Assessment of GHG Emission Reduction Potential from Source-separated Organic Waste (SOW) Management: Case Study in a Higher Educational Institution in Malaysia

(Penilaian Potensi Pengurangan Pelepasan GHG daripada Pengurusan Sumber Sisa Organik Dipisahkan (SOW): Kajian Kes di Institusi Pendidikan Tinggi di Malaysia)

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ABSTRACT

In Malaysia, the greenhouse gases (GHGs) emissions reduction via composting of source-separated organic waste (SOW) in municipal solid waste (MSW) has not been assessed. Assessment of GHG emissions reduction via composting of SOW is important as environmental impacts from waste management are waste-specific and local-specific. The study presents the case study for potential carbon reduction via composting of SOW in University of Malaya (UM). In this study, a series of calculations were used to evaluate the GHG emission of different SOW management scenarios. The calculations based on IPCC calculation methods (AM0025) include GHGs emissions from landfilling, fuel consumption in transportation and SOW composting activity. The methods were applied to assess the GHG emissions from five alternative SOW management scenarios in UM. From the baseline scenario (S0), a total of 1,636.18 tCO_{2e} *was generated. In conjunction with target of 22% recycling rate, as shown in S1, 14% reduction in potential GHG emission can be achieved. The carbon reduction can be further enhanced by increasing the SOW composting capacity. The net GHG emission for S1, S2, S3 and S4 were 1,399.52, 1,161.29, 857.70 and 1,060.48* tCO_{2e}*, respectively. In general, waste diversion for composting proved a significant net GHG emission reduction as shown in S3 (47%), S4 (35%) and S2 (29%). Despite the emission due to direct on-site activity, the significant reduction in methane generation at landfill has reduced the net GHG emission. The emission source of each scenario was studied and analysed.*

Keywords: Composting; GHG; kitchen waste; SOW; university; waste management; yard waste

ABSTRAK

Di Malaysia, pengurangan pelepasan gas rumah hijau (GHG) melalui pengkomposan punca dipisahkan sumber organik (SOW) dalam sisa pepejal perbandaran (MSW) belum pernah dinilai. Penilaian pengurangan pelepasan GHG melalui kompos daripada SOW adalah penting kerana kesannya terhadap alam sekitar disebabkan daripada pengurusan sisa buangan adalah khusus-sisa buangan dan khusus-tempatan. Kertas ini membentangkan kajian kes bagi potensi pengurangan karbon melalui aktiviti pengkomposan SOW di Universiti Malaya (UM). Dalam kajian ini, satu siri pengiraan digunakan untuk menilai pelepasan GHG melalui pengurusan SOW berbeza. Pengiraan berdasarkan kaedah pengiraan IPCC (AM0025) adalah termasuk pelepasan GHG dari tapak pelupusan, penggunaan bahan api kenderaan dan aktiviti pengkomposan SOW. Kaedah ini digunakan untuk menilai pelepasan GHG daripada lima alternatif senario pengurusan SOW di UM. Daripada senario asas (S0), sejumlah 1636.18 tCO_{2e} *telah dijana. Selaras dengan sasaran kadar kitar semula 22%, seperti yang ditunjukkan dalam S1, 14% potensi pengurangan dalam pelepasan GHG boleh dicapai. Pengurangan karbon boleh dipertingkatkan lagi dengan meningkatkan kapasiti pengkomposan SOW. Pelepasan bersih GHG untuk S1, S2, S3 dan S4, masing-masing adalah 1,399.52, 1,161.29, 857.70 dan 1,060.48* tCO_{2e}*. Secara umum, sisa lencongan untuk pengkomposan terbukti bersih GHG mengurangkan pelepasan ketara secara signifikan seperti ditunjukkan dalam S3 (47%), S4 (35%) dan S2 (29%). Walaupun pelepasan adalah secara langsung disebabkan aktiviti di lokasi, penurunan ketara dalam penghasilan metana di tapak pelupusan sampah telah mengurangkan pelepasan bersih GHG. Sumber pelepasan setiap senario dikaji dan dianalisis.*

Kata kunci: GHG; pengkomposan; pengurusan sisa; sisa dapur; sisa lapangan; SOW; universiti

INTRODUCTION

Waste sector which comprises of municipal solid waste (MSW) is deemed to be one of the major contributors of greenhouse gas (GHG) emission. Rapid urbanization and increase in population have caused the increment of GHG emission from waste disposal (Ngoc & Schnitzer 2009). In Peninsular Malaysia, the solid waste generated has increased from 16,200 tons per day in year 2001 to 19100 tons per day in year 2005 (Tarmudi et al. 2012). The waste generation is foreseen to reach 31000 tons of waste generation per day by year 2020 (Manaf et al. 2009). The waste disposal in Malaysia has contributed to the national GHG emission of 18.64% and 11.83% in year 1994 and 2000, respectively (Chua et al. 2011). The significance volume of GHG emitted necessitates the need to control the GHG emission by waste reduction via alternative management strategy.

