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Management and Life Cycle Assessment of Market Food Waste in Khulna Metropolitan City, Bangladesh: A Case Study

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ABSTRACT

Life Cycle Assessment is an essential tool for evaluating the environmental burden caused throughout the life cycle of a product or waste. Life cycle of waste starts when it is considered as unwanted or no longer in use. The aim of this study is to evaluate and asses the environmental impact caused by the market food wastes throughout its life cycle. The study area was taken in Khulna Metropolitan City in Bangladesh. Functional Unit for LCA was taken as the total amount of market food wastes generated each day in the study area. The impact categories that are included in this study are Green House effect, Global Warming, Acidification, Human Toxicidity, Eutrophication. Four possible scenarios are explained with their impact assessment. This was performed by calculating the amount of green house and hazardous gasses emission in each scenario. Finally a management options were recommended based on the impact assessment. By assessing the possible impacts it was found that recycling (which includes rendering, bone recycling poultry wastes and litter recycling) and composting are the best management options for market food wastes.

Keywords: *Life Cycle Assessment; composting; rendering; Eutrophication; Acidification.*

1. INTRODUCTION

Waste is generally defined as something that is no longer wanted or useful: it is what is left over after the valuable and useful components have been removed (Cambridge English Dictionary, 2010). Today's environmentally conscious, global society has, waste is being seen not as an end product, but as countries have had recycling recognized that the production of waste is counterproductive to the attainment of a sustainable society. However, with the current global emphasis on the reduction of environmental impacts, and in particular greenhouse gas (GHG) emissions, principles such as sustainable resource use and life cycle thinking are being applied to waste management, clearly treating waste as a resource that is to be exploited to the greatest extent possible.

Waste prevention, also known as waste reduction at source is the most preferred solid waste management alternative that is it is at the top of solid waste management hierarchy. The solid waste management hierarchy is often cited as a means of justifying the desire to process solid waste by any means other than landfill. This hierarchy is seen resource that can be exploited to recover materials and energy. The idea of using waste as a resource is not a new one: Many in Fig 1.This hierarchy provides waste treatment option in a fixed order of preference with waste reduction at source (which normally include reduce, reuse) as the most preferred and landfill as the least preferred options. The waste reduction at source is the most preferred option because it would give the least impact to the environments opposed to landfill, which will have the most impact on the environment. This strategy of waste prevention at source is important to enable us to achieve a better quality of life and working towards a more sustainable living.

