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The holistic impact of integrated solid waste management on greenhouse gas emissions in Phuket

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Abstract

Continually increasing amounts of municipal solid waste (MSW) and the limited capacity of the existing waste management system in Phuket have led to the consideration of integrated waste management system (IWMS). Life cycle assessment (LCA) was employed to compare the greenhouse gas emissions expressed as global warming potential (GWP) of the existing waste management system (the base scenario) and other three IWMSs for Phuket MSW. Besides incineration and landfilling, the proposed scenarios include 30% source separation for recycling (scenario 2), anaerobic digestion (scenario 3) and both (scenario 4).

The functional unit is set as 1 t of Phuket MSW treated. Results from the impact assessment of the base scenario shows that the net GWP is 1006 kg CO_2 equivalent. Landfilling contributes to the highest potentials of this impact. The results from a holistic comparison show that scenario 4 is the best option among all the scenarios, contributing GWP of 415 kg CO_2 eq., whereas the base scenario is the worst. The emission of greenhouse gas from landfilling is reduced by the introduction of landfill gas recovery and utilization for electricity production. By assumption, 50% recovery of landfill gas leads to the GWP reduction around 58% by total GWP of landfilling and 36% by the net GWP of the whole system in the base scenario. The study suggests that a policy that promotes source separation should be pursued, preferably combined with the application of landfill gas recovery for electricity. Policy promoting recycling is favorable over anaerobic digestion in the situation that both treatment systems could not be established at the same time. The major conclusion from the study is that results from the LCA can support Phuket Municipality for decision-making with respect to planning and optimizing IWMS. It can benefit other municipalities or policy makers to apply in their waste management projects.

Keywords: Global warming potential; Greenhouse gas emissions; Integrated solid waste management; Life cycle assessment; Municipal solid waste; Policy

1. Introduction

Management of municipal solid waste (MSW) has continued to be an important environmental challenge. The threat of global climate change is also a serious issue and a driving force for changes in MSW management systems in many countries, including Thailand, to reduce greenhouse gas emissions.

Many opportunities exist for greenhouse gas (GHG) emissions reduction in MSW management systems. Incineration allows energy recovery to displace electricity generated from fossil fuel. The recovered energy can reduce the amount of energy consumption and also emissions that would otherwise be produced by other energy systems such as fossil-fired power plants. Diverting organic materials from landfilling by composting or anaerobic digestion also reduces methane emission contributing to climate change. Moreover, soil conditioner recovered from both systems and energy recovered from the latter system can avoid the production of chemical soil conditioner and generation of energy, respectively, and the consequent reduction in GHG emissions. The reduction of energy and resource consumption by recycling is also a very interesting option for reduction of GHG emissions.

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Phuket, a province in the southern part of Thailand, is selected as the study site. MSW in Phuket is collected and transported by trucks to the treatment and disposal center. All trucks are registered with the center according to the source of waste (community, hotels, market place, etc.) which reflects the characteristics of waste. After being weighed, the trucks are diverted to the appropriate waste management place – the incineration plant, the separation plant and the landfill site. Of the total MSW collected, an estimated 71% is sent to the incinerator, 26% landfilled and 3% sorted and recovered for recycling.

In 2004, MSW collected from communities in Phuket was about 364 t/day, tourism activities being an important contributor. Management of Phuket MSW is currently in a critical condition because of the continually increasing amount of MSW whereas the capacity of incinerator, the main treatment system, is limited to 250 t/day. The issue is compounded due to ineffective sorting and limited area of landfill site. A fresh look should therefore be taken at the MSW management strategy.

There is no single treatment system which is most appropriate for all waste fractions. Hence, MSW should be treated by an integrated approach. This paper presents the environmental evaluation, focusing on GHG emissions, of the existing MSW management system in Phuket. It also illustrates how emissions of GHG can be reduced by considering different integrated waste management systems (IWMSs). Life cycle assessment (LCA) is used as the evaluation tool in the study. There have not been many studies, and none in Thailand, evaluating actual IWMSs. This study presents such an evaluation including environmental comparison between several integrated management options. The result from this study can support Phuket Municipality for decision concerning future MSW management strategy. Moreover, it can be a useful demonstration for other municipalities or policy makers to apply in their waste management projects.

LCA is a technique for assessing the environmental aspects and potential impacts associated with a product (or service), by compiling an inventory of relevant inputs and outputs of the 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 [1].

LCA considers the entire life cycle of products or services from cradle-to-grave (from raw material acquisition through production, use and disposal). It is thus a holistic assessment methodology of products or services. LCA has been proven to be a valuable tool to document the environmental considerations that need to be part of decision-making towards environmental sustainability [2,3].

LCA has been successfully utilized in the field of solid waste management, for example, to assess differences in environmental performance between different waste incineration strategies [4] or relate activities such as flue gas cleaning process of MSW incinerators [5], to compare the environmental performance of different scenarios for management of mixed solid waste as well as of specific waste fractions [6–12]. It has also been successfully utilized for comparative assessment of MSW systems in the Southeast Asian region [13–17].

2. Methodology

In this study, life cycle assessment (LCA) is used as evaluation tool. The technical framework for the LCA methodology as defined in ISO 14040 [1] is explained below.

2.1. Goal and scope definition

The goal of this study is to evaluate GHG emissions of the existing MSW management system and different IWMSs based on life cycle perspective for Phuket MSW. Only GHG emissions are considered in this study as climate change is a priority area in Thailand particularly for policy making. The composition of Phuket MSW is specified in Table 1 [18]. The functional unit (FU) providing a reference to which the inputs and outputs are related is defined as ‘‘1 t of Phuket MSW treated’’.

2.1.1. Comparative scenarios

The study is change-orientated (prospective). The existing MSW management system in Phuket is defined as the base scenario (scenario 1). To better understand the effects of different MSW management options, three different scenarios are considered in addition to the base scenario.

Scenario 2: 30% of recyclable materials are separated at source and collected to be recycled. Other combustible fractions are sent to be incinerated at the rate of 70%. The remaining fractions are disposed in landfill.
Scenario 3: 30% of food waste and garden waste are separated at source and collected to be anaerobically digested. Other combustible fractions are sent to be incinerated at the rate of 70%. The remaining fractions are disposed in landfill.
Scenario 4: by source separation, 30% of recyclable materials are separated at source and collected to be recycled and 30% of food waste and garden waste are separated and collected to be anaerobically digested. Other combustible fractions are sent to be incinerated at the rate of 70%. The remaining fractions are disposed in landfill.

Table 1
Phuket MSW composition

Composition	Amount (%)
Food waste	44.13
Plastic	15.08
Paper	14.74
Glass	9.67
Garden waste	5.26
Metals	3.44
Rubber/leather	2.28
Cloth	2.07
Stone/ceramic	1.39
Other	1.94