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Report

CRADLE-TO-GATE LIFE CYCLE INVENTORY ANALYSIS FOR BIO-MATE COMPOSTING SYSTEM

Prepared for:

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1.0 Introduction

Solid waste management system is considered as one of the main environment related issues in Malaysia currently. The amount of waste generated continues to increase annually due to the increasing population and development, and at the same time only ~5% of the waste is being recycled. Improper solid waste management contributes to climate changes problem during decomposing of wastes that produces methane gas which is one of the green house gas (GHG). The effectiveness of solid waste management can be identifying using Life Cycle Assessment (LCA) regarding to its environmental performance.

Life Cycle Assessment, LCA has been introduced as a method to evaluate the environmental burdens associated with a product, process or activity which includes the identification of energy, materials and substances used and emissions and wastes released to the environment, over its whole life cycle. The life cycle represents all relevant interventions and measures of resource extraction, transports, energy supply, production, use and end-of-life of the product, process or activity under study.

One of the key impact categories considered in LCA is climate change, typically using the IPCC (Intergovernmental Panel on Climate Change) characterization factors for carbon dioxide equivalents ($CO_{2eqv.}$). Hence, a carbon footprint (CF) is a life cycle inventory analysis confined to emissions that have an effect on climate change. A carbon footprint is usually expressed as kilograms of $CO_{2eqv.}$per functional unit of product system.

SIRIM has been approached by Promise Earth (M) Sdn. Bhd. to develop a carbon foot print for their product that is ***Bio-Mate Composting System***. The system is unique in its ability to convert mixture of high moisture organic waste generated from food sources into valuable product which considered as compost

2.0 Bio-Mate Composting System

The **Bio-Mate Composting System** is a high-speed on-site organic waste composting technology where mixture of organic waste such as, fish, meat and vegetables are mixed in a composting compartment and processed continuously for several days to get compost as final product.

After the organic waste is separated with unwanted materials and rinsed with water to remove or reduce oil content, it is mixed with saw dust, water and enzyme in the composting compartment. Than the system is rotated and milled the mixture on a regular basis. At the same time, composting process occurs and accelerated by existing of the enzyme. The composting process is aerated by passing fresh air from the environment using a blower. Besides supplying excess oxygen to the process, passage of fresh air will remove excess heat generated in the composting compartment during the process. After several days, the compost is collected and ready for application as a mineral fertilizer replacement.

3.0 Project Brief

Promise Earth (M) Sdn. Bhd. is a biotechnology company involved in treatment of organic waste especially food waste through fermentation and composting process. One of the company's products is Bio-Mate Composting System.

The objective of this study is to identify the environmental load of Bio-Mate composting system in term of Green house Gas (GHG) profile and to compare to other system for the management of commercial organic waste in Malaysia. To achieve this objective, Life Cycle Assessment (LCA) tools has been used. The study was based on Bio-Mate Composting System model BM750S with maximum capacity 750kg/week that was installed at Berjaya Hills Resort in Bukit Tinggi, Pahang. The calculation was based on foreground data provided by the company together with data from analysis of GHG emission conducted by SIRIM personnel.

4.0 Methodology

LCA is an analytical and quantitative method used to evaluate the environmental impacts arising from the production, the use and the end of life phases of a product/service. According to ISO 14041. Life Cycle Inventory (LCI), the second phase of LCA is concerned with "the collection of the data necessary to meet the goals of the defined study" and with the associated "data collection and calculation procedures" and is essentially an input/output data with the respect to the system being studied. The LCI is an iterative process involving numerous data inputs and outputs from the product life cycle, all of which have their own life cycle that must be included in the assessment.

The data was collected from three different sources; primary, secondary and other resources. Primary data, being the most reliable and accurate data obtained from the company databases include information from the production sites associated with the unit processes within system boundaries as described in Figure 1. The direct measurements and calculations based on real processes and equipment available in that factory. Secondary data are data gathered from published sources of other LCI studies. Other sources of data include journals, textbooks and reference materials.

The strategy of this study focus on evaluating environmental performance of Bio-Mate composting system and do comparison to other waste management techniques such as landfill. The impact category of climate change based on the characterization factors for CO_2 equivalents is considered as indicator in this study. It is expressed as kilograms of CO_2 equivalents per functional unit of product system.

