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A Review on the Economic Feasibility of Composting for Organic Waste Management in Asian Countries

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The rising rate of population growth and industrial development mainly in urban areas have led to significant increase in municipal solid waste (MSW) production. It has been a challenge to materialise a sustainable solid waste management notably in many developing countries. Organic portion represents a significant component in the municipal solid waste across countries with different level of income, ranging from about 25 to 70 %. Composting can be a viable option to manage waste sustainably by transforming waste into value-added fertiliser. Large-scale operation of composting is confronted with concern over feasible economic performance, which varied following different mode of operation. This study aims to review the economic feasibility (EF) on two different composting systems, which are the in-vessel and windrow system, implemented in several developed and developing countries. The review considered the cost factors for both composting systems, including the capital cost and operating cost. The return on investment (ROI) is estimated for both composting systems based on the potential cost benefits from the compost sale and the saving of waste tipping fee. This review provides a better insight into the desirability and applicability of both composting systems as an alternative to the landfilling practice. It is expected that the review of the various composting system could be very useful for improving the sustainable composting technology in the developing countries.

1. Introduction

The rising world population is among the factors that influence the principle of sustainable development. United Nations (2017) reported that world population had reached approximately $7.6*10^9$ people in 2017. It is estimated to achieve $8.6*10^9$ in 2030 and will amount to $9.8*10^9$ in 2050 and $11.2*10^9$ by 2100 due to enormous economic growth, rapid urbanisation and industrial development. Increased population poses significant challenges to the national and local governments, including the increase in municipal solid waste (MSW) production. The MSW management remains a challenging task in urban areas around the world, especially in the fast-growing cities in the developing countries.
The last report of The World Bank stated that the world cities have produced about $1.3*10^9$ t/y or 1.2 kg/ca/d of MSW as of 2012, and this value is expected to reach $2.2*10^9$ t by 2025 (Hoornweg and Bhada-Tata, 2012). They reported in the same year, the cost of solid waste management around the world is USD $205.4*10^9$ annually and will increase to about USD $375.5*10^9$ in 2025. The increasing generation of MSW and poorly developed MSW management may lead to higher budgets for municipalities in the developing countries to manage and dispose of solid waste. Inefficient MSW management may cause degradation of invaluable land resources, human health hazards and long-term environmental impacts. A sustainable and efficient MSW management strategy is required to balance the need for development, the quality of human life and the environment.
According to the Intergovernmental Panel on Climate Change (IPCC) (2006), MSW refers to the “waste collected by municipalities or other local authorities”. Despite having definition that varies by country, the IPCC definition of MSW typically includes the following waste streams: “food waste, garden and park waste, paper and

cardboard, wood, textiles, nappies (disposable diapers), rubber and leather, plastics, metal, glass (including pottery and china), and others (e.g., ash, dirt, dust, soil, electronic waste)". MSW usually excludes construction and demolition waste, as well as industrial and liquid wastes from municipal sewage networks.
The key factors that influence MSW composition are the level of economic growth, geographical location, culture, energy sources, and climate. As urbanisation occurs and population in a country prospers, inorganic materials consumption increases, while the relative organic fraction decreases. Low- and middle-income countries usually have a higher percentage of organic matter in the MSW stream compared to inorganic fractions such as paper, plastic, glass and metal, where these portions are higher in the MSW stream of middle- and high-income countries. Current estimation of organic waste ranges within about 25 to 70 % of the MSW across countries with different level of income as shown in Table 1 (Hoornweg and Bhada-Tata, 2012). Based on Table 1, low-income countries have the highest organic fraction of 64 %, while high-income countries have the least at 28 %. The total amount of organic waste is still the highest in these countries.

Table 1: Waste composition by income level of a country

Income level	Organic (%)	Paper (%)	Plastic (%)	Glass (%)	Metal (%)	Other (%)
Low income	64	5	8	3	3	17
Lower Middle Income	59	9	12	3	2	15
Upper Middle Income	54	14	11	5	3	13
High Income	28	31	11	7	6	17

