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Sustainable Organic Waste Management Framework: A Case Study in Minhang District, Shanghai, China

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The high rate of population growth along with economic and industrial development especially in city areas have led to significant increase in the generation of municipal solid waste (MSW) in China. It has been a challenging task for government and municipalities to develop a sustainable solid waste management, especially in the developing countries. Organic waste predominates MSW composition across countries with different level of income. Due to the absence of waste segregation at source, China has 55.86 % of food waste (FW) from MSW with high moisture content. Composting is a viable technology to manage organic waste sustainably by transforming FW into organic fertiliser. This study focuses on the sustainable development of organic waste management model via large-scale FW composting based on a case study in Minhang District, Shanghai, China. The study evaluates the upstream, bio-waste management, and downstream level involved in the organic waste management along with the strategies implemented that will impact the sustainability of the framework, such as waste collection, availability of policy and incentive, the role of authority as well as compost quality and its market. The assessment of the sustainable model of organic waste management can be very beneficial for improving the compost application towards sustainable composting in the developing countries.

1. Introduction

Solid waste is an emerging global issue which is mainly affecting municipalities in many countries. It is a challenging task for municipalities to manage solid waste in the cities and implement an effective and sustainable system for the citizens. The annual generation of municipal solid waste (MSW) is increasing at an alarming rate especially in the fast-growing cities in the developing countries due to immense economic growth, rapid urbanisation and industrial development. The last report of The World Bank stated that the world cities have produced approximately 1.3 x 10^9 t/y or 1.2 kg/ca/d of MSW as of 2012, and this value is expected to reach 2.2 x 10^9 t by 2025 (Hoornweg and Bhada-Tata, 2012). Hoornweg and Bhada-Tata (2012) also reported that China has higher MSW generation compared to other Asian countries, as 70 % of the total waste generated in East Asia and the Pacific region is influenced by China. China has exceeded the US as the world's largest generator of waste in 2004 and it was forecasted that China will probably generate twice as much MSW as the US in 2030.

Organic waste is the major constituent of overall MSW in developing Asian countries. In China, the major component in the national waste composition is food waste (FW), which contributes around 55.86 % (Mian et al., 2017). The high organic waste ratio in China is likely because of the diet, which consists of more fresh vegetables and fruit, and preferences for unprocessed and unpackaged food (Zhang et al., 2010). The MSW composition in a country influences the technology selection for waste management treatment. The high organic content in the MSW has resulted in higher moisture content in the MSW composition that lowers the

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calorific value. This condition causes thermal treatment to be a less favourable choice, making biological treatment such as composting and anaerobic digestion (AD) more preferable (Pandyaswargo et al., 2012).

1.1 Composting as an alternative technology to treat FW

Compost is a product of biodegradation and mineralisation of organic matter. Lim et al. (2016) reported that composting can be considered as a sustainable method for MSW management, thereby a viable technology to treat the organic waste in the developing countries. Zulkepli et al. (2017) suggested that composting is the most feasible alternative in terms of economic and environmental as compared to AD, and the feasibility relies on the consistency and quality of compost produced as they drive the market of compost and its application. Aleluia and Ferrão (2017) reported that composting facilities have the least investment cost to treat waste compared to incineration plants, which has the highest capital cost among the four treatment methods assessed.

A study by Chen (2016) showed that FW composting is a reliable treatment method because of its simple process and ease of operation. FW recycling via composting can be valuable for agricultural activities and lead to lesser environmental impacts compared to other waste disposal methods, such as landfilling and incineration (Saer et al., 2013). Wong et al. (2017) reported that composting is a more applicable technology to treat organic waste and potentially can mitigate GHG emissions. The treatment of organic waste especially FW from the MSW can minimise waste disposal to the landfill and reduce resources consumption to produce beneficial compost.