5.0 Goal and Scope of the Study

5.1 Goal of Study

Effective management of commercially generated organic waste presents an opportunity for avoided global warming potential, renewable energy production and renewable agrochemical production. PROMISE EARTH (M) Sdn. Bhd. requires an assessment and decision support tool to know position of their product (Bio-Mate Composting System) compared to other technique of municipal waste management such as landfill in term of environmental performance.

5.2 Scope of Study

The objective of study will establish the followings;

- The GHG profile for Bio-Mate composting system model BM750S with maximum capacity 750kg
- The comparison of GHG profile of Bio-Mate composting system to land fill to treats one tonne of waste
- The advantage of Bio-Mate composting system compared to land fill

5.2.1 Function of the Product

Bio-Mate composting system is intended for use to treats organic waste into organic compost.

5.2.2 Functional Units

Green house gas (GHG) profile is presented as per unit tonne of organic waste treated by the system (kg CO_2/ tonne organic waste).

5.2.3 Product System

“Cradle-to-gate” for Bio-Mate composting system covering all unit process from initial processing of organic waste, composting process and transportation of materials.

5.2.4 Bio-Mate System Boundary Description

The system boundary for this study has been defined within the context of the Bio-Mate composting system model BM750S, and is shown in Figure 1. The system boundary includes;

- Emissions associated with initial processing of the organic waste.

- Emissions associated with fuel usage for transportation of the feedstock materials to the composting system.
- Emissions associated with the electricity used by a facility during composting process.
- Emissions associated with fuel usage for transportation and application of end-product to the application site.

