Emission Reduction in MSW Management Using Composting

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EXECUTIVE SUMMARY

Eighteen percent of global anthropogenic methane emission is contributed by waste sector. Today, landfilling is the most common municipal solid waste (MSW) management technology. Due to the worsening global warming, MSW management is switching to more environmental friendly options such as energy recovery from landfill gas and composting.

This paper presents an estimation of emissions reduction from MSW management using composting compared to landfilling. MSW samples were taken from residential and commercial areas in Selayang and Rawang. The samples were then sorted into categories by material types. 'Baseline' is the scenario where the collected MSW was originally disposed off at the Bukit Tagar Sanitary Landfill. In order to prevent greenhouse gas (GHG) released into the atmosphere, a composting plant is proposed as an alternative to convert the organic materials into compost, which is the 'project activity'. Emissions from baseline and project activity were calculated and compared based on methodology ASM III-F under Clean Development Mechanism (CDM), United Nation Framework Convention on Climate Change (UNFCCC). Differences in the emissions between baseline and project activity is taken as the emission reduction. Emissions from baseline and project activity will be 8,058.97 tCO_2e and 132.18 tCO_2e (for 10 years), respectively. Composting as an alternative will generate an emission reduction of 7,926.79 tCO_2e, equivalent to 98% of methane being prevented.

INTRODUCTION

In 2009, Malaysia generated 30,000 tonnes of MSW daily (or an average of 1.3kg/capita/day) (Agamuthu et al., 2009) compared to 18,000 tonnes in 2004 (Agamuthu et al., 2004). This increase was in response to accelerated urbanization, industrialization, rapid growth of population, increase in per-capita income and changes in the consumption pattern (Mohd Osman et al., 2009).

Currently, landfilling is the most common waste management method in Malaysia as 95% of total MSW generated are disposed off at the landfills (Fauziah & Agamuthu, 2009). There are 301 disposal sites in the country, where 260 are operating landfills and 41 closed (Fauziah, 2010). Waste reduction and waste separation are seldom practiced in the country as the recycling rate is relatively low, at only 5% (Agamuthu et al., 2004; Chenayah et al., 2007; Mohd Osman et al., 2009). Besides that, composting rate in Malaysia is relatively low too, at only 1% (Agamuthu et al., 2006).

Since landfilling is the main international waste management option, landfills are identified as the main source of GHG (Lou & Nair, 2009). More than 45% of the landfill gas (LFG) is methane (EPA, 2007). Under the Kyoto Protocol, Clean Development Mechanism (CDM) is one of the mechanisms designed to the Annex I countries (industrialized and developed countries) to reduce carbon equivalent emissions of GHG by 5.2% of their 1990 levels (Seema & Anju, 2010).

This study compares GHG emissions from landfilling and composting. GHG emissions at landfill are due to anaerobic degradation of MSW, while throughout the whole composting process, GHG emissions are caused by the transportation of MSW and compost for sale, machines involved in the process and methane emissions during anaerobic composting process. The objective of this paper is to estimate how much GHG emissions can be reduced by converting organic fraction MSW into compost instead of disposed off at landfill by comparing respective GHG emissions from landfilling and composting.

EXPERIMENTAL METHODS AND MATERIAL

Data collection

MSW samples were taken from Rawang and Selayang by using garbage trucks. Approximately 2.5 tonnes to 6.0 tonnes of MSW were collected daily. Each truck was unloaded and divided into eight (8) portions. Two (2) portions were selected randomly for sampling. The waste was separated manually base on the waste categories stated in the CDM methodology under UNFCCC, called AMS III-F: Avoidance of methane emissions through controlled biological treatment of biomass (Version 08, Scope 13) (thereafter known as AMS III-F) as below:

i. Wood and wood products
ii. Pulp, paper and cardboard (other than sludge)
iii. Food, food waste, beverages and tobacco (other than sludge)
iv. Textiles
v. Garden, yard and park waste, and
vi. Inerts (such as glass, plastic, metal and rubber)

