted to nitrogen gas biologically through a process called denitrification. Some bacteria can fix nitrogen from nitrogen gas to protein.

Another often used term in food processing waste water was Total Kjeldhahl Nitrogen (TKN), as seen on (table 3) TN=20.79mg/L which measures the concentration total of organic nitrogen and ammonia. Organic nitrogen can be determined if ammonia was removed from the TKN analysis. Its protein content was determined by the organic nitrogen content.

Phosphorous as phosphate (PO_4^{2-}) was another essential element in many living organisms, and was often considered the growth limiting factor in numerous water bodies, such as rivers and lakes. According to (Reddy, et al., 2011): Category Total PO_4 (mg/L) Low < 0.06, Medium 0.06 – 0.15, High > 0.15 – 0.45 and Very High > 0.45. As shown on (table 3), when compared with

the category, it was excess 13.14mg/L > 0.15mg/L the medium growth limiting factor. Phosphorous input to receiving water, and can cause eutrophication in rivers and lakes, characterized by the abundant growth of algae and other aquatic plants, which during the respiration phase at night can deplete the dissolved oxygen in water bodies, causing fish kill and Sulfur compounds in waste water were a major problem for some food processors. The use of sulfur dioxide in pre-treatment of fruits results in sulfur content in waste water. Sulfur compounds exist in water primarily as sulfide and sulfate ions or precipitates. Hydrogen sulfide, a product of anaerobic processes, can cause bad odor problems *(*Prasad, 2013) Water reuse refers to using processed water, treated or untreated, in other applications where the quality requirements are usually less critical. For example, there are several recycling options in canned fruits and vegetable processing: (1) the waterfall used for transporting raw, unpeeled commodities, (2) retorted can cooling water recycled through a cooling tower, and brine systems used in preserve or curing. In product transport, dry transport by mechanical conveying systems can be substituted for some hydraulic transport systems prior to hydraulic washing. Also, raw incoming fruits and vegetables can be dry cleaned, by using vibrating screens and air blowers to remove loss dirt, leaves, and branches.

Significant amounts of water consumption can be saving through well planned water recycling and reuse. However, according to (Prasad, 2013) the build up of organic and mineral compounds, microbial populations, and temperature (increases or decreases) must be considered. Each successive contact of water with the product contributes to changing the quality of water, and measures should be taken to ensure acceptable water quality conditions for the recycled applications. Typical methods include: (1) treating the recycling water, using screens, filters or cooling towers (or heaters) to re-establish acceptable quality conditions of solids content and temperature, (2) disinfecting the microbial populations, to meet the sanitary conditions, and (3) adding make-up water to recycled water stream, to dilute stream and provide acceptable quality conditions or to maintain desired water volume. Additionally, any recycling and reuse program must meet the requirements of federal and state food regulatory agencies.

Dissolved oxygen (DO) concentration in wastewater (Singh et al., 2015) was a measure of oxygen availability in the waste water. A variety of aquatic life and many types of aerobic bacteria rely on DO for proper function. Adequate DO was required in a water body to support

aquatic life. Thus, DO was often the limiting factor in protecting the safety of an aquatic environment because of the competition for DO between different organisms.

The Biochemical oxygen demand (BOD) was a parameter that describes the amount of biological degradable organic matter in wastewater. The BOD (Table 3) was determined by (Latif & Dickert, 2015*)* measuring the amount of DO consumed in a waste water sample for a given time period under a given temperature. And BOD_5 was typically used in environmental regulations for indicating the amount of DO required for the decay of organic constituents in the wastewater sample within five days at 20^0C. A more rapid analysis (Merkley et al , 2012) such as COD was correlated with BOD. In the absence of prior knowledge, the following dilutions were used: 0.0 to 1.0% for strong industrial wastes, 1 to 5% for raw and settled wastewater, 5 to 25% for biologically treated effluent, and 25 to100% for polluted river waters.

And the chemical oxygen demand (COD) measures the amount of oxygen needed for chemical oxidization of organic material contained in the waste water sample that was susceptible to oxidation by a strong chemical oxidant. For samples from a specific source, COD related empirically to BOD. The test was useful for monitoring and control after correlation had been established (Merkley & Luo, 2012). COD represents the maximum impact of waste water on the DO of the receiving water. COD analysis was conducted using a strong chemical oxidant, which was more rapid than BOD measurement. For specific waste water, there was a correlation between COD and BOD values.