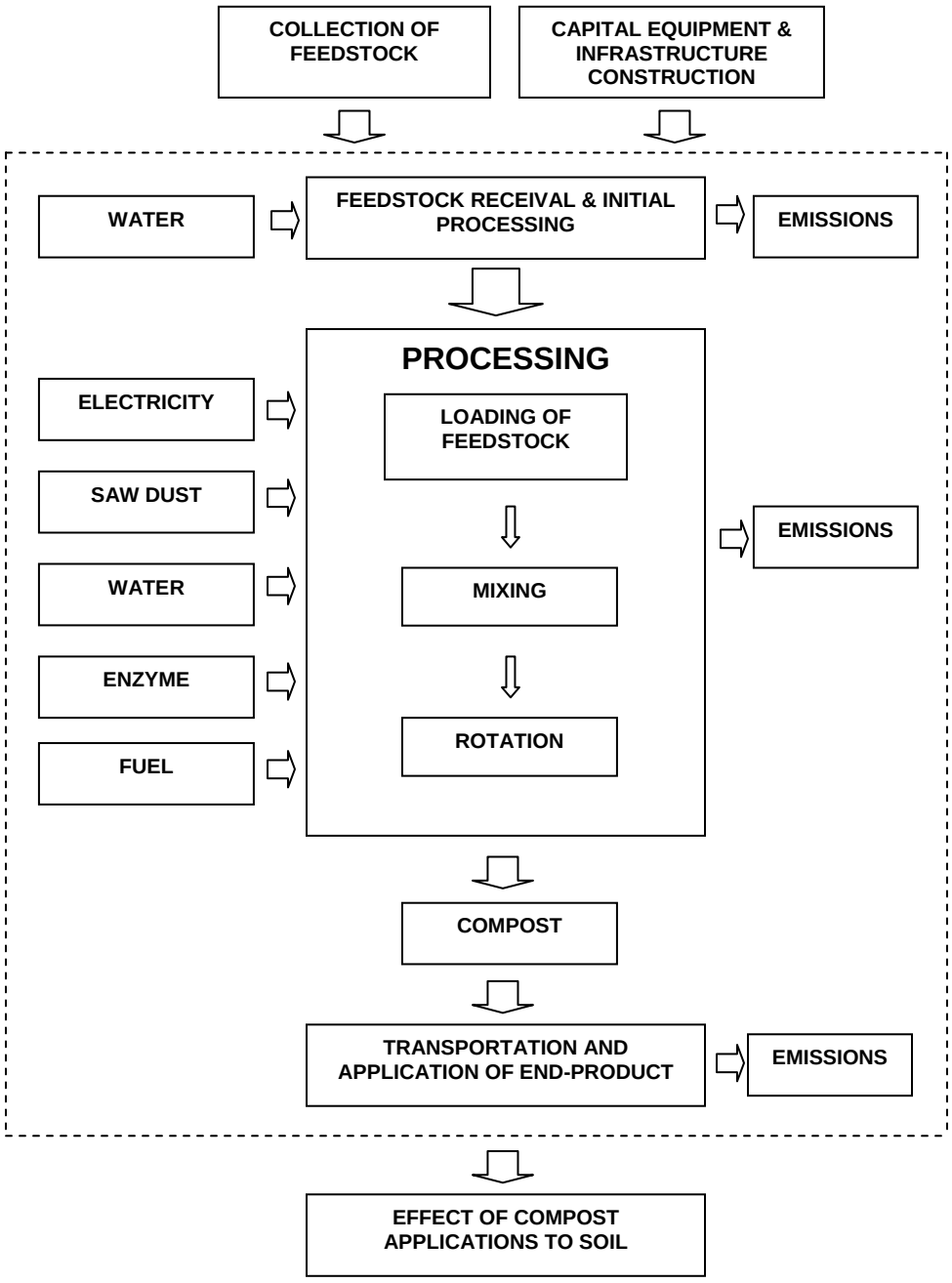

Figure 1: Schematic diagram of system boundary for composting of organic waste using Bio-Mate composting unit. Dotted line indicates system boundary used in current study.

In defining this system boundary, the following elements were excluded from the study;

- The GHG emission associated with the collection of feedstock materials (organic waste) is not considered in this study.
- The GHG emission from the construction of Bio-Mate composting equipment is not considered, as relevant data is currently not available.

5.2.4.1 Collection of the Feedstock Materials (Organic Waste).

Although collection of the feedstock materials (organic waste) is recognized as one of the important aspect in any composting operation system, it is excluded in this study. Normally the Bio-Mate composting system is installed nearby the food court premises and the feed stock which is organic waste is supplied by the food court operators. In this single collection system, the organic waste is collected and dumped into a container before sends to the Bio-Mate composting system using manual mode of transportation. The GHG calculation should be included at a later stage if there are varieties of collection system whereby transportation of the feedstock materials involves fuel usage.

5.2.4.2 Capital Equipment and Infrastructure.

The GHG emissions associated with the construction of Bio-Mate composting system and infrastructure were not included in this study because of insufficient relevant life cycle inventory data. If these components were included, the total emissions from construction of the Bio-Mate composting system together with its infrastructure shall be divided by the expected life span of the system.

5.2.5 Allocation Procedures

According to ISO 14040:2006 (E), allocation is defined as a procedure of partitioning the input or output flows of a process to the product system under study.

Compost is considered the only main product harvested from the Bio-Mate system.

5.2.6 Impact Categories

Global warming potential due to Greenhouse Gas (GHG) emissions is considered in this study.

5.2.7 Data Requirement

- Site data as foreground data for raw materials, auxiliary materials and utilities consumption

- Emissions and conversion factor from literature or Malaysia Life Cycle Inventory Database (MYLCID) and datasets from commercial software.
- Published data for landfill of municipal and hazardous waste management in Malaysia.
- References are provided for all data sources.

Component	Data description	Data source
Transportation of raw materials to composting site	Transport mode, quantity and distance	Promise Earth
	Fuel consumption	MYLCID
Bio-Mate composting process	Energy and raw materials needed for composting process	Promise Earth
Transportation of compost/ fertilizer to applicant site	Transport mode, quantity and distance	Promise Earth
	Fuel consumption	MYLCID
Background data		
Public treated water	Treatment of water supply	MYLCID
Electricity	Electricity generation	MYLCID
Diesel	Diesel production and combustion	MYLCID
Landfill	LCI for municipal and hazardous waste management in Malaysia	MYLCID

Table 1: Data sources and component involve for GHG profile.

5.2.8 Assumptions and Limitations

The GHG profile associated with production of enzyme used in the processes of Bio-Mate composting system is not easily available in the public domains. Because of this reason and the small quantity of enzyme used during the process, the GHG data for the enzyme is not considered in calculation.

5.2.9 Data Management

The collection of Life Cycle Inventory (LCI) was based on questionnaire form provided by SIRIM Berhad.

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6.0 Results of LCI Analysis

6.1 Input and Output data

Carbon footprint (CFP) is calculation of carbon dioxide equivalent (CO_{2equi}) emission of product during the entire life cycle starting from raw materials extraction, transportation, manufacture, use and disposal of product. Since disposal stage was not included in this scope of study due to limitation of data availability, the impact category was reported as GHG (Green House Gas) emission instead of CFP.