The MSW in waste streams of some developing countries have high moisture content and low calorific value due to unsystematic MSW waste collection and lacks waste separation at source (Yadav and Samadder, 2017). High organic composition leads to the high moisture content in the MSW composition and lowering the calorific value. This condition causes thermal treatment to be a less favourable choice, making biological treatment such as composting and anaerobic digestion more preferable (Pandyaswargo et al., 2012).
Lim et al. (2016) reported that composting could be a sustainable method for MSW management. Their study shows that composting is more attractive compared to landfill due to the high degradation of organic waste and conversion of the waste into the value-added product. The dependency on landfilling to manage MSW can lead to some serious issues such as the emission of greenhouse gases from the site, leachate problems, and disturbing odour. Methane (CH_4), the major gas produced by the emission of greenhouse gases, is known to cause global warming. Other than the environmental pollution, opening any landfill sites can face several challenges due to land scarcity, high land price and negative perceptions of the surrounding community. Composting is valuable to agricultural land and leads to lesser environmental impacts compared to other disposal methods, such as landfill and incineration (Saer et al., 2013). The remediation of organic waste from the MSW can minimise disposal of waste to the landfill and reduce consumption of resources through the production of beneficial compost.
Composting is relatively low-cost. However, the profitability is sensitive to process scale, compost quality, selling price, the risk of heavy metal contaminants, and costs for waste segregation and collection. It can be implemented on a variety of scales, from small-scale systems in urban apartments to large-scale system for industrial farms. Pandyaswargo and Premakumara (2014) defined the scale of small-scale composting as maximum 5 t/d, medium scale as around 5 to 100 t/d, and large scale as >100 t/d of organic waste processed. There are a variety of techniques and approaches depending on the goals for composting, size of the composting system, specific requirements, as well as the availability of the necessary composting equipment. All of these criteria contribute to the economic feasibility (EF) of a composting operation and its impact on the environment. Aerobic composting has been widely reported as viable. Some studies have reported profit losses and the requirement of external subsidies to make composting operation economically feasible (Galgani et al., 2014), and cases where composting systems failed due to economic and technical reasons (Pandyaswargo and Premakumara, 2014).
EF determines the viability of composting (Lim et al., 2016). Various factors influence the EF of composting, including the cost of capital and operation of the plant, production processes, transportation, quality assurance, compost market and continuous chain of supply and demand of the feedstock and products. The involvement of government and private sectors, including policy maker and the public is essential to support waste segregation at the source to improve the EF of composting. Several case studies in Taiwan by Chen (2016) showed that three private composting plants were able to generate profit while other three government-affiliated composting system faced profit lose. The study also highlighted the relationship between production processes (full automatic, semi-automatic, and manual operation) and production cost. The production cost of compost

produced was reported to range from TWD 2,897–23,117 /t and sold within TWD 3,000 – 9,270 /t. In this study, the price of compost per t is considered low if it is below USD 50, medium within USD 50 to USD 150, and high if it is greater than USD 150.

Lim et al. (2016) addressed that compost quality defines the potential of marketing and the EF of the composting plant. A defined quality of compost sold in right market segmentation can create higher revenue to generate profit. The variety of composts available in the market nowadays, especially in the developing countries, are sold without proper labelling of the nutrient contents that indicates their specific uses. Lack of product labelling leads to the disadvantaged competition of compost in the fertiliser market.

The assessment of compost quality is complex and requires a significant cost to conduct a full range analysis. Among several views, maturity and stability of compost are usually evaluated to determine compost quality. Since there is a huge selection of available parameters to measure compost quality, Fan et al. (2016) outlined the minimum set of quality criteria that is critical to be assessed to reduce the cost of analyses.

Some studies have reported the EF of composting operation using organic waste from MSW around the world, only a few studies have focused on Asian countries. Most reported studies did not address the critical factors causing the success or failure of the composting facilities. Most studies have not analysed the thresholds on the minimum scale required to achieve good feasibility or identify the key drivers for a viable industrial scale composting system.

The aim of the present study is to review the economic performance and profitability of the composting operation at various scales and modes in several Asian countries.

2. Materials and methods

The study analysed the EF of composting operation at different scales in several Asian countries, based on a various composting system such as the windrow system and another composting system. The study focused on the composting of organic fraction from MSW. Case studies were searched in the peer reviewed international journals and web sources such as Google Scholar, ScienceDirect using the keywords “Economic”, “Composting”, “MSW” and “Country Name” of all the selected countries in Asia, i.e., China, Taiwan, Malaysia, Indonesia, and Sri Lanka. The overall methods in the present study is shown in Figure 1.