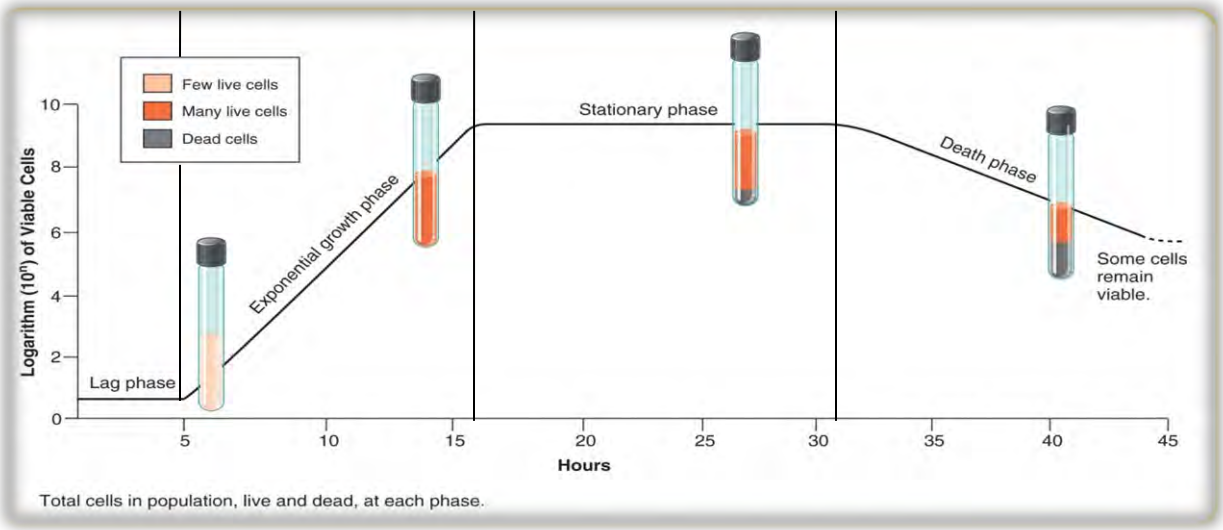
The Salinity was measured as either TDS, which measures the amount of dissolved salts in the water, or as EC, which was the property of a substance which enables it to serve as a medium for electricity *(*Bersinger, et al.,2015). Fresh water river's EC ranges from 0 - 800(µs/cm) and TDS 100–1,000(mg/L). Salty water conducts electricity more readily than purer water. A sample's EC can be converted to TDS and vice versa. But the majority of food waste samples analyzed in this study observed an electrical conductivity of 3.2 dS/m as observed on a (Table 3). According to (Bersinger et al., 2015*)* stated that it indicate high electrical conductivity affect aquatic life.

The P^{H} was related to the hydrogen ion concentration in the waste water. Most bacterial and biological life can survive only within a certain p^{H} range. Thus, the waste water's pH represents

its impact on the receiving water's acidity. As the study indicate that P^H=7.42 (Table 3). And (Merkley & Luo, 2012) states that environmental regulations for discharge to the environment typically require that p^H of the waste water were within the range of 6 to 9. Comparatively the result was conformed the range. But extreme waste water p^H also adversely affects the performance of chemical and biological waste water treatment systems, and causes corrosion of equipment as well.

The food waste types contained a variety of microbial groups. Different bacteria reproduce at different rates (Lopez et al, 2004). Some bacteria grow quickly, others grow slowly. When bacteria were placed into a favorable growth environment, they follow a characteristic pattern of increasing in number followed by a decrease in number. This can be (figure 10) plotted as the number of cells present over a period of time.

Figure 10: Food waste microbial growth curve



There was no significant variation among counts of aerobic mesophilic bacteria, Coliforms (indicative of insanitary practices), Yeast and Molds among the food waste samples (CV<10%) (Table 4). The microbial of the samples (Gregersen, 1978) were dominated by a variety of Gram positive and Gram negative bacterial groups. Among the Gram positive isolates water waste samples yielded more than the food waste samples. In contrary, (Table 4) Gram negative isolates dominated more of the food waste samples that were dangerous for human health.