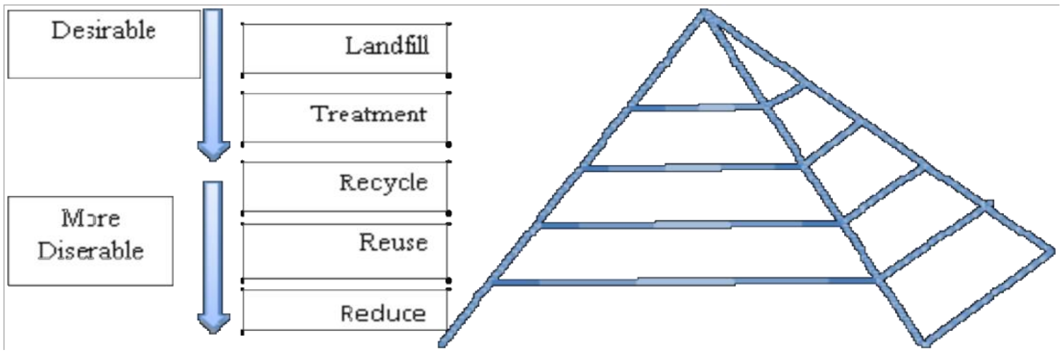


Figure 1. Municipal Solid waste management hierarchy

2. LIFE CYCLE ASSESSMENT

Life Cycle Assessment (LCA) is one of the preventive and remedial approaches in environmental Management and. Industrialists have become increasingly interested in looking into the environmental consequence of their operations. The growing awareness of product-related environmental issues with special emphasis on waste prevention and reduction at source has focused on the need for generally-accepted methods of assessing the environmental impact of products throughout their entire life cycle, referred to as 'from cradle to grave' approach. The methodology of Life Cycle Assessment is very useful on showing paths that could possibly decrease the environmental impacts caused by the waste management process. Cristopher) LCA originates from "net energy analysis" studies, first published in the 1970s (Boustead, 1972; Hannon, 1972; Sundstrom, 1973). These studies took into consideration only energy use over the life cycle of a product or a process. Later studies included wastes and emissions (Lundolm and Sundstrom, 1985; Boustead, 1989); nevertheless, none of them went further than the quantification of materials and energy use. As a result the Society of Environmental Toxicology and Chemistry and the International Organization for Standardization (ISO 14040, 1997; ISO 14041, 1998; ISO 14042, 2000a; ISO 14043, 2000b) developed in the 1990s a complete LCA methodology. In2006, standard ISO 14040 was revised (ISO 14040, 2006) and a new standard ISO 14044 (ISO 14044, 2006) was presented. Formal changes include the reduced number of standards, the reduced number of annexes and the reduced number of pages that contain all the requirements. All these changes are intended to increase their ability and accessibility of the standards. The two new standards, ISO 14040 and ISO 14044, reconfirm the validity of the main technical content of the previous standards. Errors and inconsistencies were removed and the readability was improved (Finkbeiner et al., 2006). Further details on the current state-of-the art of the LCA methodology can be found on the publications pages of the European Platform of Life Cycle Assessment or the UNEP/SETAC Life Cycle Initiative (UNEP, 2010; European Commission, 2010). As far as integrated solid waste management systems are concerned, they incorporate all the policies, programs and technologies that are necessary to manage the waste streams. The mix and emphasis of approaches that are taken, generally varies from region-to-region and depends on local conditions (UNEP, 2005). A number of studies have been published during the past decade, investigating the usefulness of LCA methodology in sustainable waste management (Finnveden et al., 1995; Liamsanguan andGheewala, 2012; Moberg et al., 2005; Reich, 2005). The concept of Integrated Solid Waste Management (ISWM) can be defined in various ways, but generally it is considered as an optimized waste management system in which environmentally and economically best solution for each individual case is sought (Sundqvist, 1999;McDougall and Hruska, 2000).

The methodological framework for conducting an LCA has been standardized by the International Organization for Standardization (ISO). The ISO 14040 series describes four phases in conducting an LCA: Goal and Scope (ISO 14041), Life Cycle Inventory (ISO 14041), Life Cycle Impact Assessment (ISO 14042), and Life Cycle Interpretation (ISO 14043). In 2006 these Standards were revised and amalgamated to form a single standard, ISO 14044. Although there is a basic chronological order to be followed, the process is iterative and should be continually under review.

So LCA may be broken down into several stages, namely:

Stage 1 which is Goal definition

Stage 2 which consists of Inventory Analysis

Stage 3 which includes Classifications and evaluation

Stage 4 which is Improvement Assessment

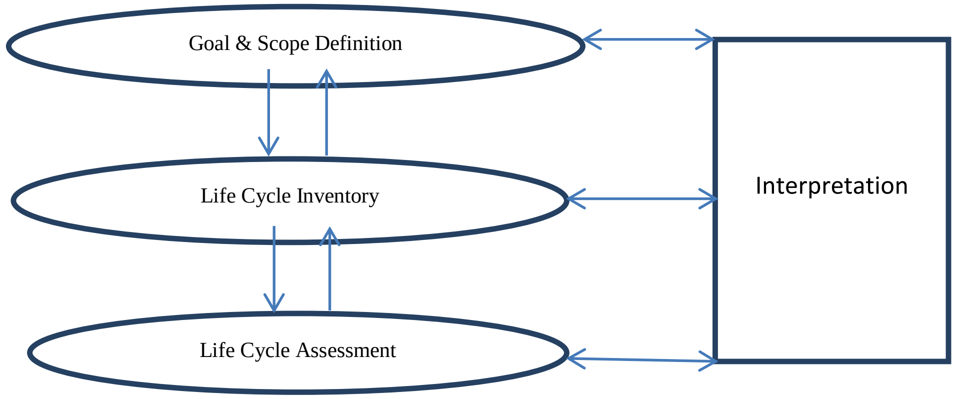


Figure 2. Phases of LCA

In this study, LCA of market food wastes in Khulna metropolitan city is explained and performed according to the methodological framework of LCA.

Khulna is one of the population growing cities in Bangladesh. Due to increasing number of population municipal solid waste is also increased considerably. Market food wastes occupy a considerable amount in total municipal solid waste. Each day large amount of market food wastes are generated at various markets in Khulna metropolitan city. These wastes include vegetable and fruit wastes, slaughterhouse wastes, and poultry and fish wastes. Below table shows the amount of food wastes generated each day in Khulna Metropolitan city.

Table: 1 Amount of market food waste produced in different market

Bazar	Waste (kg)		
	Vegetables	Poultry	slaughter House
Fultola Bazar	200	90	430
Shiromoni Bazar	130	75	320
Moilapota Bazar	175	55	165
Rupsha Bazar	280	55	190
Nerala Bazar	110	45	110
Khalishpur Bazar	220	90	245
Dawlutpur Bazar	265	60	300
Phulbarigate Bazar	65	100	140

The emissions of GHG gases were estimated in this study using the following general equations This large amount of wastes are either thrown to landfill or other places like drain, nearby lands, rivers which makes a potential threat to the environment. The objective of this study is to analyze the environmental impacts caused by waste management methods and to compare alternative scenarios regarding these methods. The methods of treatment considered in this work include landfill of all waste fractions, anaerobic biological treatment of food waste, and recycling of slaughter house, poultry waste, fish wastes. Emphasis has been given to air pollution, water pollution, human toxicidity due to emission of gases in different scenarios and comparison was done to indentify the best scenario for waste management.

For landfill**,**

$$C_aH_bO_cN_d + xH_2O = \infty CH_4 + zCO_2 + dNH_3$$

Where, x= (4a-b-2c+3d)/4; ∞= (4a+b-2c-3d)/8; z= (4a-b+2c+3d)/8 (Tchobanoglous et al., 1993)

For composting and incineration,

$$C_aH_bO_cN_d + (4a+b-2c-3d)\ O2/4 = aCO_2 + (b-3d)\ H_2O/2 + dNH_3$$

3. LCA OF MARKET FOOD WASTES

3.1 Goal & Scope Definition

Goal definition and scoping is perhaps the most important component of an LCA because the study is carried out according to the statements made in this phase, which defines the purpose of the study, the expected product of the study, system boundaries, functional unit (FU) and assumptions.

In this study, four different scenarios of Solid Waste Management Systems (SWMSs) that include different MSW process in and/or disposal methods were developed, and then, compared with respect to their environmental burdens. Then the (SWMSs) were compared in a LCA context, which considered the following components: collection and transportation of SW, MRF/Transfer Station (TS), thermal (direct incineration) and biological (anaerobic digestion) treatment and land filling.

