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Analyzing environmental hotspots of proposed landfill extension and advanced incineration facility in Hong Kong using life cycle assessment

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ABSTRACT

This paper evaluates the environmental impacts and identifies the hotspots associated with the sub-processes of the proposed landfill extension (LFE) and advanced incineration facility (AIF) for municipal solid waste (MSW) disposal in Hong Kong using life cycle assessment methodology. On the basis of the data collected, assumptions made, and system boundary defined, results show that sub-processes of LFE that provide most burdens on human health and ecosystem quality are biological reactions at landfill cells and sludge collection and treatment system, respectively. Meanwhile, stack discharge system in the AIF has highest impact on human health and ecosystem quality. Overall, the LFE performs more poorly than the AIF in view of human health but vice versa for ecosystem quality. The comparison of the LFE and AIF, with and without energy recovery systems, indicates quantitatively that the energy recovery systems provide benefits in regard to climate change, respiratory inorganics and acidification/eutrophication. Energy recovery in the waste sector could be enhanced through technological improvement and economic incentives. The environmental performances by applying Hong Kong's target emission levels for the stack discharge system in the AIF are also more favorable with respect to human health and ecosystem quality than those of Mainland China's and U.S.EPA standards. This study provides an additional view to the stakeholders in decision making process for pledging a sustainable management of MSW disposal in Hong Kong.

1. Introduction

Currently, nearly 1.3 billion tonnes of solid waste per year is generated by the major world cities, and is projected to increase to 2.2 billion tonnes by 2025 (Hoornweg and Bhada-Tata, 2012). Of the solid waste requiring disposal, municipal solid waste (MSW) has become a major environmental challenge throughout the world. In Hong Kong, the percentages of total solid waste consisting of MSW ranged from 62% to 67% by wet mass from year 2006 to 2010 (HKEPD, 2010). At present, Hong Kong relies solely on landfills for MSW disposal. Despite the concerted efforts to reduce, reuse and recycle, approximately 9000 tonnes of MSW are still discarded in the landfills every day (HKEPD, 2010). It is expected that the current three strategic landfills in Hong Kong, namely South East New Territories (SENT), North East New Territories (NENT), and West New Territories (WENT), will reach their maximum capacities in 2015, 2017, and 2019, respectively (HKEPD, 2013). Faced by this imminent issue, both landfill extension (LFE) and advanced incineration facility (AIF) have been proposed by the Government of the Hong Kong Special Administrative Region (HKSAR) in late 2005 (HKEPD, 2005). The proposals of the LFE and AIF, however, have engendered a lot of concerns from Hong Kong citizens and green groups (Ng, 2011; Tang, 2011). It has invoked hot debates over the environmental feasibilities and sustainability issues of these two waste disposal options (i.e., LFE and AIF) on the MSW management practices in Hong Kong.

The Hong Kong Environmental Protection Department (HKEPD) has implemented environmental impact assessment (EIA) studies to assess the nature and extent of the environmental risks arising from the implementation of these two proposed waste disposal facilities on the surroundings (HKEPD, 2009, 2011). Nevertheless, a new decision analytical tool, which is based on a scientific approach from a life-cycle perspective, is required to help the stakeholders in generating decision criteria and formulating management frameworks in the context of environmental sustainability (Linkov and Seager, 2011). To this extent, life cycle assessment (LCA) can be

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applied to provide a systematic analysis to the LFE and AIF by synthesizing information from collected data and decoding the complexity of the problem.

There are several recent studies that evaluate the environmental impacts of landfill and incineration systems from a life-cycle perspective (Hong et al., 2010; Zaman, 2010; Koci and Trecakova, 2011; Assamoi and Lawryshyn, 2012; Menikpura et al., 2012). On the one hand, all of these studies did not investigate the environmental impacts contributed by the individual sub-process of landfill and incineration in any depth. By investigating the environmental impacts of the sub-processes of the waste disposal facilities, it allows us to identify the hotspot (i.e., major sub-process) that provides most environmental burden and facilitate improvements on the design and operating criteria for the waste disposal facilities. On the other hand, these studies are region-specific due to the variation of waste characteristics and multi-complex criteria technology performance factors in different regions and countries. Despite intense debates among the Hong Kong people over the proposals of LFE and AIF, to date, a holistic and locally relevant analysis of potential environmental burdens of the proposed LFE and AIF from a life cycle perspective is yet to be conducted. It is hoped that this study can provide a greater certainty on the environmental performances of these two waste disposal options, thus aiding the policy makers in decision making processes and generating a policy framework in the context of sustainable MSW management development.