Table 4: Microbial counts cfu/ml of solid waste and liquid waste samples collected from six randomly selected hotels in Addis Ababa

Bacterial groups	**Solid waste samples**			**Liquid waste samples**		
	Mean	**S.D[1]**	**%CV[1]**	**Mean**	**S.D[2]**	**%CV[2]**
Aerobic mesophiles	11.5	0.42	3.65	11.9	0.43	3.61
Coliforms	7.51	0. 54	7.19	7.1	0.59	8.3
Yeast and Molds	6.64	0.49	7.38	7.3	0. 36	4.93
Gram positive and gram negative	G^+ 17	0.83	4.88	19	0.66	3.47
	G^- 113	0.45	0.4	111	0.41	0.37

[1]S.D= Standard deviation, [2]G+= Gram positive, [3]G^-=Gram negative, [4]Coefficient of variation= CV

The food waste and water waste samples considered in this study (Table 4) had a colony forming unit bacteria of 1.1 x 10^{23} CFU/ml and 1.3 x 10^{23} CFU/ml microbial loads. The 10^7 CFU/ml represents an index of spoilage and 10^8 CFU/ml represents odour development (Fung, 1980). The data suggests that the food waste obtained contained high counts of microorganisms. Because of the high initial counts, reduction of number by sterilizing or chemical treatment may still leave a good proportion of the microorganisms.

High count of aerobic mesophilic bacteria, Enterobacteriaceae, coliforms, yeasts and molds indicated that the food waste might be contaminated with microorganism during growth, harvesting, distribution or preparation. Therefore; the food waste did not fit for human consumption. There was high variability in the counts of all microbial groups within the samples of each food waste. This shows the lack of consistent washing and sanitation practices. In addition, there is an increased potential for vegetables and dairy products to become contaminated with pathogenic species during production and processing as there is no system of microbiological control of the raw vegetable or the processed one.

The presence of much amount of gram negative bacteria in 25g of a sample examined was regarded as potentially hazardous to consumers, and was unacceptable for human being consumption. This study showed that the food waste was heavily contaminated with a variety of

microbial groups and enteric pathogens were isolated from the samples. As their preparation require further treatment, it is important to thoroughly sterilize food waste and dip them in food grade antibacterial chemicals for an appropriate time to eliminate pathogens and significantly reduce the microbial load. And can turn food waste in to different products like to methane production (Nathao et al., 2013), Vegetable oil waste into fuel oil (Vehlow et al.,2012), used for aerobic compost process (Di Lonardo et al., 2012), and in to succinic acid (Zhang et al., 2013).

CHAPTER 5: CONCLUSIONS AND RECOMMENDATIONS

5.1. CONCLUSIONS

Collecting food waste in Addis Ababa hotels is not a minor task as every hotel generates food waste. City of Addis Ababa generates about 666,600,000 kg food wastes per a year. This means that the existence of a huge number of sources of food waste isolated in multiple locations. Since food waste is perishable, hygiene and Public health issues it must be considered during collection and disposal. Therefore, collecting this food waste will require some innovative strategies and change of habits from the communities to separate their waste at source like that of solid and liquid waste separation into food/organic waste, recyclable materials and unwanted materials. Overall, in order to make waste separation at source a success, strong cooperation and participation from the public, government, industries, non-government organizations, and other concerned groups will be required. In the long run, to ensure a sustainable society, treatment technologies and zero food waste is the ultimate solution.

The technology to treat food waste to produce biogas and succinic acid may be feasible, one of the challenges we need to overcome in order to make the treatment process a success is to separate the food waste at source from garbage and recyclable materials. Most importantly, for the production of biogas, non-biodegradable materials cannot be mixed with food. But for the production of succinic acid, a more homogeneous type of food waste will give a higher yield and purity of the acid. However, food waste reduction will not happen at a single overnight. In the meantime, developing treatment technology in combination with effective source separation systems, as well as education that waste reduction and separation is a social responsibility will prevent food waste from ending up in landfills and ultimately allow Addis Ababa to better manage her food waste. Since this study is done for the first time it needs a continual study to develop new technologies to work towards this goal by collaboration with food industries. Treated food industries waste water, unlike water supplied for domestic and industrial purposes, and the food waste contains higher concentrations of inorganic suspended and dissolved materials that can develop microbial which damage the soil and irrigated crops. But the presence of nutrients can become an advantage due to possible saving in fertilizers.

