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Greenhouse Gas Emission of Organic Waste Composting: A Case Study of Universiti Teknologi Malaysia Green Campus Flagship Project

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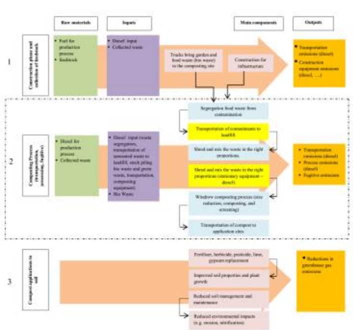
Graphical abstract



Abstract

Waste generation nowadays is rising in the world and it seems hard to prevent it. Solid Waste Management (SWM) has been a major problem worldwide in most of the fast growing towns and cities among the developing countries all around the world. Food waste and green waste constitute high volumes of municipal solid waste (MSW). The application of compost in the agricultural sector can contribute to sustainable soil health and other co-benefits. The compost produced from biological waste does not contain any chemicals unfavorable to living soil. The objective of this research was to calculate the greenhouse gas emission from the compost processed from the food and green wastes generated on-campus in Universiti Teknologi Malaysia (UTM) as a pilot project. The result indicated that the composting process promotes the university as a green campus by converting organic wastes into valuable products such as organic fertilizer.

Keywords: Greenhouse gas emissions; compost; organic waste; green campus; Malaysia

■1.0 INTRODUCTION

The release of greenhouse gases onto the living atmosphere is becoming a major concern nowadays. Mainly the ramifications of inaction are greater as to increase the global temperatures and resulting in the release of uncontrolled greenhouse gases that may lead to the rising of sea levels, melting glaciers and climatic change. So, it is very essential to examine the emission of greenhouse gases that are arising from different sources as to address the problems related to the above mentioned issues [1]. In Australia, the significant source of greenhouse gas emission contributing nearly 3.5% of the total gas emissions has been identified by the waste management team [2].

The generation of waste in Malaysia on daily basis has shown an increasing trend and it was estimated to be 16,200 ton in the year 2001. This amount increased to 19,100 ton in 2005, 17,000 ton in 2007 and 21,000 ton in 2009 [3]. Due to the increased population growth rate, the daily solid waste generated is estimated to rise to 31,000 ton per day by 2020 [4]. Malaysia is in critical need of effective measure for the planning and transition towards a sustainable solid waste management (SWM) approach. Ineffective management of the waste may result in the degradation of many valuable resources present in the land, increase land costs, and in turn can cause human health related issues and long-term environmental related problems [5]. During United Nation's Summit on Climatic Change that happened in Copenhagen, Denmark 2009, Malaysia has pledged to reduce greenhouse gas emissions by 40% of the country's gross domestic product by the year 2020 compared to the year 2005 as base level [6].

The current methods of managing waste as practiced in Malaysia are highly dependent on landfill due to low operational cost and the absence of alternative treatments [7, 8]. It is stated by the Boards of Engineers Malaysia (BEM) [9] that only 5.5% of MSW is recycled, 1% is being composted and the remaining 94.5% of the municipal solid waste (MSW) is disposed to the landfill. The more efficient and sustainable waste management strategies are required in order to reduce the reliance on landfills. Malaysia aims to establish a holistic framework that considers the trade-off involved in the segregation process and the economic performance of different MSW practices to achieve the national MSW recycling rate (22% of the total MSW) by the year 2020 according to the Ministry of Housing and Local Government [10]. The recycling and segregation of the waste are important for improving the performance of waste processing.

Generally, MSW is made up of around several categories including cardboard, food waste, mixed paper, plastics made from film, foam, waste generated from wood, textile, ferrous or non-ferrous metals, newsprint, diapers, waste generated from wood, batteries, glass construction waste and all of these materials can be grouped into inorganic and organic according based on the guidelines by Malaysian National Strategic Plan for Solid Waste Management 2009 [11]. The production of CO_2, CH_4, N_2O and NH_3 is due to the microbial activities that occurred during the process of composting [12].

Solid waste in Malaysia consists of 50% of food waste (at source), and 70% (as disposed) at the landfill sites. Treatment of the food wastes generated in Malaysia is extremely limited. The disposal of food wastes at the landfill sites is the largest source for emission of greenhouse gasses (GHGs). A sustainable approach to handle food waste or kitchen waste is to treat and reprocess the organic waste at source. The reduction in the volume and mass of solid organic wastes can be achieved via the composting process, assisted by naturally occurring microbes, that results in the production of a stabilized, safer and nutrient enriched soil enhancer [7, 13]. The application of composting process will lead to the reduced use of synthetic fertilizer, including the reduction of total amount of water used, decrease in soil erosion, reduced use of herbicides and enhancing soil carbon storage.