1.2 The solid waste management system in China

Various approaches have been taken by the Chinese government including promoting the green economy (GE), developing industrial systems and encouraging social and market participation to handle solid waste problem (Tian et al., 2014). According to China Statistical Yearbook 2017, in 2016, the Chinese government has implemented several waste management systems, including landfill and incineration. Chinese solid waste management is dominated by approximately 70 % landfilling, whereas incineration and other treatments are 26 % and 4 %. The current distribution of solid waste management system is shown in Figure 1 (National Bureau of Statistics of China, 2017). Although the dependency on landfill and incineration increases over the years, poor treatment of leachate has been reported in most landfill sites and the majority of Chinese incineration plants have low heating value (Mian et al., 2017). As Chinese MSW has a higher portion of organic waste which gives negative impact on energy recovery via incineration and proper landfilling, alternative technology such as composting should be utilised. China today has composting plants that can process the segregated organic waste from sources upon collection, along with others that treat MSW especially kitchen waste collected in mass using mechanical equipment to screen off the organic fraction (Zhang et al., 2013). One of the conventional composting methods in composting plants in China is the large-scale trough composting under regular mechanical turning without forced aeration (Zeng et al., 2016).

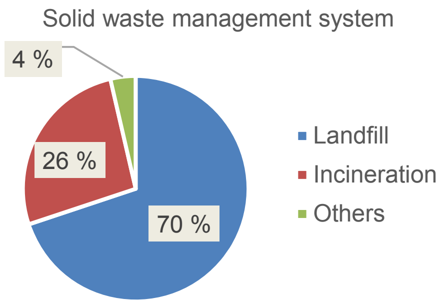

Figure 1: Solid waste management system in China

1.3 A case study in Minhang District: Large-scale composting scenario

This study has selected a large-scale FW composting plant in Minhang District, Shanghai, China as a case study. The plant, operated by Shanghai Wen Xin Bio-Tech Co., Ltd. (a subsidiary of Beijing Goldenway Bio-Tech Co., Ltd.), was built based on the government investment, specialised enterprise operation, and supervision by a third-party. The plant is fully automated and the main process system utilises aerobic biological humic acid fermentation technology in its reactors to process all types of FW and produce compost every day. It can process up to 200 t/d of FW to manage waste disposed of restaurant and kitchen within the district. The waste will undergo two screening processes to remove large substances, inorganic materials and water content. The second screening process usually removes 40 t of water which will go through waste water treatment, while 160 t is the remaining waste. There are currently 35 workers in the plant to handle the 160 t of waste, 5 managerial staff, and the rest are general workers. The technical team is based at their Beijing headquarter. The plant can efficiently process around 4 t of FW into 1 t of compost, i.e., 25 % waste-to-compost conversion efficiency. The products can be used for soil improvement and organic farming. The investment cost to set-up the plant to process up to 200 t/d of FW is 136 x 10^6 RMB. Although the plant is able to sustain its operation since its establishment in March 2017, only 90 % of revenue has been derived from selling compost, and another 10 % comes from government subsidies to top-up the balance.

2. Materials and methods

The study analysed the sustainable framework model of organic waste management of the present case study. The data source in this study are primarily from on-site visits of the plant and surveys with plant operators. Supplementary data were searched in the peer reviewed international journals and web sources. The overall methods of this study are shown in Figure 2.

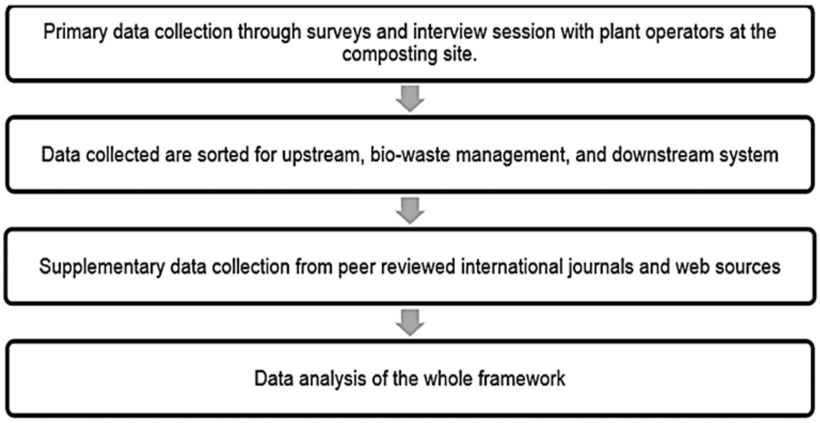

Figure 2: Overall methods of the present study

3. Results and discussion

Figure 3 shows the sustainable framework model of a large-scale FW composting operation based on the case study in Minhang District, Shanghai, China. Based on the primary data collection, the study analysed the components involved in the upstream, bio-waste management, and downstream systems to sustain the whole framework of organic waste management in Minhang District.

