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Greenhouse gas emission and its potential mitigation process from the waste sector in a large-scale exhibition

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ABSTRACT

As one of the largest human activities, World Expo is an important source of anthropogenic Greenhouse Gas emission (GHG), and the GHG emission and other environmental impacts of the Expo Shanghai 2010, where around 59,397 tons of waste was generated during 184 Expo running days, were assessed by life cycle assessment (LCA). Two scenarios, *i.e.*, the actual and expected figures of the waste sector, were assessed and compared, and 124.01 kg CO_2-equivalent (CO_2-eq.), 4.43 kg SO_2-eq., 4.88 kg NO_3^--eq., and 3509 m^3 water per ton tourist waste were found to be released in terms of global warming (GW), acidification (AC), nutrient enrichment (NE) and spoiled groundwater resources (SGWR), respectively. The total GHG emission was around 3499 ton CO_2-eq. from the waste sector in Expo Park, among which 86.47% was generated during the waste landfilling at the rate of 107.24 kg CO_2-eq., and CH_4, CO and other hydrocarbons (HC) were the main contributors. If the waste sorting process had been implemented according to the plan scenario, around 497 ton CO_2-eq. savings could have been attained. Unlike municipal solid waste, with more organic matter content, an incineration plant is more suitable for tourist waste disposal due to its high heating value, from the GHG reduction perspective.

Introduction

Climate change presents unprecedented challenges to the global community (Kiem and Austin, 2013; Metz et al., 2007). The increase in greenhouse gas (GHG) levels in the atmosphere and the already observed global warming of the Earth's surface have raised concerns about GHG emission from human activities (Metz et al., 2007; AUMA, 2011), and therefore the reduction of anthropogenic GHG emission is an urgent matter (Metz et al., 2007; Kerr, 2007).

Large-scale exhibitions are important intensive human activities, which are constantly on the rise following rapid global economic growth and urbanization. For example, around 157 international trade fairs and exhibitions were held in Germany in 2010, with 10,074,724 visitors (AUMA, 2011). Similarly, in China, there are about 80 exhibition centers distributed in 39 cities,

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where numbers of exhibitions are presented every year. These anthropogenic activities result in the generation of waste, which may cause some problems for the local environment and global warming (GW) through GHG emission (Vergara and Tchobanoglous, 2012). Against this background, large-scale event organizers have the responsibility to neutralize the carbon generated, or minimize its impact on climate and the environment.

Shanghai Expo, 2010 was the latest large-scale exhibition event, and was also the first time an event of this kind was held in China, the most populous developing country. It provided a good opportunity to assess the influence of human activities on climate change (Ping, 2009; Liu and Li, 2010). Meanwhile, the ever-increasing amount of waste is one of the urgent challenges for modern cities, to an extent that most of them have been christened as “city besieged by garbage”. In fact, the waste industry is considered one of the most significant sources of anthropogenic GHG, a matter that is currently a great concern to environmentalists. Therefore, the waste sector is an important component in the achievement of a low carbon world Expo, and has become a big challenge to the organizers (Hong et al., 2006; Cao and Zhang, 2010). Measurement and estimation of the carbon footprint are the prerequisite requirements in addressing and understanding the environmental impact from such huge events.