Baseline emissions

The baseline emissions from the landfill, BE_y were determined using the following Equation (1) based on paragraph 17 of AMS III-F:

$$BE_y = BE_{CH4,SWDS,y} - (MD_{y,reg} * GWP_{CH4}) + (MEP_{y,ww} * GWP_{CH4}) + BE_{CH4,manure,y} \quad (1)$$

Where:

$BE_{CH4,SWDS,y}$ Yearly methane generation potential of the solid waste composted or anaerobically digested by the project activity during the years *x* from the beginning of the project activity (x = 1) up to the year *y* estimated as per latest version of the “tool to determine methane emissions avoided from disposal of waste at a solid waste disposal site” (tCO_2e)

$MD_{y,reg}$ Amount of methane that would have to be captured and combusted in the year *y* to comply with the prevailing regulations (tonne)

$MEP_{y,ww}$ Methane emission potential in the year *y* of the wastewater co-composted. The value of this term is zero if co-composting of wastewater is not included in the project activity (tonne)

$BE_{CH4,manure,y}$ Where applicable, baseline emissions from manure composted by the project activities, as per the procedures of AMS-III.D

GWP_{CH4} Global Warming Potential for methane (value 21 is used)

$BE_{CH4,SWDS,y}$ is calculated based on multi-phase model in the “Tool to determine methane emissions avoided from disposal of waste at a solid waste disposal site (Version 05)” using the following Equantion (2):

$$BE_{CH4,SWDS,y} = \varphi * (1\text{-}f) * GWP_{CH4} * (1\text{-}OX) * 16/12 * F * DOC_f * MCF * \sum_{x=1}^{y} \sum_{j} W_{j,x} * DOC_j * e^{-k_j * (y-x)} * (1-e^{-k_j}) \quad (2)$$

Where:

Φ	Model correction factor to account for model uncertainties
f	Fraction of methane captured at the solid waste disposal site (SWDS) and flared, combusted or used in another manner
GWP_{CH4}	Global Warming Potential (GWP) of methane, valid for the relevant commitment period (value 21 is used)
OX	Oxidation factor (reflecting the amount of methane from SWDS that is oxidized in the soil or other material covering the waste)
16/12	Stoichiometric ratio of carbon to methane
F	Fraction of methane at the SWDS gas (volume fraction)
DOC_f	Fraction of degradable organic carbon (DOC) that can decompose
MCF	Methane correction factor
$W_{j,x}$	Amount of organic waste type j prevented from disposal in the SWDS in the year *x* (tonnes)
DOC_j	Fraction of degradable organic carbon (by weight) in the waste type j
k_j	Decay rate for the waste type j
j	Waste type category (index)
x	Year during the crediting period: x runs from the first year of the first crediting period (x=1) to the year y for which avoided emissions are calculated(x=y)
y	Year for which methane emissions are calculated

Project emissions

The project emissions from composting activities, PE_y were determined by using the Equation (3) based on paragraph 20 of AMS III-F:

$$PE_y = PE_{y,\ transp} + PE_{power} + PE_{y,\ phy\ leakage} + PE_{y,\ comp} + PE_{y,\ runoff} + PE_{y,\ res\ waste} \quad (3)$$

Where:

$PE_{y,transp}$ Emissions from incremental of transport in the year *y* (tCO_2e)

$PE_{y,power}$	Emissions from electricity or fossil fuel consumption in the year *y* (tCO_2e)
$PE_{y,phy\ leage}$	In case of anaerobic digestion: methane emissions from physical leakage of the anaerobic digester in the year *y* (tCO_2e)
$PE_{y,comp}$	In case of composting: methane emissions during composting process in the year *y* (tCO_2e)
$PE_{y,runoff}$	In case of composting: methane emissions from runoff in the year *y* (tCO_2e)
$PE_{y,res\ waste}$	In the case of residual waste/ slurry/ products are subjected to anaerobic storage or disposed in a landfill: methane emissions from the anaerobic decay of the residual waste/ products (tCO_2e)

$$PE_{y,transp} = (Q_y / CT_y) * DAF_w * EF_{CO2} + (Q_{y,treatment,i} / CT_{y,treatment,i}) * DAF_{treatment,i} * EF_{CO2} \quad (4)$$