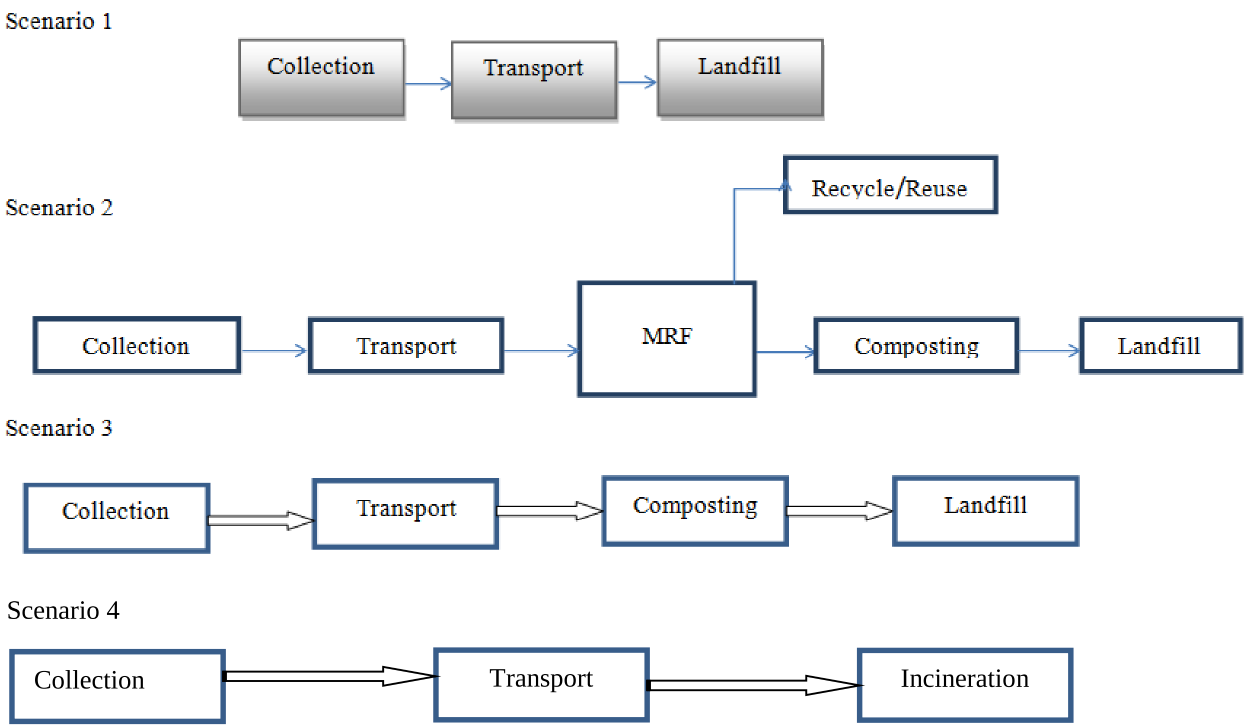
3.2 Functional Unit & System Boundaries

Following the previous work performed by Ozeler et al. (2006) using the IWM-1 model, the functional unit in this study has been defined as the amount of market food wastes generated in Khulna metropolitan city every day. The system boundaries selected for the life cycle of the wasted articles was defined as the moment when material ceases to have value, becoming evidently labeled as waste.

4. LIFE CYCLE INVENTORY

4.1 Data Collection

Data were collected from the markets in Khulna metropolitan city. All The data used in this work is the amount of wastes generated in each day. In order to assess the impact on environment, four scenarios are chosen in this study.
The Four scenarios for assessing the environmental impact of market food wastes are shown below.



Scenario 1:

The first scenario (Fig.1a) consists of three main steps: collection, transport and land filling of market food waste. In this scenario 100% of the food waste is dumped in the landfill which is the present condition of management in Khulna city.

Scenario 2:

This scenario consists of steps: collection, transport, material recovery facility, recycles, composting (anaerobic degradation). Here 40% of the food wastes are recycled or reused and the rests are composed. The recycling options include slaughterhouse wastes recycling, poultry wastes recycling. The vegetable and fruit wastes along with other slaughterhouse and poultry wastes are engaged to composting.

Scenario 3:

In this scenario 70% of the wastes are composed and the rests are thrown to the landfill site. All vegetable & fruit wastes are composed for production of biogas. Vegetable and fruit wastes occupy about 40% of the total market food waste.

Scenario 4:

This scenario shows the total incineration of the food waste rather than recycling or composting.

