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Performance evaluation model of a pilot food waste collection system in Suzhou City, China

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ABSTRACT

This paper analyses the food waste collection and transportation (C&T) system in a pilot project in Suzhou by using a novel performance evaluation method. The method employed to conduct this analysis involves a unified performance evaluation index containing qualitative and quantitative indicators applied to data from Suzhou City. Two major inefficiencies were identified: a) low system efficiency due to insufficient processing capacity of commercial food waste facilities; and b) low waste resource utilization due to low efficiency of manual sorting. The performance evaluation indicated that the pilot project collection system's strong points included strong economics, low environmental impact and low social impact. This study also shows that Suzhou's integrated system has developed a comprehensive body of laws and clarified regulatory responsibilities for each of the various government departments to solve the problems of commercial food waste management. Based on Suzhou's experience, perspectives and lessons can be drawn for other cities and areas where food waste management systems are in the planning stage, or are encountering operational problems.

1. Introduction

According to the Handbook of Solid Waste Management (2002), Municipal Solid Waste (MSW) refers to wastes from residential, commercial, institutional, and some industrial sources. Food waste is an important element in the production of MSW, and the sustainable collection of food waste within an integrated MSW management system is important to reduce the environmental burden on urban centers. Decisions concerning investment in new collection methods must be justified based on environmental, technical and economic feasibility (Aranda Usón et al., 2013). Our research seeks to address problems surrounding commercial food waste disposal from a food waste collection standpoint based on a pilot project in Suzhou City, China.

In recent years, catering industries in urban areas of China have been developing at a rapid pace, producing increasing amounts of commercial food waste. According to the National Bureau of Statistics of China, 512 cities produced more than 50 tonnes per day (tpd) of commercial food waste. Chinese gastronomy is very diverse, and involves complicated preparation procedures and a broad array of ingredients. The moisture content of commercial food waste averages about 80%–90% (wet basis) (Xu et al., 2011). This level of moisture, compounded by the waste's low calorific value, renders it inappropriate for incineration, which is widely used for MSW treatment in China. Rapid growth in the quantity of commercial food waste generated has therefore raised serious disposal issues, forcing the country to improve the management of this waste.

1.1. Definition of "commercial food waste" in China

According to the definition given in the "Food waste treatment technology specification (draft)" established by the Ministry of Housing and Urban-Rural Development (MOHURD), commercial food waste is composed of two segments: 1) Food residue, generated from commercial dining tables (i.e. in catering enterprises), kitchens and food processing plants; and 2) Waste edible oil, which includes fried oil and oil or grease collected from oil-water separators and grease traps. The logistics of commercial food waste C&T are different to the logistics of C&T of domestic food waste. Domestic food waste is not the focus of this paper.

Commercial food waste possesses useful attributes. Firstly, it can be processed and recycled as animal feed due to its high organic matter, calcium, potassium, nitrogen and phosphorus content.

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Secondly, it can produce biogas via the anaerobic digestion process. Thirdly, it can be used to manufacture biodiesel by separating the waste oil fraction as a raw material input.

In the past, commercial food waste was disposed of together with other municipal solid wastes via incineration or landfill (Cheng et al., 2007). However, in recent years, dedicated centralized collection, transportation and disposal of commercial food waste has started to develop since 2010, with aid from local municipal government subsidies for waste transportation and disposal, China has implemented commercial food waste disposal and recycling pilot projects in more than 33 cities.

1.2. Challenges for China

China's commercial food waste-to-resource strategy lacks mature policy support, a monitoring system and standards for processing technologies. Weak implementation of laws and regulations lead to weak waste flow reporting and the absence of a waste registration system to regulate the food waste flows. Moreover, there is a lack of technical and industry standards for factors including food waste collection containers, collection transport job specifications, and food waste-to-resource processing technologies.