The amount of waste discarded and fraction of degradable organic waste would give impact on the generation of GHG. Studies by several researchers have found out that composting is a favourable mitigation option for GHG emissions in waste sector (Rogger et al. 2011). Composting would help in achieving carbon neutral condition while anaerobic digestion with energy production could achieve carbon negative condition, particularly in developing countries (Barton et al. 2008). In Africa, studies have shown that waste separation at source can reduce the carbon emission generated from municipal waste comprising averagely 56% of organic content (Couth & Trois 2010). Couth and Trois (2010) also discussed the strategies that have been carried out to promote emission reduction and mentioned that composting should have more carbon emission reductions and would generate more Clean Development Mechanism (CDM) income than landfill gas combustion with energy recovery. In China, biological recycling such as composting and anaerobic digestion was the most preferred technique applied to maximizing the material and energy recovery from organic waste (Zhang & Matsuto 2011). Furthermore, biological recycling of organic waste is widely applied due to their environmentally friendly techniques (Cadena et al. 2009).

In Malaysia, however, the GHG emissions reduction via composting of source separated organic waste (SOW) has not been assessed. There was a pilot project to turn SOW in municipal solid waste (MSW) into compost in Putrajaya, Malaysia. It was proven that recyling of SOW can directly reduce the amount of waste and lengthen the lifespan of landfill, but the potential of GHG emissions reduction was not accounted. The Ministry of Housing and Local Government (MHLG) has set the target to increase recycled waste from 5 to 20% by 2020. By increasing the recycling rate to 22% the GHG emission from waste sector can be reduced to 25.5% in year 2020 (Chua et al. 2011). However, the specific GHG emissions reduction from SOW recycling was not considered. Hence, assessment of GHG emissions reduction via composting of SOW is important as environmental impacts from waste management are waste-specific and local-specific.

Objective

The main objective of the present study was to investigate the carbon emission of MSW management in University of Malaya (UM). The hot spots for GHG emissions from the SOW management in the context of UM were identified. The study further evaluates the GHGs emissions reduction potential from diversion of SOW in MSW for compost production via aerobic fermentation process within the campus. The SOW refers to source-separated kitchen waste collected from canteens and source-separated yard waste collected by the UM landscape management team.

Study Area

This paper presented a real case study of MSW management in UM with high number of staff and students in the region and it is located in Kuala Lumpur, Malaysia. With student community over 32018, including over 3571 international students from over 100 different countries, the university has a global network alumni spanning of 78 countries (UM, 2011). It generated large volumes of waste from its residences, catering areas, laboratories, workshops and public area which has caused the management to spend over RM240000 per year on waste disposal. The MSW was collected on a daily basis and was disposed at a waste collection centre located inside the campus. The wastes were then transported out from campus and disposed at the nearest landfill.

Since September 2010, the SOW composting site has been in operation, located next to waste collection centre within UM. Before composting, the SOW were screened and shredded. Takakura composting method was applied where the kitchen waste was mixed with seed compost which was rich in effective microorganism (EM). The compost piles were turned everyday by the site operator to allow aerobic reaction to happen throughout 1-2 months before it became mature and stored. After that, the compost is ready to be used as soil conditioner.

METHODS

SYSTEM BOUNDARY AND EMISSION SOURCES OF THE STUDY

The system of the study started with the temporary storage of the MSW in UM and followed by SOW diversion process, waste treatment alternative (on-site composting), waste transportation and landfilling of waste. The scope of the study was clearly shown in Figure 1. Components outside the dash dotted lines were not in the boundaries of this study although they were recognized to have some impacts on the environment. The total number of trips from UM (with full waste cargo) made to disposal sites in year 2012 were summarized in Table 1. Waste generation in UM shows variation by month. MSW generation was relative higher during academic months (September-December and February-Jun). A total of 825 collection trips were recorded for MSW in 2012. The transportation factor of 1 ton of yard waste/trip and 1.5 ton of MSW/trip, respectively, were assumed for estimated waste generation in UM. The estimated weight of kitchen waste was 219 ton, taking into consideration that 40% of total MSW collected which was made up of kitchen waste. The functional unit selected for the study was the management of 1,007.5 ton MSW, comprising of 679 ton SOW (total of yard waste and

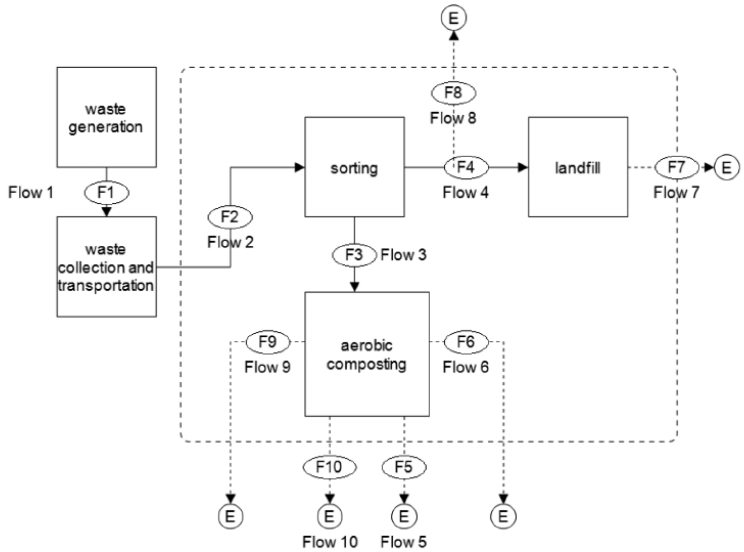

FIGURE 1. System boundaries of composting and landfilling project

TABLE 1. Number of UM waste collection by trip for disposal by external waste company in 2012