The main goal of this research is to calculate the greenhouse gases (GHGs) emissions of the organic waste during the composting process in Universiti Teknologi Malaysia (UTM), under the initiative of the university to become a sustainable green campus. Due to the bulk amount of green wastes produced within the campus, both the food and green wastes are composted on-site in the campus.

■2.0 METHODOLOGY

2.1 The Framework of the Research

Figure 1 illustrates the framework for the calculation of GHGs emission during the composting process in UTM.

2.2 Composting Emissions

The three main sources of GHGs emission occur during the composting include: composting emissions during the decomposition of the composed materials; energy emissions resulting from the waste shredding process and transportation emissions during the collection of initial feedstock and delivery of the completed compost. The significance of each emission is important because it detracts from the overall emission benefit of the compost. The overall GHGs emission arising from the composting process is represented by the following equation:

$$E_{total} = Te + Pe + Fe \qquad \text{(Equation 1)}$$

where,

Etotal = Total emission arising from the composting ($MTCO_2E$/ton of the feedstock)

Te = Transportation emissions resulting from the composting ($MTCO_2E$/ton of the feedstock)

Pe = Process emissions occurring from composting ($MTCO_2E$/ton of the feedstock)

Fe = Fugitive emissions resulting from the composting ($MTCO_2E$/ton of the feedstock)

2.2.1 Transportation Emissions (Te)

The transportation emission arising from the fossil fuel and CO_2 emission from the diesel are associated with the process of composting that happens during the collection of organic feedstock to the composting area until the delivery of the finished compost to the consumer. The distance travelled between the outbound and inbound along with the combination of emission factor indicates the amount of GHGs gas emitted per distance travelled (g CO_2/ton.mile), this provides the estimate of emissions resulting from the transportation.

2.2.2 Process Emissions (Pe)

Process emissions refers to the emissions arise from the energy requirement to chop and shred the material by means of the consumption of diesel by the shredder machine. The GHGs emission from water consumption is assumed to be negligible.

2.2.3 Fugitive Emissions (Fe)

Fugitive emissions arise from methane (CH_4) and nitrous oxide (N_2O) released during the composting process. Methane is produced in the anaerobic pockets of a compost pile, while nitrous oxide is a product of nitrification or identification [14]. Even though the overall emissions of these two GHGs are low relative to carbon dioxide, their emissions are significant because their global warming potential (GWP) is 21 and 310 times greater than CO_2 for CH_4 and N_2O, respectively [15]. Numerous research articles discussed the release of CH_4 and N_2O emissions from composting [16-18].