Where:

Q_y	Quantity of waste composted in the year *y* (tonnes)
CT_y	Average truck capacity for waste transportation (tonnes/truck)
DAF_w	Average incremental distance for waste transportation (km/truck)
EF_{CO2}	CO_2 emission factor from fuel use due to transportation ($kgCO_2$/km, IPCC default values or local values may be used)
i	Type of compost
$Q_{y,\ treatment,i}$	Quantity of compost *i* produced in the year *y* (tonnes)
$CT_{y,\ treatment,i}$	Average truck capacity for compost *i* transportation (tonnes/truck)
$DAF_{treatment,i}$	Average distance for compost *i* transportation (km/truck)

$$PE_{y,power} = PE_{y,\ diesel\ on\text{-}site} + PE_{y,electricity} \quad (5)$$

Where:

$PE_{y,diesel\ on\text{-}site}$	Emissions through fossil fuel consumption on-site in the year *y* (tCO_2e)
$PE_{y,electricity}$	Emissions through electricity consumption in the year *y* (tCO_2e)

Electricity consumption is very minimum and its emisisons are insignificant. Hence, $PE_{y,electricity} = 0$

Physical leakage happens in case of anaerobic digestion. However, this project activity is solely involves a composting plant. Hence, $PE_{y,phy\ leage} = 0$.

$$PE_{y,comp} = Q_y * EF_{composting} * GWP_{CH4} \quad (6)$$

Where:

$EF_{composting}$	Emission factor for composting of waste (t CH_4/tonne waste treated). Emission factors can be based on facility/site-specific measurements,country specific values or IPCC default values (Table 4.1, Chapter 4, Volume 5, 2006 IPCC Guidelines for National Greenhouse Gas Inventories). IPCC default values are 10g CH_4/kg waste treated on a dry weight basis and 4g CH_4/kg waste treated on a wet weight basis.

The composting plant is roofed and with concrete flooring. Thus the collected runoff is 100% from the composting process and it will be recycled onto the windrows. Hence, $PE_{y,runoff} = 0$. After production, the compost will be transported for distribution at the market. Hence, $PE_{y,\ res\ waste} = 0$

Emission reduction

Emission reduction were determined by using the Equation (7):

$$ER_y = BE_y – (PE_y + LE_y) \quad (7)$$

Where:

LE_y Leakage emissions in the year *y* (tCO_2e)

Leakages happen when project equipment is transferred from another activity or if the existing equipment is transferred to another activity project. The project activity does not involve both of the aspects. Hence leakage = 0. Equation (8) becomes:

$$ER_y = BE_y - PE_y$$

RESULTS AND DISCUSSION

Baseline emissions

As shown in Table 1, food, food waste, beverages and tobacco (other than sludge) took up almost half of the total compositon (48.01%), followed by inerts such as rubber, metal and plastic (27.32%) and garden, yard and park waste (8.22%). However, inerts are not accounted for emissions in this case as they are inorganic materials.

Table 1. MSW compositions

Waste category	% (wet weight)
Wood and wood products	5.84
Pulp, paper and cardboard (other than sludge)	7.69
Food, food waste, beverages and tobacco (other than sludge)	48.01
Textiles	2.92
Garden, yard and park waste	8.22
Inerts	27.32
Total	100.00

Table 2 shows emissions of each waste category in 10 years. Emissions from food, food waste, beverages and tobacco (other than sludge) will be far ahead other types of waste category, 5,516.90 tCO_2e. Second contributor is pulp, paper and cardboard (other than sludge) (966.27 tCO_2e) followed by garden, yard and park waste (916.14 tCO_2e) at the third place. Baseline emissions will increase year by year and reach a total baseline emissions of 8,058.97 tCO_2e.