There are three major sources of GHG in this study which is electricity, water and transportation. The calculation of GHG was based on one tonne of organic waste treated by the system. The detail GHG profile is shown in Table 2 below.

Component	**Unit**	**Quantity/ tonne organic waste**	**Kg CO_2 emission/ tonne organic waste**
Electricity	kWh	453.33	308.27
Water	m^3	0.16	0.034
Transportation	kg	1000	0.0026
Total GHG emission			**308.31**

Table 2: Composition of GHG emission from Bio-Mate Composting system.

Methane is considered as one of the major greenhouse gas contributor with 21 times more effective as a greenhouse gas than carbon dioxide. SIRIM has conducted analysis on carbon dioxide (CO_2) and methane (CH_4) emission from the Bio-mate composting system. The result shown that only small concentration of CO_2 (~0.2%) was released to the environment with no detection of methane. However this CO_2 gas was not included in the CFP calculation because it was considered as biogenic gas, which is produced by living organisms naturally, not by human activities. Methane gas was not produced during the operation of Bio-Mate Composting System because the system is aerobic process.

The electricity used by the Bio-Mate composting system is considered as the major source of GHG in this study. The electricity utilization was supplied from national grid transmission network. The GHG emission from the production of the electricity was determined from Malaysia Life Cycle Inventory Database (MY-LCID), which established as 0.68kg carbon dioxide equivalent per KWh electricity utilized.

The GHG emission for transportation includes emissions from the transportation of raw materials (saw dust) to the composting site and transportation of end-product (compost) to the application site. The emission estimation was based on vehicle type and distance travelled for certain quantity of materials. The GHG emissions from the production and combustion of diesel were estimated using Malaysia Life Cycle Inventory Database (MY-LCID). From the database, the emission factor for production of one tonne diesel is 299kg CO_2 and 3208kg CO_2 for the combustion.

6.2 Comparison to Landfill Process

Landfill is considered one of the most widely practiced method for disposal of Municipal Solid Waste (MSW) in Malaysia. Disposing of waste materials in a landfill must be managed properly with good planning and the facilities should be maintained during the operations, closure or post-closure period. During operation, the materials should be buried and covered with soil or clay daily and final covers should be applied when the landfill is permanently closed. The system boundary for the landfill in this comparison study is shown in Figure 2 below. This system boundary represents landfill with good management system in Malaysia which included transportation, energy utilization and material consumption.