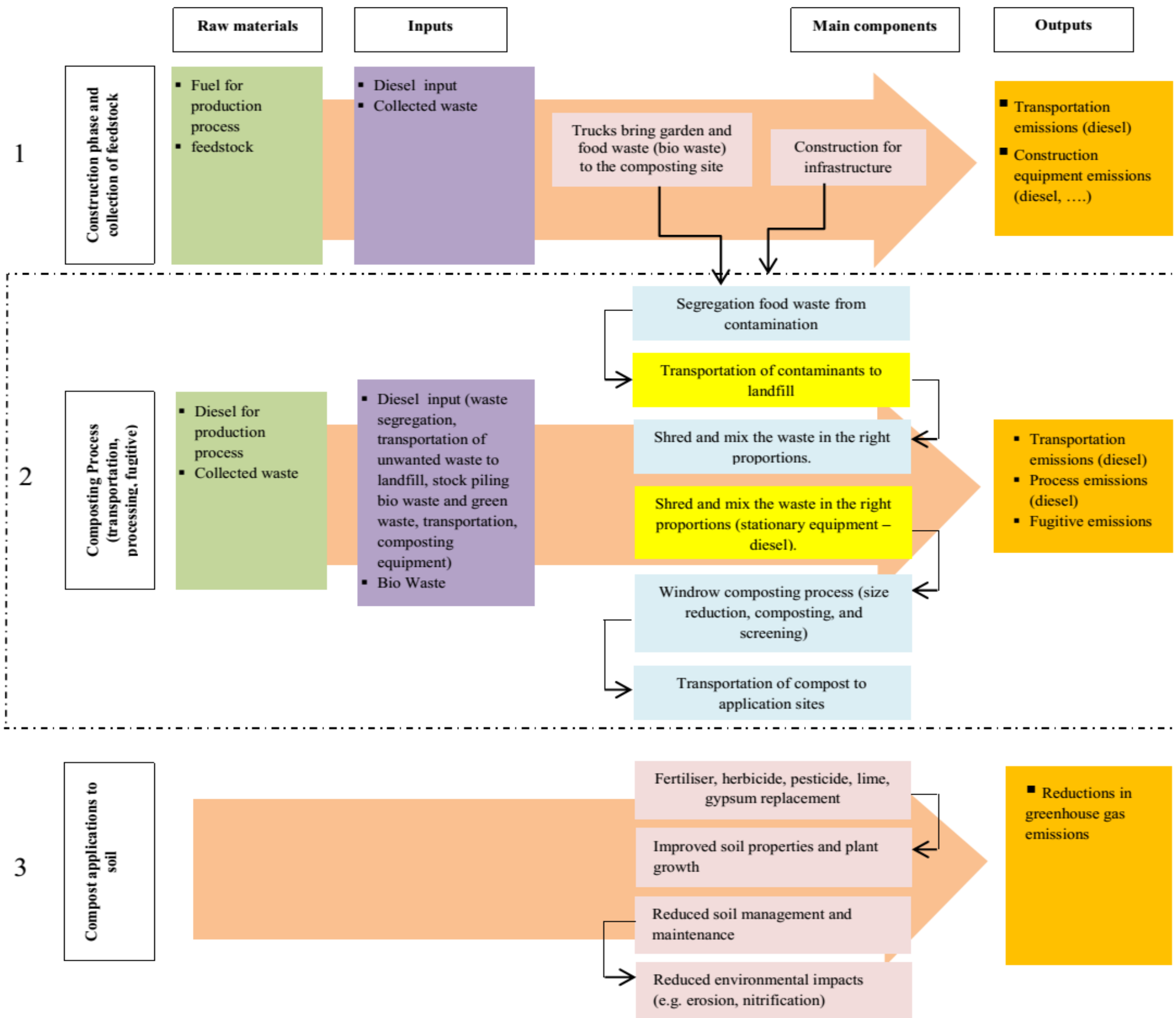


Figure 1 The framework for the calculation of GHGs emission during organic waste composting in UTM. The dashed line illustrates the scopes of the present study

■3.0 RESULTS AND DISCUSSION

This study analyzed the GHGs emitted during the organic waste composting in Universiti Teknologi Malaysia (UTM). The feedstock used for producing the compost included food waste and green waste that were generated within UTM campus. UTM generates approximately 5 ton of food waste (from 13 different cafeterias) and 10 ton of green waste daily. Assuming all of these organic wastes were composted, the resulted GHGs emissions from the composting process are presented hereafter.

3.1 Composting Emissions

Three sources of GHGs emissions were calculated for the composting process: process emissions (shredding of food and green wastes), fugitives (emissions by the compost piles) and emissions resulting from the transportation including for the inbound waste collections and the outbound for product delivery. The GHGs emission values obtained from the calculation are reported as below.

3.1.1 Transportation Emissions (Te)

Transportation emissions occur during the collection of feedstock when it is collected to the compost site (inbound) and also during the distribution of end-product to the site or consumers (outbound). Therefore, transportation emissions depend on the distance travelled by the vehicle and its type. To study this, two truck sizes (15 ton) were used for estimating the transportation emissions. Table 1 indicates the location of feedstock sources and its application sites.

Table 1 Feedstock collection (inbound) and end-product delivery (outbound)

Location of Cafeterias in UTM		**Distance (Km)**
Feedstock collection (inbound)	Meranti	2
	Cengal	3
	SUB	3.5
	N24	4
	N04 FKKSA	5
	P19 FKE	4.5
	KTHO	1.5
	KTDI	2
	KDSE K13	1
	Pak Lah Scholar Inn	7
	Rumah Alumni MakJah	6
	Sekolah Agama	5
	Pejabat Harta Bina	7
Compost delivery (outbound)	Nursery	7
	Plantation sites	6.5
	Orchard	0.5
Sum		**65.5**
Emissions		**0.004 $MTCO_2$/ton**

3.1.2 Process Emissions (Pe)

The composting process is completed under the influence of several varying conditions along with the involvement of some specific physical parameters, for instance the characteristics of the green and food wastes collected per batch might varies in terms of sizes and wetness, hence contributing to the variation of diesel needed to shred the wastes. The amount of diesel used for shredding was translated into the GHG emissions in metric ton of carbon dioxide equivalent ($MTCO_2E$/ton) produced per ton of feedstock shredded. By average, 0.43 gallons of diesel was used per ton of initial feedstock for the random three composting piles as shown in Table 2.

