LCA in Asian/Pacific Regions

The Application of an Life Cycle Inventory (LCI) Model for Solid Waste Disposal Systems in Malaysia

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Abstract

This paper discusses the application of an LCI model for solid waste management systems in Malaysia. The model was used to analyze the environmental and economic impacts of municipal waste management systems in Malaysia. In the first part of the study, the LCI model was adapted to analyze waste management systems of four selected cities: Kuala Lumpur and Penang to represent urban areas; Seremban to represent moderately urban areas and Muar to represent rural areas. The results have shown that Kuala Lumpur and Penang had greater Global Warming Potential (GWP) and the costs spent on the solid waste management were also higher as compared to that in suburban areas. In the second part of the study, a detailed evaluation was carried out by analyzing the implication of introducing incineration and composting into the solid waste management system, and the results were compared with the current system, i.e. 100 % landfilled. The relative GWP was lower for incineration, but the cost was extremely high. The results also showed that the final solid waste to be disposed to landfills and the impact due to water emissions could be reduced significantly when incineration and composting were introduced.

Keywords: Composting; Global Warming Potential; GWP; incineration; LCI; Life Cycle Inventory; Malaysia; management, solid waste; solid waste disposal; waste disposal

1 Introduction

Collectively, the yearly operation of solid waste management is a multimillion-dollar activity. Inadequate and poor solid waste management are some of the major causes of urban environmental degradation. In the near future, there is a need for Solid Waste Management to become more sustainable when environmental, economic and social elements have to come into consideration [1,2,3]. An life cycle inventory model of solid waste system can be used in comparative studies to determine the relative environmental and economic advantages and disadvantages of waste management options. No LCI study has ever been conducted on the waste management systems in Malaysia and this paper presents an application of an established LCI model to calculate the overall environmental and economic costs of waste management systems here. "What if...?" calculations were conducted in the study to compare the relative economic costs and environmental impacts of a number of hypothetical waste management systems. The study serves as a preliminary study, which predicts the consequences of solid waste management policies which do not yet exist in Malaysia.

2 Methodology

An established LCI model was used to evaluate the cost and environmental impacts of waste management systems in Malaysia [4]. Although some conditions could hardly be fulfilled in Malaysia, the results of the application of the model with basic local primary data still proved useful in developing future LCI models.

The LCI model consists of five sub-models, which covers the entire life cycle of a waste stream: waste generation, collection, sorting, and recycling, waste treatment and disposal, and environmental impact. The general LCI system boundaries of the studied system are shown in Figure 1. The LCI was carried out to quantify the raw materials and energy consumption together with all solid wastes, emissions to air and water for all the processes within the system boundary identified.

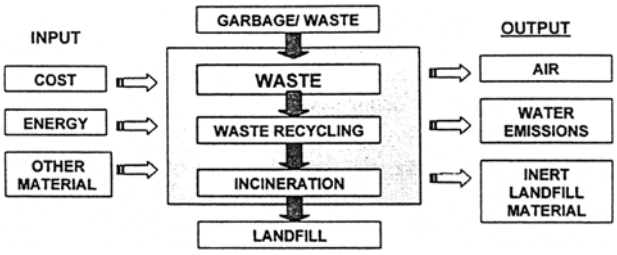

Fig. 1: The boundaries for LCI of a solid waste management system

The first part of the study involved the comparison of four local municipal waste management systems in Malaysia. Kuala Lumpur and Penang were selected to represent urban areas, Seremban was selected to represent moderately urban areas and Muar was selected to represent rural areas. The second part of the study investigated alternative solid waste disposal systems in Penang. The study analyzed the impact of introducing incineration (scenario 1: combustible components were incinerated) and composting (scenario 2: organic components of wastes were composted)

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into the systems and the results were compared with the current system, i.e. 100 % landfilled (baseline scenario).

Both the economic and environmental LCI are included in one computer spreadsheet. Local data applicable were entered into the model. The following outputs were obtained from the model: (1) final solid waste weight and volume generated at each stage, (2) overall cost of municipal solid waste management, and (3) environmental impact assessment. The variables used for the impact assessment study are as follows [5,6]:

Global Warming Potential (GWP): = Emission from LCI model (kg) x GWP weighting factor

Relative GWP for Scenario 1 (i.e. incineration is introduced): = (Total GWP for Scenario 1 / Total GWP for Baseline Scenario) x 100%

Relative Final Solid Waste for Scenario 1: = (Total Final Solid Waste for Scenario 1/Total Final Solid Waste for Baseline Scenario) x 100%

The calculation of the GWP was based on the weighting factor stated in the Intergovernmental Panel on Climate Change (IPCC) Assessment 1992.

3 Results and Discussion

For the first part of study, it was found that Kuala Lumpur has the highest global warming potential (1.75×10^{10} kg) compared to other areas (→ *Table 1*). In addition, the total amount of cost spent was also the highest (RM 82,836,000). Therefore, it could be concluded that the global warming potential and cost increase with waste generation rates.

Table 2 shows the difference of life cycle environmental loads (GWP and final solid waste) of alternative disposal methods applied in Penang. In scenario 1 (incineration), the CO_2 emissions increased almost 5 times relative to the baseline scenario, but the CH_4 emission could be reduced by almost 100 %. The cost for incineration, however, was extremely high, i.e. it was approximately nine times greater than the current system.

