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Review

Environmental challenges impeding the composting of biodegradable municipal solid waste: A critical review

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ABSTRACT

Biodegradable material, primarily composed of food waste, accounts for 40–70 wt% of municipal solid waste (MSW) in developing countries. Therefore, to establish a sustainable waste management system, it is essential to separate and recycle biodegradable organic material from the municipal waste stream. Of all the recycling methods, composting is recommended due to its environmental and economic benefits. However, compared with readily recyclable materials (e.g., paper, metals, etc.), recycling/composting biodegradable MSW presents a great challenge to furthering the promotion of waste recycling.

This review provides a systematic analysis of organic waste sorting and recycling/composting practices in several countries: the UK, US, Japan, and China. Compared to the great efforts that have been made in developed countries for the promotion of waste composting, much less has been achieved in developing countries. For example, the MSW composting rate in China decreased from 10% to less than 2% in the past 15 years, and similar trends may exist in other developing countries. Therefore, it is essential to identify the barriers that impede waste composting and predict developing trends. This article emphasizes environmental challenges (i.e., odor, bioaerosols, and heavy metals), focusing on their generation and control strategies, in an effort to identify barriers hindering MSW composting. Successful practices in several European countries suggest that source-separated composting presents many advantages over mechanical-separated composting. This may partially be ascribed to the fact that source separation of organic waste can prevent contact with heavy metal-bearing items, resulting in the production of high-quality compost. Mixed collection MSW normally contains significantly higher concentrations of heavy metals, which could affect the marketing of composting products. Moreover, source separation of organic waste can minimize waste pretreatment operations, leading to lower bioaerosol and malodor generation during composting. Implementing source separation of MSW in more countries would increase the amount of organic waste available for composting. In addition, attention should focus on secondary pollutant production for proper composting management. Finally, setting standards for end product quality control is highly recommended for controlling both marketing and environmental risks.

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1. Introduction

There has been increasing attention on improving the management of the organic fraction of municipal solid waste (OFMSW). Biodegradable material, especially food waste, normally accounts for over 50 wt% of the municipal/residential waste stream in less developed countries (Alexis and James, 2009; Tai et al., 2011; Thi et al., 2015). Thus, diversion of organic material from the waste stream, by either source separation or centralized mechanical separation, is a prerequisite for further treatment by more environmentally friendly methods, such as composting. Composting is a method of waste recycling based on the biological degradation of organic matter under aerobic conditions, producing stabilized and sanitized compost products. Diverting municipal solid waste (MSW) organic material from landfills by composting has many environmental benefits, such as reducing greenhouse gas emissions (USEPA, 2015), decreasing leachate quantities once discarded in landfills (Adhikari et al., 2009), and increasing the calorific value of feedstock to generate more energy in case of incineration (Zhou et al., 2014). The United States Environmental Protection Agency (USEPA) calculated the improvements in greenhouse gas production associated with the recovery of organic matter from MSW by composting. According to the results, over 22 million tons of food waste and yard trimmings were composted in the USA in 2013, providing an annual reduction of more than 2.74 million tons of carbon dioxide equivalent emissions, comparable to removing the emissions from over 528,000 passenger vehicles in 1 year (USEPA, 2013). From a lifecycle perspective (Laurent et al., 2014; Eriksson et al., 2015), other benefits, such as the production of compost that can potentially be used as organic fertilizer or for soil amendments, can also be derived from the diversion of organic material from landfill disposal or incineration. Adding compost to soil provides nutrients for plant growth, improves the soil structure, increases the water retention capacity, and reduces the reliance on fossil-fuel-based fertilizers (Jordão et al., 2006; Chen et al., 2015; Hernández et al., 2015). Centralized composting has been adopted in many regions worldwide to divert organic waste (e.g., green waste, kitchen waste, etc.) from landfills and incinerators (Eurostat, 2015). Removing green waste, such as yard trimmings, sweeping waste, and garden waste from the municipal waste stream has long been implemented in North America (Levis et al., 2010; USEPA, 2013) and some European countries, including the UK, Germany, and Spain (Slater and Frederickson, 2001). However, food waste diversion lags far behind green waste diversion. Regardless, great efforts to recycle food waste for composting have been undertaken, especially in several European countries. The Landfill Directive (1999/31/EC) and Waste Framework Directive (2008/98/EC) require European Union (EU) member states to reduce the amount of biodegradable municipal waste sent to landfills and recycle organic fractions using more environmentally benign options. In the past two decades, EU member states have adopted a series of measures to comply with such targets. For example, more stringent landfill tax policies have been adopted by more than 20 countries to minimize the biodegradable municipal waste sent to landfills (Fischer et al., 2012). In addition, separate collection of organic waste has been implemented in half of the EU member states. Specifically, door-to-door food waste collection systems have been established in 13 member states, and an additional two member states operate door-to-door collection systems for garden waste alone. Meanwhile, 12 EU member states do not collect organic waste separately in their primary collection system (Seyring et al., 2015). Finally, setting standards for the end-products of composting is a key element in promoting sustainable organic material recycling. Such criteria include national compost quality assurance systems and Europe-wide quality assurance for compost (i.e., the “Standardization & Quality Assurance” directive developed by the European Compost Network) (ECN, 2014).

Various environmental issues may arise during the composting process, including the formation of malodorous or toxic gases (Komilis et al., 2004; Mao et al., 2006; Maulini-Duran et al., 2014a), bioaerosols (Albrecht et al., 2007; Sykes et al., 2011; Wéry, 2014), and dust (Byeon et al., 2008; Sykes et al., 2011), resulting in occupational health risks or disturbance to nearby residents (Sykes et al., 2007; van Kampen et al., 2012; Pearson et al., 2015). This is especially pertinent to composting plants operated in open spaces. Moreover, waste-derived compost may elevate heavy metal concentrations in soil and food products cultivated in soil amended with MSW compost (Smith, 2009). Composting, when managed appropriately, is a sustainable waste management option that has various benefits, including reducing greenhouse gas production and improving soil quality when used as a soil amendment. However, when improperly managed and performed, composting may lead to the above-mentioned environmental issues.

This article provides a critical review of MSW composting practices in developed and less-developed countries, the environmental and ecological impacts of MSW composting and compost due to chemical or biological contaminants, their control strategies, and compost quality control measures. Such information may be particularly useful in assisting less developed countries seeking to upgrade their sustainable waste management strategies.