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Environmental impacts of a large-scale incinerator with mixed MSW of high water content from a LCA perspective

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ABSTRACT

Large-scale incinerators are applied widely as a result of the heavy burden of municipal solid waste (MSW) generated, while strong opposition is arising from the public living nearby. A large-scale working incineration plant of 1500 ton/day was chosen for evaluation using life cycle assessment. It was found that the corresponding human toxicity impacts *via* soil (HTs), human toxicity impacts *via* water (HTw) and human toxicity impacts *via* air (HTa) categories are 0.213, 2.171, and 0.012 personal equivalents (PE), and global warming (GW100) and nutrient enrichment (NE) impacts are 0.002 and 0.001 PE per ton of waste burned for this plant. Heavy metals in flue gas, such as Hg and Pb, are the two dominant contributors to the toxicity impact categories, and energy recovery could reduce the GW100 and NE greatly. The corresponding HTs, HTw and HTa decrease to 0.087, 0.911 and 0.008 PE, and GW100 turns into savings of −0.007 PE due to the increase of the heating value from 3935 to 5811 kJ/kg, if a trommel screener of 40 mm mesh size is used to pre-separate MSW. MSW sorting and the reduction of water content by physical pressure might be two promising pre-treatment methods to improve the combustion performance, and the application of stricter standards for leachate discharge and the flue gas purification process are two critical factors for improvement of the environmental profile identified in this work.

Introduction

Municipal solid waste (MSW) disposal leads to a significant environmental burden due to the huge amounts of pollutant emissions. Incineration is regarded as one of the effective ways to minimize waste mass and volume, and has increased from 2.5% (2001) to 19.8% (2011) of total MSW disposal due to the heavy burden of MSW generated as a result of the rapidly increasing urban population and the improvement of people's lifestyles in China. Around 31 million tons of MSW collected was burned in 109 incineration plants in China, with a corresponding total treatment capacity of 94,114 ton/day (National Bureau of statistics of China, 2011).

Large scale incinerator plants are an attractive way to deal with the sharp increase of MSW, and grate firing has been demonstrated to be the most promising type of furnace for non-classified MSW (Shi et al., 2008; Xi et al., 2003). Currently, the technology for large scale incinerators is imported from

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the developed countries, such as the EU, USA, and Japan, which are designed based on burning of classified refuse with high heating value. Putrescible biodegradable materials predominate in the non-classified refuse in MSW due to the particular lifestyles in some Asian countries, which is characterized as "three high and one low", *i.e.*, high mixture, high inorganic matter content, high percentage of putrescible waste (more than 55% with consequent high moisture) and low calorific heating value (<4000 kJ/kg) (Sun et al., 2008). The application of imported incinerator technology faces an increasingly complex set of environmental and social pressure in China.

Incinerators have created many concerns in the past decade regarding the safeguarding of public health and environmental safety from toxic and cancer-causing emissions, as well as concerns about financial costs (Monni, 2012; Vermeulen et al., 2012), and the concerned people frequently oppose the construction of incineration plants, such as the Nanjing Jiangbei Incineration Plant, Guangdong Panyu Incineration Plant (Zheng, 2009), and Zhejiang Hanzhou Jiufeng Incineration Plant in China. Since the relative environmental impact is still not clear, it is necessary to assess the environmental performance of large scale incineration plants both in qualitative and quantitative terms.

The environmental profiles of grate firing incinerators and fluidized bed incinerators have been evaluated and compared (Chen and Christensen, 2010), and grate firing incinerators were found to result in more savings in terms of global warming potential than fluidized bed incinerators due to their higher net power generation from the combustion of MSW. However, only the energy consumption in the pretreatment process of MSW was considered, and the leachate generation/treatment and mass minimization were missing from the calculation process. It was also found that circulating fluidized bed incineration with auxiliary coal of 700 ton/day was beneficial for mitigating global warming with the addition of sufficient coal (Zhao et al., 2012). The environmental performance of sludge and medical waste incineration was also evaluated, and the results were found to be influenced greatly by the type of furnace and auxiliary resources (Assamoi and Lawryshyn, 2012; Chen and Christensen, 2010). It is necessary and urgent to assess the environmental performance of large scale-incineration plants for mixed MSW with high water content and organic matter as the number of incineration plants applied in China continues to increase.

In this work, the environmental impact of a full scale grate firing incinerator with three lines was examined and assessed using life cycle assessment (LCA). The specific objectives were to answer the following questions: (1) What are the environmental burdens associated with the current large-scale MSW incineration plant? (2) How do the combustion performance and the environment impact vary after application of some feasible supplemental measures, such as the pretreatment of waste and use of an advanced pollution control system?

1. LCA process

1.1. *EASEWASTE introduced briefly*

The EASEWASTE model (2008 version) Technical University of Denmark, has been developed with a database including waste technologies, recovery and disposal options, as well as external processes that might be included either upstream or downstream in a solid waste management system. The relative waste specific mass flows, resource consumption and environmental emission are considered in the environmental assessment of an incineration plant (Riber et al., 2008). A graphical overview of how the waste sector is modeled in EASEWASTE can be found in Christensen et al. (2007). All the relative environmental impacts

Table 1 – Environmental normalized potential impacts reference in China.

Potential impact category	Normalization reference	Physical basis	References
Global warming	8700	Global	(J.H. Li et al. (2007)
(kg CO_2-eq./person/year)	36	Regional	(J.H. Li et al. (2007)
Acidification	0.20	Global	(J.H. Li et al. (2007)
(kg SO_2-eq./person/ year)	62	Regional	(J.H. Li et al. (2007)
Ozone depletion	0.65	Regional	(J.H. Li et al. (2007)
(kg CFC-11-eq./person/ year)	358	Regional	(J.H. Li et al. (2007)
Nutrient enrichment (kg NO_3^-eq./person/ year)	3.52×10^5	Regional	Wenzel et al. (1997)
Photo-chemical ozone formation (kg C_2H_4-eq./person/ year)	9.64×10^5	Regional	Wenzel et al. (1997)
Human toxicity, soil (m^3 soil/person/year)	5×10^4	Regional	Wenzel et al. (1997)
Ecotoxicity, water chronic (m^3 water/person/year)	6.09×10^{10}	Regional	Wenzel et al. (1997)
Ecotoxicity, soil (m^3 soil/person/year)	140	Local	Wenzel et al. (1997)
Human toxicity, water (m^3 water/person/year)			
Human toxicity, air (m^3 air/person/year)			
Spoiled groundwater resources (m^3 water/person/year)			