GHG emission from the waste sector has been studied from different aspects in the past decades (Laurent et al., 2014; Chen and Christensen, 2010; Hong et al., 2010; Habib et al., 2013; Zhao et al., 2009, 2011), while the studies published were primarily concentrated in Europe with little application in developing countries (Laurent et al., 2014). Habib et al. (2013) assessed the implications regarding global warming potential (GWP) from waste management systems using life cycle assessment (LCA) based on the historical development in the municipality of Aalborg, Denmark, and found a continuous improvement in environmental performance from 1970 to 2010, which resulted in a shift from net emission of 618 kg CO_2-equivalent (CO_2-eq.)/ton to net saving of 670 kg CO_2-eq./ton of municipal solid waste (MSW) due to the increase in recycling. Laurent et al. (2014) concluded that the LCA results were strongly dependent on the local conditions of each waste management system, such as waste composition or energy system. Zhao et al. (2009) compared six scenarios for waste management in Tianjin city, China, and 467.34 mg CO_2-eq. per year was released from the MSW. The weak point is that most of the inventory data, such as the transfer co-efficient in landfill and incineration, are borrowed from other published reports, which does not reflect the real situation of Tianjin. To investigate trade-offs between economic factors and GHG emission mitigation in the waste sector, Zhao et al. (2011) also assessed and compared the GHG emission and the cost of Tianjin's MSW management system by combined LCA and life cycle costing (LCC), and it was found to have the highest GHG emission and lowest cost in the current situation. Hong et al. (2010) estimated the environmental impact of the four most common municipal solid waste treatment systems of landfill, incineration, composting + landfill and composting + incineration in Suzhou city, China, and the technologies were found to significantly contribute to GW and increase the adverse impact of non-carcinogens on the environment. Direct CH_4 emission contributes the most to the potential impact from landfills. In addition, some of the reported works focus on single waste treatment processes, such as landfilling, incineration, or composting (Chen and Christensen, 2010), which provides some database for the study of scenarios in waste management. To the best of our knowledge, there are still no reports concerning tourist waste, for which the composition is somewhat different from MSW, and the establishment of inventory data from the working treatment processes will also contribute to obtaining a more accurate result and reflecting the local situation.

This study focused on the performance of the waste management system during an Expo event, and the corresponding environmental impacts, risks, and sustainability were examined and assessed. Two scenarios for the waste sector in practice and in the plan of Expo Shanghai 2010 were addressed and compared. The specific objectives were to answer the following questions: (I) what are the environmental burdens associated with the current waste management system in Expo Shanghai 2010? (II) What are the potential GHG contributors and savers in the waste sector in Expo Shanghai 2010? (III) How do we improve the waste management system to reduce these corresponding environmental impacts?

1. LCA processes

1.1. *Basic information on waste management system in Expo Park*

Shanghai Expo, 2010 ran for 184 days, and 73,084,400 participants joined in this program (Shanghai Expo Official Website, 2010). It is important to note that a record of 1.03 million visitors was reported for the single day exhibition on October 16, 2010. Usually, visitors spent more time in the Pudong area, and thus the distribution of tourist waste in Puxi and Pudong areas was around 1:3. Three types of wastes, *i.e.*, food waste, construction and demolition (C&D) waste, and tourist waste, were generated in Expo Park, and the total amounts of tourist waste, food waste and C&D waste were 28,219 tons, 7441 tons and 23,737 tons, respectively. To comply with legislation and management of waste reduction and recovery in Expo 2010, some emerging waste treatment processes were also applied in the park, *i.e.*, the extraction of fat and oil from food waste, and the recycling of construction and demolition waste on-site, and thus the environmental impact of the food waste and C&D waste disposal were not considered here due to the lack of accurate data. Particularly, the waste collection systems in Expo Park were new, and the waste was collected by an advanced enclosed aero-dynamic system and electric-powered trucks.

The tourist waste was the most important part of the waste sector in the Expo Park, with around 0.386 kg tourist waste per visitor, which was mainly composed of 25% paper, 20% plastic, 0.3% metal inorganic matter, 1.45% glass inorganic matter, 50% organic matter, 1.85% textile and 1.4% wood. Clearly, the waste composition here is special, with higher plastic and paper content and lower food waste compared to MSW. Thus the corresponding environmental impact will also be different. The tourist waste was planned to be disposed in Phase IV of Laogang Landfill, with the treatment capacity of 6300 ton MSW/day. Another waste-to-energy incineration facility, located in Jiangqiao of Jiading District, was also involved in the waste management Plan, with a treatment capacity of 1500 ton MSW/day (Shanghai Environmental Online, 2010).

1.2. *LCA model and system boundary*

To identify the GHG emission and environmental impacts, LCA was applied to model the scenarios, since it can avoid a narrow outlook on environmental concerns by compiling an inventory of relevant energy and material inputs and environmental releases, and is also recognized as a valuable method for assessing direct and indirect impacts of waste systems. To