Project emissions

Project emissions are the sum of emissions from transport, diesel on-site consumption and anaerobic condition during composting process. Project emissions will be 132.18 tCO_2e (Table 3).

Table 2. Emissions of each waste category

Year	Emissions of each waste category (tCO2e)					Total
	A	B	C	D	E	
2010	6.92	16.89	192.12	3.86	20.73	240.52
2011	15.44	36.98	356.64	8.46	43.04	460.56
2012	23.83	56.13	469.34	12.83	62.27	624.4
2013	32.10	74.35	545.95	16.97	78.80	748.17
2014	40.25	91.77	598.06	20.95	93.05	844.08
2015	48.28	108.15	635.26	24.67	105.29	921.65
2016	56.18	123.91	659.65	28.26	115.84	983.84
2017	63.96	138.78	676.23	31.63	124.92	1,035.52
2018	71.61	152.94	687.51	36.39	132.73	1,081.18
2019	79.16	166.37	696.14	37.91	139.47	1,119.05
Total	437.73	966.27	5,516.90	221.93	916.14	8,058.97

Note) A: Wood and wood products, B: Pulp, paper and cardboard (other than sludge), C: Food, food waste, beverages, tobacco (other than sludge), D: Textiles, E: Garden, yard and park waste

Table 3. Project emissions

Year	$PE_{y, transp}$ (tCO_2e)	$PE_{y,diesel,on\text{-}site}$ (tCO_2e)	$PE_{y,comp}$ (tCO_2e)	Project emissions (tCO_2e)
2010	8.87	1.27	1.66×10^{-4}	10.14
2011	11.34	1.27	2.12×10^{-4}	12.61
2012	11.57	1.27	2.16×10^{-4}	12.84
2013	11.80	1.27	2.20×10^{-4}	13.07
2014	12.03	1.27	2.25×10^{-4}	13.30
2015	12.28	1.27	2.29×10^{-4}	13.55
2016	12.52	1.27	2.34×10^{-4}	13.79
2017	12.77	1.27	2.38×10^{-4}	14.04
2018	13.02	1.27	2.43×10^{-4}	14.29
2019	13.28	1.27	2.48×10^{-4}	14.55
Total	119.48	12.70	2.23×10^{-3}	132.18

Emission reduction

Emission reduction is the emissions difference between baseline and project activity. By converting organic waste into compost, 7,926.79 tCO_2e emissions will be able to be prevented from being emitted to the atmosphere (Table 4).

CONCLUSION

From this study, composting proved to be able to reduce emissions generated from MSW. Baseline emissions generated from MSW disposed off at Bukit Tagar Sanitary Landfill will be 8,058.97 tCO_2e in 10 years. By converting the MSW into compost, methane emissions being released into the atmosphere can be reduced to 132.18 tCO_2e, generating emission reduction of 7,926.79 tCO_2e.

Table 4. Emission reduction

Year	Estimation of baseline emissions (tCO_2e)	Estimation of project emissions (tCO_2e)	Estimation of leakage (tCO_2e)	Estimation of emission reduction (tCO_2e)
2010	240.52	10.14	0	230.38
2011	460.56	12.61	0	447.95
2012	624.40	12.84	0	611.56
2013	748.17	13.07	0	735.10
2014	844.08	13.30	0	830.78
2015	921.65	13.55	0	908.10
2016	983.84	13.79	0	970.05
2017	1,035.52	14.04	0	1,021.48
2018	1,081.18	14.29	0	1,066.89
2019	1,119.05	14.55	0	1,104.50
Total	8,058.97	132.18	0	7,926.79

ACKNOWLEDGEMENT

Authors would like to express their sincere gratitude to the operator of Bukit Tagar Sanitary Landfill (KUB-Berjaya Enviro Sdn Bhd) for providing information about the landfill. Special thanks dedicated to University of Malaya for allocating PPP research grant to the authors.

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