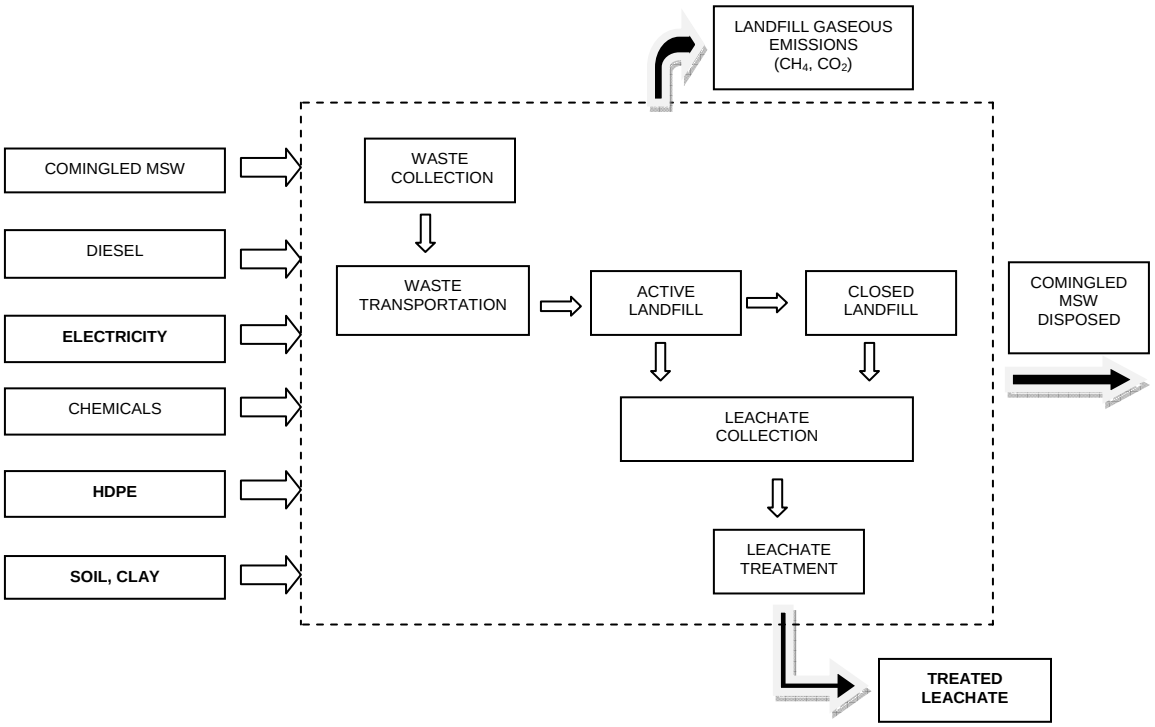

Figure 2: Schematic diagram of system boundary for composting of organic waste in sanitary landfill.

There are two main sources of GHG emission in the landfill which are;

1. Emission from processes or human activities associated with system or management of the landfill including transportation, energy utilization and materials consumption.
2. Emissions of the land fill gas (LFG) result from chemical reaction and microorganism's activity during degradation of waste materials. The rate of production depends on the composition of the solid waste, which in turns affected the population of the microorganisms.

The detail of the GHG emissions from the landfill is shown in Table 3 below.

Component	**Unit**	**GHG Emission**
CO_2 from process	Kg	13.5
CO_{2eq} from landfill gases (LFG)	kg	1200
Total GHG emissions	**kg**	**1213.5**

Table 3: GHG emitted from sanitary landfill.

In this comparison study, the landfill gases (LFG) was not collected and totally released to the atmosphere. The GHG emission for the LFG was calculated based on the CO_2 equivalent referring to methane production by microbial activities during composting process.

7.0 Advantages of Bio-Mate Composting System Compared To Landfill

Besides lower GHG profile, Bio-Mate composting system has other advantages compared to landfill which can be summarized as following;

- The operating of landfill requires the use of vehicles and compactors for collection and transportation of municipal solid waste (MSW) to the landfill site. The process requires proper planning, facilities and management of collection system. Whereas for the Bio-Mate Composting System, it can be installed at the area nearby to the food waste generator like food court or wet market. The food waste generated can be collected and processed immediately with minimum cost on transportation.
- The Bio-Mate Composting System is equipped with odor removal system to filter and remove unpleasant smell generated during the composting process. This technology provides better air quality compared to the landfill site.
- The Bio-Mate Composting System does not generate leachate during the operation. Leachate is considered as one of the main problem created in the landfill that will pollute our groundwater if not managing properly.
- No methane gas generated during composting process in Bio-Mate Composting System. Methane gas only created in anaerobic condition for microbial activities such as in the landfill condition. Methane gas is considered as one of the green house gases with 21 times more effective as a green house gas compared to carbon dioxide.
- Disposing and storage of solid waste in landfill requires a lot of land space and needs proper system and management for operating. Sometimes the land used for the landfill is suitable and more economic for other activities such as farming, residential building or recreation area. The Bio-Mate Composting System provides better solution into this problem because the system is compact and doesn't needs a lot of space for operating.
- Besides decomposing of the food waste, the compost that generated by the Bio-Mate Composting System can be recycled and used as fertilizer attributes to increase crops yields.

8.0 Conclusion

The study reveals that the GHG emission of the Bio-Mate composting system (308.27 kg CO_2/ t food waste) is lower compared to the landfill process (1213.5 kg CO_2/t solid waste). The comparison has been done based on 1 tonne of waste treated by the system. Besides lower GHG profile, Bio-Mate Composting System also has other advantages compared to the landfill that gives benefit in providing good environmental solution for food waste.

9.0 References

- 2006 Guidelines for National Greenhouse Gas Inventories, Intergovernmental Panel on Climate Change, UNEP.

- Malaysia Life Cycle Inventory database (MYLCID).

APPENDICES

APPENDIX 1: PHOTO OF BIO-MATE COMPOSTING SYSTEM

APPENDIX 2: PHOTO OF AIR SAMPLING APPARATUS