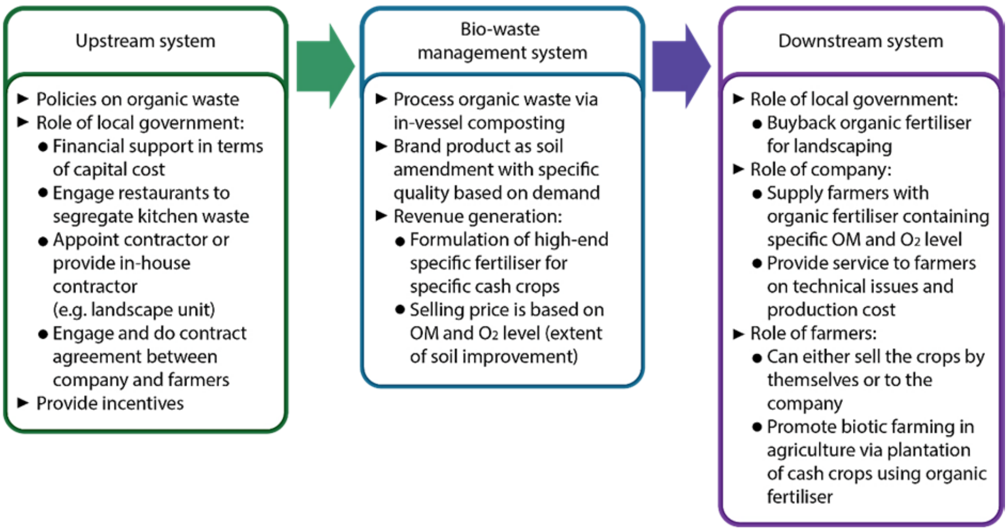

Figure 3: A conceptual model of organic waste management system in Shanghai

The system cycle is further visualised in Figure 4.

Figure 4: Sustainable organic waste management cycle

3.1 Upstream system

China has implemented a series of policies, plans and laws to regulate and control solid waste disposal by promoting the development of GE and green industries (Su et al., 2013). The large-scale FW composting can be a good commercial line of business if driven by established MSW legislations and progressive policies, specifically on environmental protection and FW recycling. The development of quality standards for organic waste treatment and compost production in the organic waste recycling sector has also generated bio-based economy in the country through agriculture.

The Chinese government has put great efforts in investing in MSW facilities and provided financial support through the centralised municipal budget for the local waste collection system resources to cope with the increasing amount of waste produced. The government has allocated 100 RMB/t for waste collection and transportation. If handled by the local private sector or industry, the government provides 200 RMB/t for waste collection and 100 RMB/t for waste transported.

Managing waste sustainably is a difficult job that requires appropriate technical solutions, sufficient organisational capacity, and the development of an effective working partnership among a wide range of stakeholders with MSW management. Under a commercialised MSW management model, the responsibility for managing MSW is shared among governments, enterprises and the public. In this case study, the plant is able to sustain its operation due to well-established framework system between the local government, industry, restaurant owners and the farmers. The municipal government has authority to engage with restaurants throughout the district and collect their kitchen waste, and appoint contractor to do daily collection of waste from the restaurants and send them to the processing plant using 10 t garbage trucks. The municipal government then works with the company to segregate the waste and use the segregated FW as a resource by composting waste in a large-scale composting plant and then sell the compost-based fertilisers to the farmers. The municipal government also provides assistance in quality control and helped the company to nationally market the compost-based fertilisers and for farmers to purchase them. These are achieved after the company signed a long-term contract with the government and farmers, which builds a public-private-community partnership. The contract is signed based on how much can the compost increase nutrient or improve the condition of the soil, in terms of organic matter (OM) increment rate over a large land area and over a certain period, i.e., 3 y.