The amount of greenhouse gas and ammonia emission in each scenario are given below in tabular form

Table: 2 Scenario 1 (100% Landfill)

Gas	Amount(Kg/ton)
CO_2	683
NH_3	23.36
CH_4	306

Table: 3 Scenario 2 (40% recycling and 60% Composting)

Gas	Amount (Kg/Ton)
CO_2	882
NH_3	23.36
CH_4	0

Table: 4 Scenario 3 (70% composting and 30% landfill)

Gas	Amount(Kg/ton)
CO_2	1714
NH_3	23.36
CH_4	92

Table: 5 Scenario 4 (100% incineration)

Gas	Amount(Kg/ton)
CO_2	1470
NH_3	23.36
CH_4	0

IMPACT ASSESSMENT

From the above table, it can be said that scenario 2 gives less burden to the environment as emission of hazardous gasses are relatively low in amount. Though CO_2 emission is less in scenario 1 than that in scenario 2 another hazardous gas CH_4 is emitted in considerable amount.CO_2 and CH_4 are the gasses responsible for global warming and green house effect. . Scientists consider methane as the second most damaging greenhouse gas produced by human activity after carbon dioxide. a new study by the Nasa Goddard Institute for Space Studies has found methane is 33 times more damaging if the effects of interaction with other airborne pollutants is included.(telegraph).However, Carbon dioxide (CO_2) and Methane (CH_4) are transparent to visible light energy but somewhat opaque to thermal or infrared radiation or energy. Both carbon dioxide and methane are greenhouse gases, which are responsible of damaging our atmosphere. This allows more sunlight to enter the atmosphere, and will be reflected by atmosphere, which makes the earth increase in temperature. On the other hand, ammonia emission is caused in all scenarios which have impacts both on environment and human health. Since ammonia is one of the only basic species in the atmosphere, it readily reacts with strong acidic species in the atmosphere such as nitric and sulfuric acids, which are byproducts of combustion process including vehicle and industrial sources, to form ammonium salts, also known as fine particulate matter or $PM_{2.5}$.

Ammonia + Acidic Species (i,e. nitric acid, sulfuric acid from NOx and SOx) = $PM_{2.5}$

Due to their small diameter (less than 2.5 microns (µm)) and increased atmospheric lifetime of 15 days, these particulates are able to travel long distances before being dry or wet deposited to the ground surface. This allows them to travel from rural areas to urban locations where they mix and build up in the atmosphere leading to smog or transportation to other areas. In Colorado transport of these particulates from urban areas to pristine mountain regions, such as Rocky Mountain National Park, has been documented. Deposition of these N rich particulates in the Park has caused changes in the Park's vegetation, lakes, and natural ecosystems.

EUTROPHICATION

Eutrophication is a result of nutrient pollution (from deposition or run-off) into natural waters (creeks, rivers, ponds, or lakes). Eutrophication generally promotes excessive plant growth and decay, favors certain weedy species over others, and is likely to cause severe reductions in water quality. In aquatic environments, enhanced growth of choking aquatic vegetation or algal blooms disrupt normal functioning of the ecosystem, causing problems such as a lack of oxygen in the water, needed for fish and other aquatic life to survive. The water then becomes cloudy, colored a shade of green, yellow, brown, or red.

SOIL ACIDIFICATION

When ammonia reaches the soil surface, it usually reacts with water in the soil and is converted into its ionic form, ammonium (NH_4+) and absorbs to the soil. The ammonium in the soil eventually disassociates or is nitrified into nitrite (NO_2-) or nitrate (NO_3-) by nitrifying bacteria, releasing H+ ions into the soil (3, 4). If not taken up by biomass and converted to methane, the surplus H+ ions eventually lead to the formation of an acidic soil environment. The nitrogen left over in the soil will either be taken up by plants, stored in the soil, returned to the atmosphere, or will be removed from the soil in runoff or leaching (3).