In addition to the aforementioned challenges, the collection of commercial food waste, especially waste oil, is currently a major difficulty in commercial food waste management in many cities in China. Cities such as Shijiazhuang City and Yinchuan City already have waste oil processing plants in operation, but these cities have not yet built a food waste collection and transportation (C&T) system. Therefore, these plants have to purchase waste oil from various vendors in society. The problem is that the collection source is uncertain, resulting in fluctuating quantity and quality of recycled food waste, which is more difficult to process. Some cities such as Shanghai City and Wuxi City have issued regulations, but the majority of waste oil is still sold on the black market for a good price. As a result, due to an insufficient quantity of commercial food waste collected, over 60% of official collection and delivery vehicles in Wuxi City are left unused. (Wuxi municipal government report on food waste management, 2013) Driven by profit motives, catering businesses shirk social responsibility and sell food waste to unofficial recyclers without business permits, who then turn the waste oil into low-quality gutter oil, or who feed the food residue to livestock. Gutter oil is prohibited cooking oil that has been reprocessed from restaurant fryers, drains, grease traps and slaughterhouse waste. It has emerged as a serious health issue in China due to its severe health risk for humans.

Compounding the aforementioned problems, existing disposal plants are facing serious challenges including low technical expertise, low processing efficiency, poor operating environments and incomplete processing. The unit disposal cost is usually high because the disposal process requires many additives and high energy consumption.

2. Aim and methodology

2.1. Literature review

2.1.1. Global waste collection review and implications for developing countries

The environmental, social and economic performance of waste C&T systems within the broader waste management context has often been ignored in past research. Laurent et al. (2014) conducted a review of 222 studies of solid waste management systems, and found that waste C&T processes were only mentioned in 63% of the studies, as some authors chose to exclude such processes based on the outcome of previous studies. Laurent et al. (2014) also found that the exclusion of C&T processes had weak foundations, and recommended case-specific evaluations before their dismissal.

Such recommendations are especially relevant in cases where different modes of collection can have significant effects on the integrated system as a whole. Aranda Usón et al. (2013) quantified the CO_2 emissions associated with different waste collection alternatives in different urban settings. Based on a case study in Spain, they found that when operating at 100% loads, stationary collection systems provided the best environmental performance compared to conventional systems.

When food waste is the major waste source being considered, C&T issues play an important role in the waste management strategy. In the United Kingdom for example, Iacovidou et al. (2012) found that food waste disposal (FWD) units mounted in household kitchens can optimize food waste management by relaying food waste to waste water treatment plants (WWTP). In Sweden, Bernstad (2012) analyzed several collection systems and determined that collection in paper bags results in the largest net avoidance of global warming, while vacuum collection results in the greatest avoidance of primary energy use. Bernstad (2013) evaluated an unconventional tank-connected food waste disposal system in Sweden, where the FWD units were connected to piping systems separate from the other wastewater piping in the buildings analyzed. Ground food waste was led to a settling tank from which supernatant was treated in a waste water treatment plant and settled matter was led to anaerobic treatment. The separated food waste sludge in this system was rich in fat and had high methane potential compared to more conventional food waste collection systems.

Developing countries such as China can learn from innovative experiments in food waste collection strategies such as those mentioned above. However, developing countries like China lack a framework to evaluate the performance of such initiatives when adopted in local contexts. This research paper contributes to the existing literature by using a novel performance indicator to analyze the environmental, economic and social performance of the waste collection system in a food waste treatment pilot project in China. This performance indicator provides a method to evaluate waste management systems.

2.1.2. Analysis of commercial food waste management

A strong commercial food waste management system must take many factors into account, including the selection of an appropriate management system; the efficiency and cost of waste collection; transportation and disposal; and the environmental and social impacts of the system. Chang et al. (1997) analyzed the economic and environmental impacts of different solid waste management systems and used a nonlinear programming model to determine the effects of separated regional collection methods on reducing operating costs. Amponsah and Salhi (2004) researched transport path problems in municipal solid waste C&T systems of developing countries, and found that developing countries were in urgent need of rational planning to calculate transport paths. Fraser Mcleod and Cherrett (2008) quantified transportation recovery systems and assessed the potential benefits of different waste collection methods. A study by Fan et al. (2006) showed that food waste source reduction, centralized recycling and waste-to-resource recycling were the future development trends in Chinese food waste management. Wang and Liu (2009) mainly focused on problems surrounding food waste recovery, channels, charge systems and subsidies, and designed an urban food waste grading recovery method. A study by Wang (2010) presented a simulation model and system optimization of Chengdu's food waste C&T systems.