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LCA: A decision support tool for environmental assessment of MSW management systems

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Abstract

Life cycle assessment (LCA) can be successfully applied to municipal solid waste (MSW) management systems to identify the overall environmental burdens and to assess the potential environmental impacts. In this study, two methods used for current MSW management in Phuket, a province of Thailand, landfilling (without energy recovery) and incineration (with energy recovery), are compared from both energy consumption and greenhouse gas emission points of view. The comparisons are based on a direct activity consideration and also a life cycle perspective. In both cases as well as for both parameters considered, incineration was found to be superior to landfilling. However, the performance of incineration was much better when a life cycle perspective was used. Also, landfilling reversed to be superior to incineration when methane recovery and electricity production were introduced. This study reveals that a complete picture of the environmental performance of MSW management systems is provided by using a life cycle perspective.

Keywords: Energy consumption; Greenhouse gas emission; Life cycle assessment; Municipal solid waste management

1. Introduction

Currently, Thailand is confronted with a high amount of municipal solid waste (MSW) and its inappropriate management, especially open dumping and non-sanitary landfill. These problems pose harm to the environment as well as human health. At the moment, major concerns associated with waste management are not only public health and safety but also sustainable development. For sustainable development, MSW management has to be balanced between environmental effectiveness, economic affordability and social acceptability to ensure the quality of life now and for coming generations. Concerning the environmental sustainability of MSW management systems, energy and resource conservation and reduced environmental impacts are desirable. To evaluate the performance of MSW management systems, life cycle assessment (LCA) is a useful tool.

LCA has been defined as a technique for assessing the environmental aspects and potential impacts associated with a product, by compiling an inventory of relevant inputs and outputs of a product system; evaluating the potential environmental impacts associated with those inputs and outputs; and interpreting the results of the inventory analysis and impact assessment phases in relation to the objectives of the study (ISO, 1997).

LCA is a methodology considering the entire life cycle of products and services—from cradle to grave (from raw material acquisition through production, use, and disposal). It is thus a holistic assessment methodology of products and services. LCA has been proven to be a valuable tool to document the environmental considerations that need to be part of decision making towards sustainability (UNEP, 2003).

LCA has been successfully utilized in the field of solid waste management to assess environmental impacts of solid waste management systems (Harrison et al., 2000), to compare the environmental performance of different scenarios for management of mixed solid waste (Denison, 1996; Mendes et al., 2004; Finnveden et al., 2000; Arena

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et al., 2003; Chaya and Gheewala, 2006; Wanichpongpan and Gheewala, 2006) as well as of specific waste fractions (Finnveden and Ekvall, 1998; Ross and Evans, 2003).

A systems approach does not always need to use impact assessment. In many cases, inventory data alone are sufficient for an evaluation (McDougall and White, 1998). The term life cycle inventory (LCI) is used to indicate that a study has excluded the impact assessment phase (Friðriksson et al., 2002).

Using LCA, an MSW management system is evaluated based on a system wide or life cycle perspective. A system that generates energy, such as incineration with energy recovery, is credited with reducing the amount of energy (and the associated resource use and emissions) that would otherwise need to be generated, typically at a power plant. If MSW management systems are compared in isolation without accounting for the system-wide environmental impacts, referred in the study as a direct activity consideration, such a limited perspective may not provide a complete picture of environmental impacts.

This study demonstrates a life cycle perspective evaluation of MSW management systems. Phuket, a province in the southern part of Thailand, was selected as the study site. Two methods currently used for MSW management in Phuket, landfilling (without energy recovery) and incineration (with energy recovery) are compared from both the energy consumption and the greenhouse gas emission points of view. The comparisons are based on a direct activity consideration as well as a life cycle perspective. The results of this study reveal the advantage of using a life cycle perspective in MSW system evaluation.

2. Current Phuket MSW management

Phuket is an island province in the south of Thailand stretching 49 km from north to south and 19 km from east to west with a total area of 570 km^2. With beautiful beaches along the western and southern parts of the island, Phuket is a major tourist attraction.

MSW in Phuket is collected and transported to the treatment and disposal center, where it is weighed and separated based on source and characteristics of the waste, to be managed by three methods—incineration, recycling, and landfilling. Flow of current Phuket MSW in a 1-year period (July 2003–June 2004) obtained from Phuket Municipality is illustrated in Fig. 1. Of the 133 374 tons of MSW collected in the 1-year period, an estimated 71% was sent for burning in incinerator, 26% landfilled, and 3% sorted and recovered for recycling.

3. Methodology

In this study, a comparison between the two methods used for current Phuket MSW management, landfilling (without energy recovery), and incineration (with energy recovery) is performed. The environmental burdens considered in the evaluation are energy consumption and greenhouse gas emission. To compare the two methods of MSW management, a fixed reference point for the environmental evaluation, called functional unit, is defined as 1 ton of MSW treated. For fairness of comparison, the same characteristics of waste are assumed to be treated by both landfilling and incineration. Waste characterization information obtained from monthly reports of Phuket incineration plant is illustrated in Table 1.

The evaluation includes activities that are of direct concern in MSW management and also activities that supply services to or interact with MSW management methods as illustrated in Fig. 2. Direct and indirect activities associated with MSW management methods contributing to energy consumption and greenhouse gas emission are listed in Table 2 and Fig. 2. Energy consumption for ash management is included in the calculations, however, greenhouse emissions are not since the ash is inorganic in nature. Based on the existing practice that there is no gas collection and flaring system in Phuket landfill and with the assumption of 10% methane oxidation in landfill cover (IPCC, 2001), 90% of the methane produced is released to the atmosphere. Although carbon dioxide is also emitted from the landfill, it is not considered because, being of biomass origin, it does not contribute to global warming. The landfill leachate is treated by pond system, which is the common method in Thailand. The energy and resource requirements are thus negligible. The main impact from this system would be on land use, which is not within the scope of this study. Transportation is not included in the system boundary as the collection and transportation of waste is common to both the waste management systems and hence will not influence the comparative result.

Findings from the study are presented based on two sets of boundary conditions (Table 2):

(1) a direct activity consideration, limited to only those processes that lie within MSW management method itself and
(2) a life cycle perspective, considering direct activities as well as other processes interacting with MSW management system. Since the function of landfilling is solid waste management, whereas the function of incineration is solid waste management with electricity production as a supplementary function, to make the systems comparable, the incineration is credited with the avoided emissions from the alternative process of producing an equivalent amount of electricity. The average electricity mix of Thailand is used for calculating the credits. Environmental burdens in the modified system are the environmental loads from the incineration minus those from the conventional power plants. In this way, both MSW management methods can be compared based on the same function which is solid waste management as illustrated in Fig. 3 (Finnveden and Ekvall, 1998).