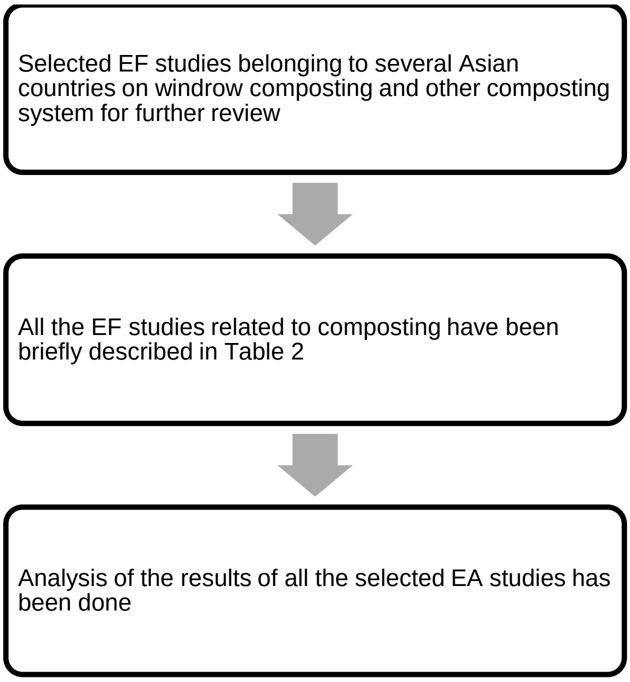

Figure 1: Overall method of the present study

3. Results and discussion

A range of composting case studies in several Asian countries is shown in Table 2. The studies reported different composting systems implemented at different scales and potential profits, arranged in ascending compost output capacity.

Table 2: Case studies on composting in several Asian countries

Author	Country/ State	Operating mode	Incentive/ Subsidy	Input capacity* (t/d)	Scale	Compost output capacity* (t/d)	Compost selling price** (USD/t) [price category]	Profitability & payback period
				Windrow Composting System				
Pandyaswargo and Premakumara (2014)	Indonesia	Government affiliated	Yes	0.6	Small	0.1	70 [Medium]	Yes (6 y)
Chen (2016)	Taiwan	Government affiliated	Yes	9	Medium	3.6	93 (TWD 3,000/t) [Medium]	No
		Private firms	No	50	Medium	27	94 (TWD 3,040/t) [Medium]	Yes (55 y)
Pandyaswargo and Premakumara (2014)	Indonesia	Government affiliated		200	Large	30	106 [Medium]	Yes (6 y)
			Other Composting System (e.g. in-vessel composting, bin composting)					
Zulkepli et al. (2017)	Malaysia	Government affiliated	Yes	0.2	Small	0.05 (18 t/y)	250 (MYR 1,000/t) [High]	Yes (N/A)
Chen (2016)	Taiwan	Government affiliated	Yes	1.5	Small	0.2	93 (TWD 3,000/t) [Medium]	No
Pandyaswargo and Premakumara, (2014)	Sri Lanka	Private firms	Yes	1	Small	0.3	180 [High]	Yes (7 y)
Chen (2016)	Taiwan	Government affiliated	Yes	8	Medium	2	93 (TWD 3,000/t) [Medium]	No
		Private firms	No	5	Small	2.36	287 (TWD 9,270/t) [High]	Yes (13.6 y)
Pandyaswargo and Premakumara (2014)	Indonesia	Government affiliated	Yes	51	Medium	15.3	53 [Medium]	Yes (3 y)
Chen (2016)	Taiwan	Private firms	No	100	Medium	50	124 (TWD 4,000/t) [Medium]	Yes (110 y)
Pandyaswargo and Premakumara (2014)	China	Government affiliated	Yes	638	Large	465.4	7.8 – 12.6 [Low]	No

* All units are converted to t/d unless the values are initially stated in t/d by the authors (conversion to t/d is based on 365 d/ y)

** All currency is converted to USD unless the values are initially stated in USD by the authors (approximate conversion value: 1 USD = 32 TWD in 2016, 1 USD = 4 MYR in 2017)