The compositions of waste disposed to landfill for the baseline, scenario 1 and scenario 2 are shown in Figure 2. Baseline scenario shows the fraction of waste disposed to landfill for the current system in Penang. Scenario 1 shows that 98 % of ash and 2 % of industrial waste were given off when incineration was applied. Scenario 2 shows that the organic waste fraction can be reduced to a significant amount, but not plastic when composting is applied.

The results of this study is very important to demonstrate that if any waste management system is to be implemented, all aspects of the waste stream within a management system has a valid and valuable role to play on a waste management system's environmental and economical impacts. As for the future efforts to develop the LCI model further [7,8,9], it is suggested that the following aspects of the adapted LCI model be taken into consideration:

- The fundamental system characteristic of the model is highly reliable as it is based on the most current data on the composition, generation and management of waste in Malaysia, and hence needs no further development. Perhaps the model could provide guidance on how better data and information collection on waste management systems could be carried out.
- Only moderate confidence can be assigned to the environmental and the financial impacts of the alternative waste management due to the complexity of the incineration and

Table 1: Overall comparison of current municipal solid waste management system between four areas in Malaysia

Area	Impact Assessment (kg)				Total Cost (RM'000)
	CO_2	CH_4	N_2O	GWP	
Kuala Lumpur	1.19×10^7	1.75×10^{10}	2.80×10^3	1.75×10^{10}	82,836
Penang	3.80×10^7	5.60×10^8	5.10×10^3	5.98×10^8	13,352
Seremban	6.64×10^6	8.93×10^7	-9.39×10^3	9.60×10^7	4,102
Muar	1.44×10^7	2.06×10^8	5.02×10^3	2.20×10^8	3,096

Table 2: Overall results of alternative solid waste management options of Penang municipal solid waste management system

Options	Impact Assessment							Relative final waste disposed (%)	Total Cost RM ('000)
	Air emissions				Water emissions (kg)				
	CO_2	CH_4	N_2O	Relative GWP (%)	BOD	COD	Total metal		
Baseline	3.80×10^7	1.60×10^7	1.97×10^1	100	7.72×10^4	7.71×10^4	3.43×10^3	100	13352
Scenario 1	2.43×10^8	8.51×10^2	9.06×10^2	40.7	2.20×10^2	1.70×10^2	8.08×10^1	19.9	130792
Scenario 2	5.57×10^7	1.60×10^7	5.10×10^2	103.0	1.99×10^2	2.80×10^4	1.33×10^3	37.5	68304

NOTES: Baseline: current system, 100 % landfilled; **Scenario 1:** All combustible waste is incinerated; **Scenario 2:** All organic wastes are composted

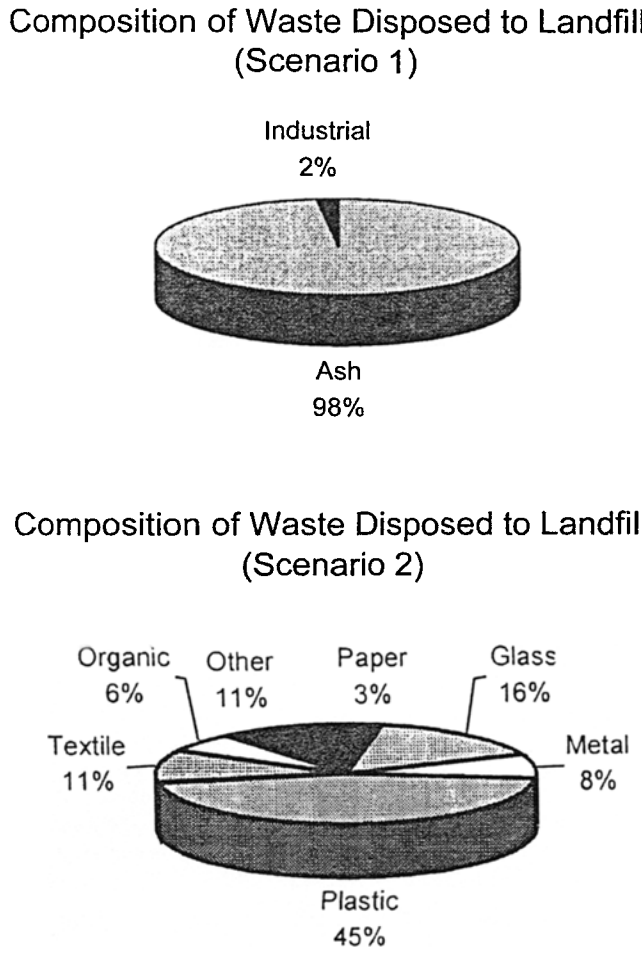

Fig. 2: Composition of waste disposed to landfill for different scenarios

composting processes. Further data collection and information gathering has to be done to improve this aspect of the model.

- The environmental impacts of various waste management systems are the least specific element of the model and the ones most in need of development.

4 Conclusions and Recommendation

An LCI model was applied for preliminary evaluation of the total waste, input relative environmental impacts and cost of a variety of waste management options. The model used in this study should only provide an understanding into the development of a future LCA model suited to local conditions. The conclusions of this study will assist in future efforts to develop an LCI model that provide a comprehensive evaluation system that allows us to lay down the most appropriate waste management plan for the entire waste management system in Malaysia. In addition, the results of this study will also lead to a more systematic and standardized data collection for solid waste management in a given area.

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