2. Material and methods

2.1. Modeling scope of study

This study follows the LCA methodology as described in the international standard ISO reports (ISO 14040, 2006; ISO 14044, 2006). The goal of this study is to evaluate the environmental performances of sub-processes of the proposed LFE and AIF, as well as to compare the environmental impacts of these two waste disposal options in Hong Kong. The functional unit used in this study is defined as "one tonne of MSW (wet basis) being discarded into the proposed waste disposal facility". This study focuses on the operational phase of the proposed LFE and AIF, which covers a 15-year operation and is considered as primary environmental burden. The construction and capital equipment are considered as secondary environmental burdens and are assumed to be relatively small in comparison to the primary environmental burden, and hence are not included in this study (McDougall et al., 2001; Finnveden et al., 2005; Cleary, 2009). In addition, since the scope of the study covers a multi-year period, it is assumed that the environmental impacts of construction, maintenance and replacement of the equipment, and decommissioning of the waste disposal facility are insignificant compared to the direct emissions and the avoided impacts of the waste disposal facility (Gentil et al., 2010).

2.2. System description of proposed LFE and AIF

West New Territories (WENT) LFE, which is located at Tuen Mun, is chosen as the subject of study as it has the highest filling capacity (81 Mm^3) among the three proposed landfill extensions in Hong Kong (LegCo, 2013). In addition, the current WENT Landfill receives the highest MSW disposal rate compared to the existing SENT and NENT Landfills (HKEPD, 2010). Meanwhile, the AIF is planned to be located at an artificial land near Shek Kwu Chau Island. The proposal of the AIF aims to considerably reduce the bulk size of MSW, in hope to alleviate the burdens on current and future landfills in Hong Kong. The schematic process flow diagrams of the LFE and AIF, depicting the defined system boundary, are presented in Fig. 1. The LFE is divided into six major sub-processes, namely (i) waste transport; (ii) biological reactions at landfill cells; (iii) flare system; (iv) leachate collection and treatment; (v) ash disposal after sludge treatment; and (vi) energy recovery system. As for AIF, it is divided into five main sub-processes, namely (i) waste transport; (ii) stack discharge system; (iii) desalination; (iv) ash treatment and disposal; and (v) energy recovery system. The detailed descriptions of each sub-process of the proposed LFE and AIF are summarized in Table 1.

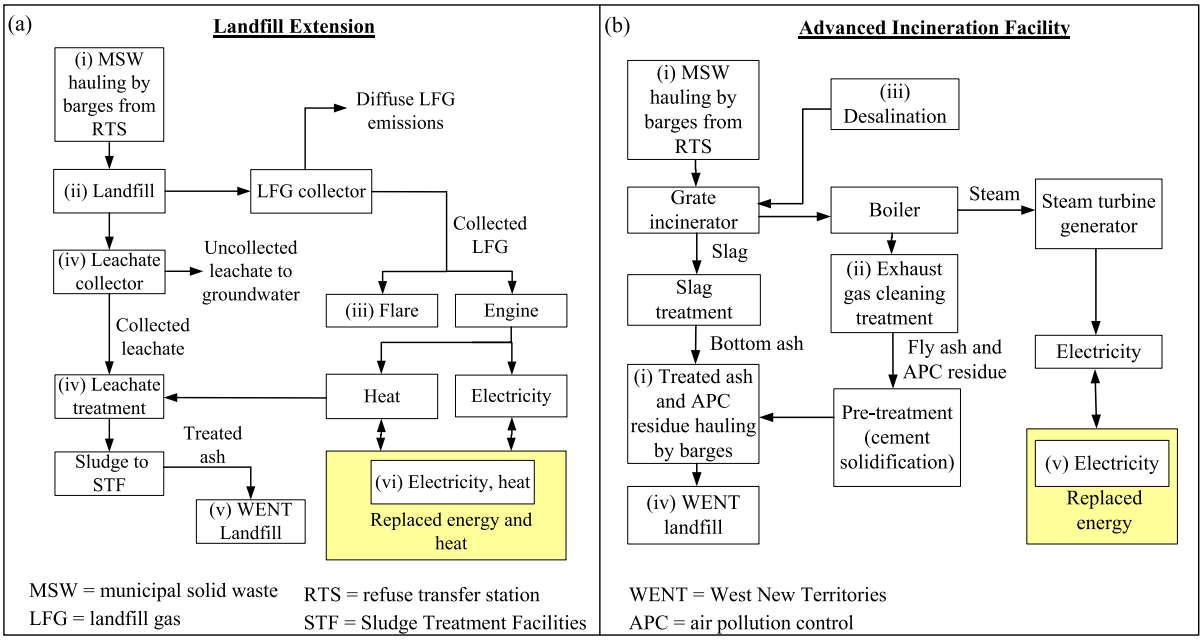

Fig. 1. Schematic process flow diagram of (a) LFE with sub-processes (i) waste transport; (ii) biological reactions at landfill cells; (iii) flare system; (iv) leachate collection and treatment; (v) ash disposal after sludge treatment; and (vi) energy recovery system; and (b) AIF with sub-processes (i) waste transport; (ii) stack discharge system; (iii) desalination; (iv) ash treatment and disposal; and (v) energy recovery system with reference to proposed waste disposal facilities by the HKEPD.