FERTILIZATION OF VEGETATION

Fertilization of vegetation by ammonia occurs in much the same way as applying fertilizer to the soil; however, in this case ammonia gas from the air deposits on the leaf or soil surface at the base of the plant and is taken up by the plant. Changes in plant growth can then occur, similar to those resulting from fertilization. In a grass plains environment, changes may be subtle; however, in natural or mountain areas, changes in plant species may be more obvious, promoting weedy plants while choking out native plants and wild flowers or promoting grasses and sages.

CHANGES IN ECOSYSTEMS

An ecosystem is a natural system consisting of plants, animal, and other microorganisms functioning together in a balanced relationship. Changes in ecosystems due to ammonia deposition occur through a combination of all the above mentioned processes. When changes in ecosystems occur, the natural balance of a system is disrupted and fragile plant and animal species can be replaced by non-native or N-responsive species. The disruption of an ecosystem can cause it to adapt by changing (positive or negative outcome), or a disruption may lead to the extinction of the ecosystem.

SMOG AND DECREASED VISIBILITY

When ammonia combines with NOx and SOx emissions from industrial and vehicle combustion processes it forms fine particulates. These fine particulates (also known as $PM_{2.5}$) are a contributor to haze/smog in cites and decreased visibility (haze) in pristine areas. Smog is also a human health issue leading to an increased rate of respiratory and heart diseases.

HUMAN HEALTH IMPACTS

Ammonia effects human and animal health both as a gas and as a particulate. The particulate form of ammonia has broader implications for the general public, where as the gaseous form is a localized concern for the health of animals and agricultural workers.

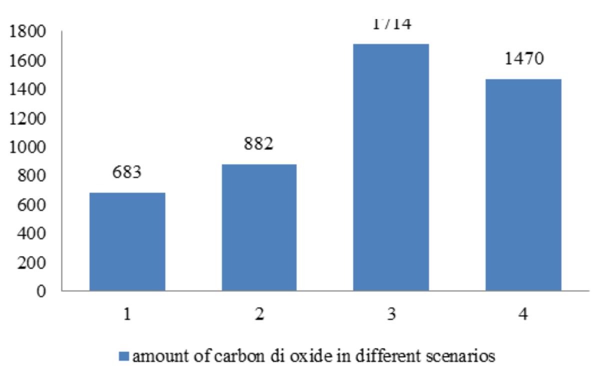


Figure 3. Bar diagram for CO_2

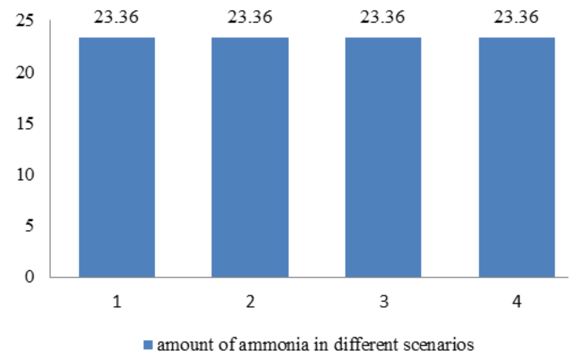


Figure 4. Bar diagram for NH_3

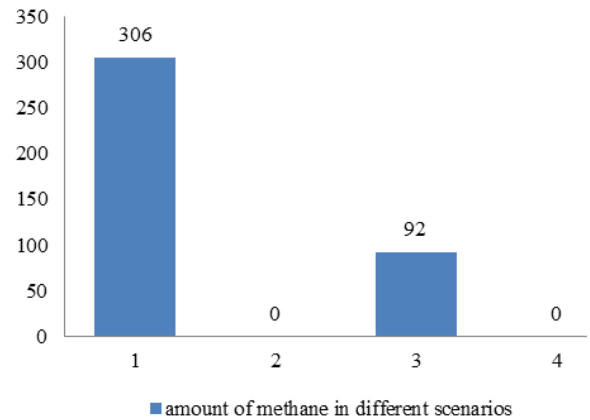


Figure 5. Bar diagram for CH_4

MARKET FOOD WASTE MANAGEMENT

Based on the scenarios mentioned above and their possible impact on environment, recycling followed by composting should be the best management option for market food wastes. Slaughter house and poultry wastes can be recycled or reused and vegetable wastes are to be degraded anaerobically.