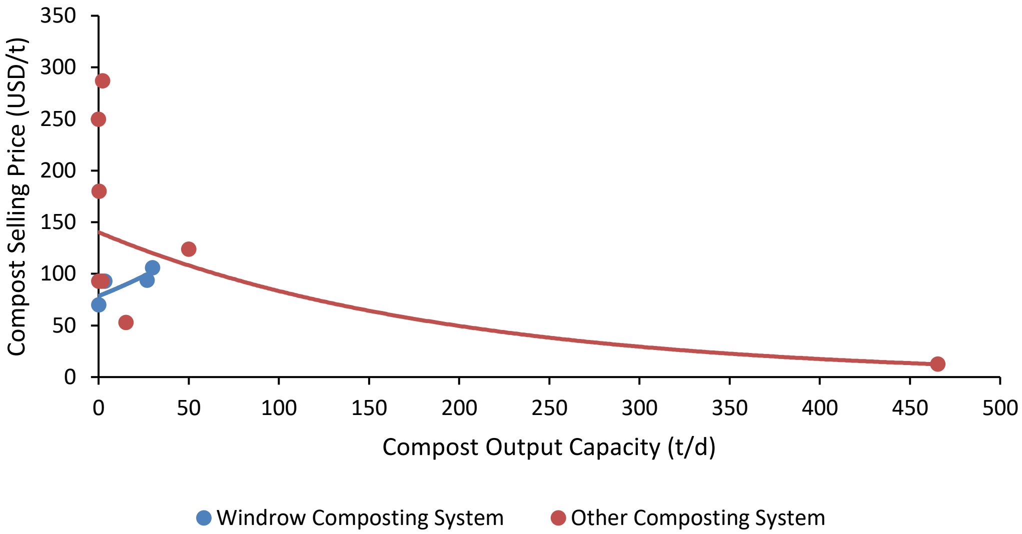

Figure 2: Selling price of compost versus compost output capacity of the composting facility, using windrow composting and another composting system

Several case studies of composting plant in Asian countries have been reported where a variety of composting systems are operating using windrow and other composting systems, in small to large scale. The performance of the operating modes between government affiliated composting units and private firms are compared, by selecting composting facility with various capacity. Based on Table 2, all private firms are making a profit, although some have a long payback period. All private firms are selling compost within medium to high price range to achieve maximum profit. One of the case studies on private firms by Chen (2017) in Taiwan is reported to sell compost at the highest price compared to other private facilities. The selling price reaches USD 287/t due to direct marketing method employed by the facility to avoid the distribution cost. Chen (2017) reported that the other two private firms sell their compost through wholesale systems with a wholesale price of USD 94/t and USD 124/t. In a Sri Lankan case study by Pandyaswargo and Premakumara (2014), the high selling price of compost set at USD 180/t was due to the good compost quality certified by the Ministry of Agriculture and efficient marketing programme. These case studies suggest that the selling price of compost set by private composting facilities can vary greatly, depending on marketing strategies and compost quality.

In comparison, the government affiliated facilities have reported losses due to a lower selling price of compost, which gave a low revenue that is insufficient to sustain the composting operation. Chen (2016) reported some case studies based on three government affiliated composting facilities, where the compost produced by all these facilities are not sold, but gave away to farmers who have involved in waste recycling as part of the national development program. The selling prices for the compost produced from these facilities were lower compared to the selling prices set by the private firms in Taiwan. No financial pressure or profit motives existed in these facilities, as there is no market-oriented objective. Most of the government affiliated composting facilities reported lower price range for the composts (from low to medium) as compared to the private composting facilities. Only Zulkepli et al. (2017) reported a rather high price of compost (USD 250 /t) from the government affiliated facility, although the reason is not clearly stated. Most of the government affiliated composting facilities are barely making any profit, they receive external subsidies or financial support from the government or agencies.

The results in Table 2 showed that most of the medium-scale composting plants have an optimal opportunity for being financially feasible as compared with the smaller and larger capacity plants. The scale of composting plant is one of the key factors to be considered at the initial stage of planning composting plants. Other factors include incentives or subsidies given, compost marketing and selling price, which may drive the feasibility of the composting plant.

Based on Figure 2, the results show that the compost output capacity of other composting system influence the compost selling price, as higher output leads to a lower compost selling price. However, composting facilities utilising windrow system showed inconsistent results, where in some cases, the price of compost increases as the output capacity increases. The potential interferences may be caused by the incentives given or compost quality. More data are needed for the case studies using windrow composting especially regarding their capacity and compost quality.

4. Conclusion

The review of EF in several Asian countries shows the general economic performance of composting plant operating in different operating mode and scales. The results suggest that composting facilities can obtain profits due to medium scale and compost market value. As private firms usually do not receive external subsidies and are more business-oriented, they tend to sell compost at a higher price and better quality to sustain the composting operation as compared to government affiliated facilities that receive financial support or subsidies. It is important to enhance the quality of compost so that compost price can be set higher to generate higher revenue and to improve the long-term economic feasibility for the compost business. Future study will study more critically on the inter-relations of compost price and quality, site selection to minimise the transportation cost, and incentive needed to sustain a viable organic waste recycling facility.

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