Table 2 Process emissions from the production of compost

Facility	**Activity**	**Emission Factor**	**Emissions ($MTCO_2E$/ton of feedstock)[a]**
Compost pile I	0.43 gal diesel/ton	10.2 kg CO_2E/gal	0.004
Compost pile II	0.39 gal diesel/ton	10.2 kg CO_2E/gal	0.003
Compost pile III	0.53gal diesel/ton	10.2 kg CO_2E/gal	0.005
Average			**0.004**

[a]For obtaining the total value of Emissions, the average of each process emission type was taken into consideration.

According to the findings from the previous studies [19-21], the values used for the process emissions were being compared to the multiple studies that were completed in Europe. Their study shows that the direct diesel emissions resulting from the front loaders, shredders and turning equipment is usually in the range between 0.03 -1.4 gallon/ton of the feedstock [19]. As indicated in Table 2, the process emission value obtained from this study (0.4 gallon/ton of feedstock) is within this range of values.

3.1.3 Fugitive Emissions (Fe)

Fugitive CH_4 and N_2O emissions are being compiled from different studies [14, 16, 22, 23] and it was averaged for determining this emissions. Most of the studies have referred to the guideline values as set by the Intergovernmental Panel on Climate Change (IPCC), more additional studies were included as to take into consideration that more recent data is being included from the green waste composting studies obtained from the Mediterranean climates [18, 20]. Table 3 shows the fugitive CH_4 and N_2O emissions from the composting processes as reported by various researchers.

Table 3 Fugitive CH_4 and N_2O emissions from previous composting studies.

CH_4			
	Reference	**Feedstock**	**Emission factor (gCH_4/kg)**
	Beck-Friis *et al* (2003)a	Household organics	3.6
	Beck-Friis *et al* (2000)b	Household organic mixed with coarsely chipped bushes and branches	11.9
	Hellmann *et al* (1997)c	Organic MSW with bush, grass clippings and leaves	0.172
	Hellebrand (2000)d	Green waste and grass	5.1
	Martinez-Blanco *et al* (2009)e	Pruning waste and organic MSW	0.38
	Amlinger *et al* (2008)f	sewage sludge, green waste and biowaste	0.21
	Manios *et al* (2007)g	Mixture of olive branches, mill sludge and leaves	7
		Average	**4.1**
			0.078 $MTCO_2E$/ton
N_2O			**(g_{N2O}/kg)**
	Beck-Friis *et al* (2000)b	Household organic mixed with coarsely chipped bushes and branches bushes	0.1
	Hellmann *et al* (1997)c	Organic MSW with bush, grass clippings and leaves	0.022
	Hellebrand (2000)d	Grass and Green waste	0.1
	Amlinger *et al* (2008)f	Bio-waste, Green waste, sewage sludge	0.13
		Average	**0.09**
			0.025 MTCO2E/ton

Based on the average emission factors of fugitive emissions from the literature, the fugitive emission for methane and nitrous oxide gases are found to be 0.078 and 0.025 $MTCO_2E$/ton of feedstock, respectively for this study. These values were consistent with the respective values as reported in the literature.

3.1.4 Summary of Emissions

Table 4 shows the total emissions (Etotal) of the present composting process in UTM to be 0.111 $MTCO_2E$/ton of feedstock.

Table 4 The summary of composting emission (Etotal)

Emission type	Emission ($MTCO_2E$/ton of feedstock)
Transportation emissions (Te)	0.004
Process emissions (Pe)	0.004
Fugitive CH_4 emissions (Fe)	0.078
Fugitive N_2O emissions (Fe)	0.025
Total	0.111

4.0 CONCLUSION

This study presents a sustainable waste treatment method in converting the organic wastes (food waste and green waste) produced within UTM campus into valuable products such as the fertilizer. The total GHGs emission taking into consideration the emission from the compost (fugitive), transportation and process was calculated as 0.111 $MTCO_2E$/ton of feedstock. The findings of this research are significant to enable the further calculation of the avoidance of GHGs emissions should the feedstock were to be transported to different waste disposal sites at different locations. Importantly, applying this method in UTM represents a proactive showcase in Malaysia where campus can serve as the best practices venue for sustainable solid waste management. It is crucial for university to showcase green campus as a way to accelerate the transformation into a responsible society for the conservation of environment. Various initiatives were taken by UTM such as the application of waste minimization efforts via 3R Campaign to promote UTM as a zero-waste campus.

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