Based on scenario 2, various waste management options can be utilized. in order to lessen environmental burden and human toxicidity of the food wastes, it is necessary to recycle or reuse the food wastes including slaughter house wastes, poultry wastes etc in large extent and the rests especially vegetable wastes are to be composted which was shown in scenario 2.

MANAGEMENT OF SLAUGHTER HOUSE WASTE

Slaughterhouse wastes contain decaying animal carcasses, blood and faecal matter, and they are a significant source of pathogens and bad odours. These wastes may also pollute water supplies. As slaughterhouse wastes represent a particular hazard, their collection and disposal should be carried out by trained staff and the wastes disposed of in properly maintained sites. The main wastes of small scale slaughterhouses in our country includes hides, skins, blood, rumen contents, bones, horns, hoofs, urinary bladder, gall bladder, uterus, rectum, udder, fetes, snout, ear, penis, meat trimmings, hide and skin trimmings, condemned meat, condemned carcass, esophagus, hair . All most all by-product of slaughter house can be utilized.Slaughter house waste contains mostly biodegradable matter. For the slaughter house wastes composting, biomethanation and rendering systems are suggested. Selection of appropriate method, however, depends mainly on type of wastes and its quantity. Incineration is also an option for treatment of slaughter house waste. But it causes high emission of GHG gases.

Biomenthation

Biomethanation of slaughterhouse wastes is done in many places. The success of the process, especially the effective removal BOD has led Biogas plant to be acceptable for slaughter house.

Composting

Composting involves the aerobic biological decomposition of organic materials to produce a stable humus-like Product which is used as fertilizer for lands.

Rendering

This is a useful method for the physical separation of fats from solids and water. All the animal matter such as inedible offal, tissues, meat trimmings, waste and condemned meat, bones etc. can be processed in a rendering system as the main constituents of animal matter are fat, water and solids. Rendering is affected by heating and rupturing connective tissue of individual fat and muscle cells so that raw fat and other material bound within is freed. In rendering, fat recovered is used for industrial purposes, such as soap and greases. Fat recovered from flesh of healthy parts can also be used for edible purposes. Solid portion, which is known as meat meal or bone meal, is utilized for the manufacture of stock feed and fertilizers.

MANAGEMENT OF VEGETABLE & FRUIT WASTES

Composting

Fruits and vegetables can easily be repurposed as compost. This use benefits the environment in several ways. First, it reduces landfill waste. By fruits and vegetables we can provide garden and lawn with a high-quality source of organic material for reducing your use of chemical fertilizers. Since these foods are biodegradable, we can quickly realize the benefits of your decision to compost. By recycling your fruits and vegetables, you reduce the amount of greenhouse gas emissions caused by rotting foods. Because these foods are organic, they decompose quickly, releasing methane into the atmosphere. The EPA explains that methane is more dangerous to the environment than carbon dioxide because of its global warming potential. Your decision to recycle your fruits and vegetables can reduce the amount of methane generated by landfills and thus, decrease your contribution to climate change

Poultry Waste

Poultry wastes consist of litter, manure, intestine, feather etc. These wastes can be used as fertilizer and nutrients for the plants by composting. It is a good option of management rather than land filling. Feather can be used in various purposes.

5. CONCLUSION

Based on the results from the above discussion the following conclusion can be drawn.

- Market food waste is one of the major sources of municipal solid waste. However, this huge amount of food waste can be made eco-friendly by proper management process. In this study, management options including recycling and composting are highly recommended. This is because of less emission of carbon di-oxide and methane.

- Incineration is another management option for waste management but it emits large amount of CO_2 which plays vital role in global warming. On the other hand, anaerobic digestion might be another option which emits considerable amount of CH_4.

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