There was a high count of microbial of 1.1 x 10^{23} CFU/ml and 1.3 x 10^{23} CFU/ml in the food waste. The 10^{7} CFU/ml represents an index of spoilage and 10^{8} CFU/ml represents odour development. The data suggests that the food waste obtained contained high counts of microorganisms. This was indicated that the food waste might be contaminated with microorganism during growth, harvesting, distribution or preparation. Therefore; the food waste did not fit for human consumption. This study showed that food waste and its waste water were heavily contaminated with a variety of microbial groups and enteric pathogens were isolated from the samples. As their preparation require further treatment, it is important to thoroughly sterilize food waste and dip them in food grade antibacterial chemicals for an appropriate time to eliminate pathogens and significantly reduce the microbial load. And can turn food waste in to methane, Vegetable oil waste into fuel oil, used for compost, and converted in to succinic acid.

5.2. RECOMMENDATIONS

1 The science behind methane and succinic acid production is of interest in its own right as the process is carried out by a complex group of microorganisms. Hence, research has to be carried out to investigate how the microorganisms are breaking down the food waste and subsequently producing the methane and succinic acid so that we can maximize such production and concentration to generate electricity and support green technology

2 The food handlers and the responsible officials need to have training on basic principles of food handling and preparation practices.

3 It is recommended that daily measurement is standardized and reported regularly. Reporting food waste separately provides a clear indicator of progress on food waste prevention.

4 Let we wish to see our Addis Ababa people taking pride in “Everyone being a Recycler” and in adopting a “Food Matters” culture that will spread through our society and become one of our core values. We can eat well but we must not waste. Let us all adopt these practices as a part of how we wish to live. Addis Ababa’s catering sectors can be well-known for not only providing good food but also how they minimize to zero level at source and recycle food waste.

6. REFERENCES

Beck, Hayden J, & Birch, Gavin F. (2012). Metals, nutrients and total suspended solids discharged during different flow conditions in highly urbanised catchments. Environmental monitoring and assessment, 184(2), 637-653.

Bersinger, Thomas, Le Hécho, Isabelle, Bareille, Gilles, Pigot, Thierry, & Lecomte, Alexandre. (2015). Continuous Monitoring of Turbidity and Conductivity in Wastewater Networks: An Easy Tool to Assess the Pollution Load discharged into receiving water. *Journal of Water Science*, 28, 9-17.

Chefetz, Benny, Hatcher, Patrick G, Hadar, Yitzhak, & Chen, Yona. (1996). Chemical and biological characterization of organic matter during composting of municipal solid waste. *Journal of Environmental Quality*, 25, 776-785.

Chen, Shulin.(1996) Food Waste.

Dearman, Benjamin, Marschner, P, & Bentham, Richard H. (2006). Methane production and microbial community structure in single-stage batch and sequential batch systems anaerobically codigesting food waste and biosolids. Applied microbiology and biotechnology, 69(5), 589-596.

Di Lonardo, MC, Lombardi, F, & Gavasci, R. (2012). Characterization of MBT plants input and outputs: a review. Reviews in Environmental Science and Bio-technology, 11(4), 353-363.

Food, A. (2014). Panel on Environmental Affairs. Policy, 27(2014).

Fung, (1980) "Ranges of Microorganisms for Applied Microbiology," *Journal of Food Protection*, Vol. 43, 1980, pp. 547-550.

Gregersen, T. (1978). Rapid method for distinction of Gram-negative from Gram-positive bacteria. *European Journal of Applied Microbiology and Biotechnology*, 5, 123-127.

Gupta, Vinod Kumar, Ali, Imran, Saleh, Tawfik A, Nayak, Arunima, & Agarwal, Shilpi. (2012). Chemical treatment technologies for waste-water recycling an overview. RSC Advances, 2(16), 6380-6388.