Month	Yard waste	Municipal waste	Total
January	31	22	53
February	32	26	58
March	31	31	62
April	36	24	60
May	42	20	62
Jun	38	35	73
July	63	20	83
August	41	9	50
September	51	48	99
October	36	61	97
November	20	25	45
December	39	44	83
Total by trip	460	365	825
Total by weight (ton)	460	547.5	1007.5

Source: (UM 2012)

kitchen waste) where the remaining was the mixed residual waste (UM 2012).

The boundary in this present case study was the site of the project activity where the SOW was recovered in UM and composted on-site. The project boundary included the facilities for composting, on-site electricity consumption, on-site fuel consumption, fuel consumption of waste transportation from UM to landfill, direct emission from composting process and direct emission from landfill. The emissions included in the study are summarized in Table 2.

The facilities for waste collection and transportation to the composting site were excluded from the study. The application of compost as soil conditioner for landscaping was excluded as well due to its insignificant amount in association to the replacement of chemical fertilizer. The summary of the methodology flow is shown in Figure 2.

SCENARIO SET-UP

It was assessed based on four scenario cases: S0 as the baseline scenario where all wastes were disposed at landfill; S1 where 22% of total waste generated (130 t/y kitchen waste and 130 t/y yard waste) was sorted and composted on-site; S2 where 35% of total waste (204 t/y kitchen waste and 204 t/y yard waste) was collected and composted on-

TABLE 2. Emissions included in the case study

Carbon emission (tCO_{2e})	Flow
Landfilling	Flow 7
Transportation	Flow 8
Composting site electricity consumption	Flow 5
Composting site fuel consumption	Flow 6
N_2O emission from composting	Flow 9
CH_4 emission from composting	Flow 10

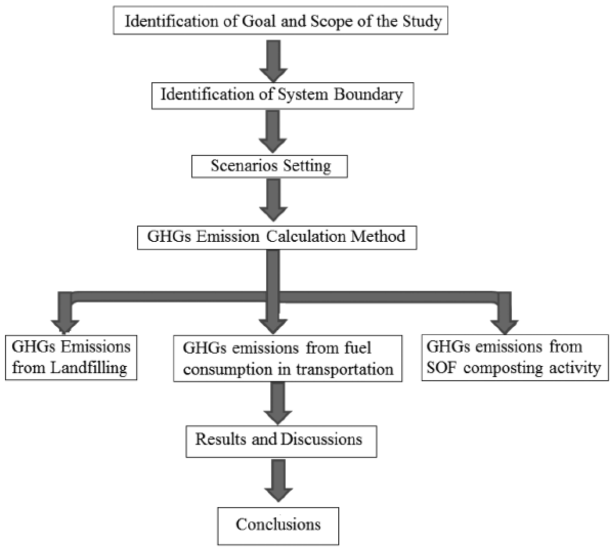

FIGURE 2. The flow of methods

site; S3 where 55% of total waste (204 t/y kitchen waste and 460 t/y yard waste) were collected and composted on-site and S4 where a total of 460 t/y of yard waste was collected and composted on-site while the rest was disposed of in landfill without energy recovery.

Scenarios were proposed in line with the national target to achieve recycling rate of 22% of total waste generated (as shown in S1). The diversion of SOW from MSW was expended gradually through S2 (35%) and S3 (55%). S4 considers the possible immediate diversion of yard waste alone due to its current availability of separated collection in UM campus. The summary of the scenario for alternative SOW management is shown in Table 3.

CARBON EMISSION CALCULATION METHOD

The methods used to analyze the GHG emission for this case study in UM are in accordance to CDM methodology AM0025 (UNFCCC 2008). The emission reduction was calculated from the deduction of baseline emissions and project emissions.

METHANE EMISSION FROM LANDFILL

A simple mass balance approach (default IPCC method) was used to estimate the total generation of methane gas from waste disposed in landfill. This method is suggested due to the intention to compare maximum GHG generation potential from different scenarios of kitchen waste and yard waste management. It does not reflect the generation of GHG over time, which is beyond the intention of the present paper. IPCC default method is based on (1). The method assumes that all the potential CH_4 emissions are released during the same year the waste is disposed of. The method is simple and emission calculations require only input of a limited set of parameters.

$$Me,y = \left(MSWt * MCF * DOC * DOCf * F * \left(\tfrac{16}{12}\right) - R\right) * (1 - OX), \quad (1)$$

where Me_y is the methane emission in year "y" (t/year); MSW_t is the total MSW disposed in year "y" (t/year); MCF is the methane correction factor (fraction); DOC is the

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