3.2 Bio-waste management system

The main goal of a waste management system is to treat a certain amount of waste from the system in an appropriate way. From technical aspects, the company implements in-vessel composting that operates 2 batch/d, where a batch takes up to 12 h to process FW into compost. It has a parallel operation of 12 reactors, where each reactor can process up to 15 t/d of FW, which sums up to around 200 t/d. During first screening process, the waste is segregated in a vibrating rotary drum with 55 mm holes. The food waste enters the rotary drum and passes through the holes, while large substances (such as chopsticks, plastic and paper) remain in the drum. The large substances are sent to incineration plant for disposal. There are 7 incineration plants in Shanghai, each can process up to 20,000 t/d of waste. The screened FW then enters the digester for fermentation until it reaches a moisture content of 15 %, then another screening to remove inorganic materials and water content prior to entering the vessel for composting. Bulking agents of 15 % of total weight are used, which include rice bran and husk to increase the carbon-nitrogen (C/N) ratio from 15 to 25 and the aeration efficiency. On average, the end product has 75 % of OM and < 5 % of O_2 level.

The inoculum used has a concentration of 3 x 10^4 cfu/mL. It contains spore-forming bacteria that is activated by water steam at high temperature, thus it is heat resistant. No enzyme is added along the process. Compressor is used to pump air into reactor. Parameters are well-controlled to ensure optimum condition, i.e., level of O_2, moisture content and temperature are controlled and monitored. Functional curves on the O_2 supply timing, anaerobic timing and temperature growth curve are also monitored.

The company branded their products as a soil amendment. The agricultural department poses strict regulation on the license to produce bio-fertiliser or organic fertiliser. To generate more revenue, the company works on the formulation of high-end fertiliser with specific OM and O_2 content based on demand and sells the product to farmers who plant high-value crops such as herbs, tea, and fruits. Compost can be sold at an increased value, i.e., 1,800 RMB/t for base products, 3,000 – 4,000 RMB/t for soil amendment products used in vegetables and common crops plantation, and 6,000 RMB/t for specialised organic fertilisers.

3.3 Downstream system

The local government buy back the organic fertilisers from the company for landscaping purpose. Based on demand received from farmers, the company formulates organic fertilisers with specific OM and O_2 content to meet the nutrient requirements of certain cash crops, such as herbs and fruits. The selling price of the organic fertilisers is based on OM and O_2 level, which influence the extent of soil improvement. The company also provide services to farmers on technical issues and production cost. With the production of high-end specific organic fertilisers, the farmers pay based on the increased nutrient or improved soil condition, as well as increased percentage of OM over time. The utilisation of organic fertiliser containing high OM and O_2 level enhances soil condition, thereby promoting biotic farming. The farmers can either sell the crops by themselves or to the company.

4. Limitations and future work

The integration of some additional parameters can potentially improve further this present study. Acquiring certain primary data from a business corporation can be challenging due to limited access and confidentiality. Further research can be directed at identifying and describing the economic and environmental impact of FW composting. Extensive discussion on the waste water treatment system implemented at the plant can also be considered to expand the scope of the present study. A broader discussion of the waste management from a social point of view may also be of interest. The effort needed from society, e.g. farmers and households, may differ between different waste management strategies, and this most certainly can have a major influence on the framework.

5. Conclusion

The advancement of a high-quality MSW industry in China especially on organic waste management not only improves technology, social, financial and environmental efficiency, and promotes sustainable development, but can also hinder resource insufficiency and environmental deterioration. This paper has analysed the key drivers for developing a sustainable framework of organic waste management in Minhang District, which includes environmental policy and value of waste utilisation. Organic waste is composted and sold as high-value and bio-rich fertiliser, thus reducing emissions, cleaning up the city and generating jobs due to green and bio-based economy. As FW recycling trend is materialising, the potential of GE concept with relevance to organic waste minimisation in China should be examined. GE may develop sustainable business-driven opportunities through optimal resources consumption and utilisation which leads to minimal energy use and environmental impacts. In this case study, GE depends on well-established and excellent recovery system from restaurants within Minhang District which requires great support and involvement from the government as well as initiatives and engagement from business organisations and other private sectors. The continuous commitment and participation from the government, private sector and public have created a successful model of an organic waste management system that enables large-scale FW composting to be sustainable. They are essential elements that determine the success of a systematic commercial MSW industry that will create new prospects for environmental industries in China.

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