Gustavsson, Jenny, Cederberg, Christel, Sonesson, Ulf, Van Otterdijk, Robert, & Meybeck, Alexandre. (2011). Global food losses and food waste. Food and Agriculture Organization of the United Nations, Rom.

Hassanpour Aslani, S, Ghafourian, H, Ardakani, MR, & Torabi, S. (2013). Feasibility study of reducing the total dissolved solids (TDS) from contaminated water in radish plant (Raphanus Sativus) using nano activated carbon and zeolite. *Journal of Nano Structures*, 3, 219-225.

Knipe, AD. (2005). The management of household food waste. Environmental Research and Consultancy. West Morden, United Kingdom (November *29)*.

Latif, Usman, & Dickert, Franz L. (2015). Biochemical Oxygen Demand (BOD) Environmental Analysis by Electrochemical Sensors and Biosensor*s* (pp. 729-734): Springer.

Lopez, S., Prieto, M., Dijkstra, J., Dhanoa, M. S., & France, J. (2004). Statistical evaluation of mathematical models for microbial growth. *International journal of food microbiology*, *96*(3), 289-300.

Maxwell, Dorothy, & McAndrew, Ms Laure. (2011). European Commission DG ENV.

Mena, Carlos, Adenso-Diaz, B, & Yurt, Oznur. (2011). The causes of food waste in the supplier–retailer interface: evidences from the UK and Spain. Resources, Conservation and Recycling*, 55*(6), 648-658.

Merkley, Donald J, & Luo, Caidian. (2012). Washing the pulps in hot aqueous solution and agitating to remove chemical oxygen demand (COD) components; low COD pulp; building materials: Google Patents.

Nathao, Chananchida, Sirisukpoka, Ubonrat, & Pisutpaisal, Nipon. (2013). Production of hydrogen and methane by one and two stage fermentation of food waste. *International Journal of Hydrogen Energy*, 38, 15764-15769.

Prasad, Ananda S. (2013). Essential and Toxic Element: Trace Elements in Human Health and Disease: Elsevier.

Ragonig, A, & Faist, V. (2009). Destination-process-specific optimization of waste processing using innovative treatment technology. Paper presented at the ISWA World Congress.

Reddy, KR, Newman, S, Osborne, TZ, White, JR, & Fitz, HC. (2011). Phosphorous cycling in the greater Everglades ecosystem: legacy phosphorous implications for management and restoration. Critical Reviews in Environmental Science and Technology, 41(S1), 149-186.

Regassa, Nigatu, Sundaraa, Rajan D, & Seboka, Bizunesh Bogale. (2011). Challenges and opportunities in municipal solid waste management: The case of Addis Ababa city, central Ethiopia. *Journal of human ecology*, 33, 179-190.

Singh, Omkar, & Sharma, MK. (2015). Measurement of dissolved oxygen and biochemical oxygen demond for the hindon river, Hindia. *Journal of Indian Water Resources Society*, 35 152-153.

Sosnowski, P, Wieczorek, A, & Ledakowicz, S. (2003). Anaerobic co-digestion of sewage sludge and organic fraction of municipal solid wastes. Advances in Environmental Research, 7(3), 609-616.

Tessema, M. (2010). Overview of Addis Ababa city solid waste management system. Addis Ababa, Ethiopia: Addis Ababa City Administration.

Ukpaka, CP. (2013). The concept of chemical and biochemical oxygen demand in inhibiting crude oil degradation in fresh water pond system.

Vehlow, Jürgen, Seifert, Helmut, & Eyssen, Ralf. Japans Abfall management in Strukturwandel. Mull und Abfall*, 5*(2012), 255.

Wilson, Jessica M, Wang, Yuxin, & VanBriesen, Jeanne M. (2013). Sources of high total dissolved solids to drinking water supply in southwestern Pennsylvania. *Journal of Environmental Engineering*, 140, 401-403.

Zhang, Andrew Yan-zhu, Sun, Zheng, Leung, Cho Chark Joe, Han, Wei, Lau, Kin Yan, Li, Mingji, & Lin, Carol Sze Ki. (2013). Valorisation of bakery waste for succinic acid production. Green chemistry, 15(3), 690-695.