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Review

Sustainability of using composting and vermicomposting technologies for organic solid waste biotransformation: recent overview, greenhouse gases emissions and economic analysis

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ABSTRACT

Organic solid waste poses a serious threat to the environment as the world struggles to keep up with its rapid generation. Biological waste treatment technologies such as composting and vermicomposting are widely regarded as a clean and sustainable method to manage organic waste. The focus of this review is to evaluate the feasibility of composting and vermicomposting as a means to recover nutrients from the organic waste and returning them to the environment. The environmental impact and economic potential of these processes are also discussed. This review shows that composting and vermicomposting are capable of degrading various types of organic waste, thus enabling them to be adopted widely. The present review also reveals that greenhouse gases are emitted during composting and vermicomposting processes. However, introductions of intermittent aeration, bulking agents and earthworm abundance may reduce the greenhouse gases emissions. Economic assessments of composting and vermicomposting technologies show that these technologies are generally viable except in some cases. The differences are due to the wide range in market value for organic fertilizer and differences in cost for the type of composing or vermicomposting system which could affect its economic feasibility. However, if organic fertilizer value increases and carbon offsets are available for nutrient recycling, it will affect the economic feasibility in a positive way.

Contents

1. Introduction

World cities generate approximately 1.3 billion metric tons of solid waste annually, which is almost double the amounts that

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Table 1
Current and projected waste generation rates and composition by income level (adapted from Hoornweg and Bhada-Tata, 2012).

Income level		Urban population (millions)	Waste generation rates (kg/capita/d)	Solid waste composition (%)						Total organic solid waste volume (t)
				Organic	Paper	Plastic	Glass	Metal	Others	
Lower	Current	343	0.60	64	5	8	3	3	17	48×10^6
	2025	676	0.86	62	6	9	3	3	17	132×10^6
Lower Middle	Current	1293	0.78	59	9	12	3	2	15	218×10^6
	2025	2080	1.30	55	10	13	4	3	15	526×10^6
Upper Middle	Current	572	1.16	54	14	11	5	3	13	131×10^6
	2025	618	1.60	50	15	12	4	4	15	180×10^6
High	Current	774	2.13	28	31	11	7	6	17	169×10^6
	2025	912	2.10	28	30	11	7	6	18	192×10^6

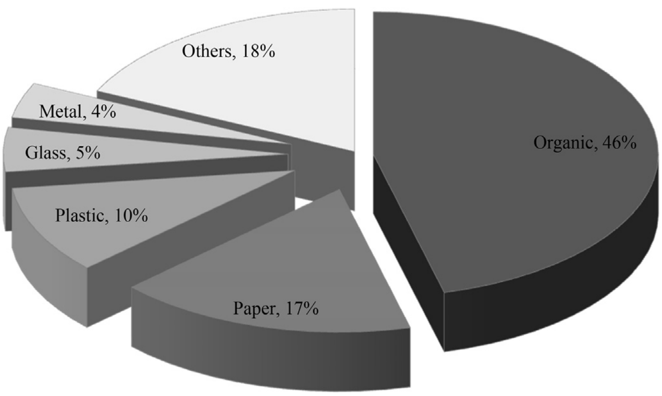

Fig. 1. Global solid waste composition (adapted from Hoornweg and Bhada-Tata, 2012).

were generated a decade ago (Hoornweg and Bhada-Tata, 2012). By 2025, solid waste generations will double again (Hoornweg et al., 2013). The annual increase in solid waste generation is inextricably link to the rapid rise in global population and rate of urbanization. As a country urbanizes, its standard of living and income level increases which leads to higher consumption of goods and services, thereby generating larger amount of solid waste per capita (Hoornweg and Bhada-Tata, 2012). Table 1 shows the current and projected waste generation rates according to income level. The waste generation rates in 2025 are predicted to be 38–67% increase of the current waste generation rates for the lower to middle income countries. In higher income countries, as their total population are largely urban population (Hoornweg and Bhada-Tata, 2012), the waste generation rates have more or less stabilized during the last decade (UNEP, 2011). Although higher income countries generate more solid waste, they recycle more and have the resources to deploy new technologies for treating their waste, which eventually decrease waste generation and disposal (Sim and Wu, 2010). On the contrary, developing countries generally do not have the technical skills nor financial capability, leading to limited resources for safe disposal of final waste. The limitations of resources in developing countries to manage organic waste pose a significant challenge that needs to be resolved (UNEP, 2011).

Among the total solid waste generated globally, organic waste is the largest proportion with 46% (Fig. 1) (Hoornweg and Bhada-Tata, 2012). The organic waste includes food scraps, yard waste and agricultural waste. The rest of the waste is inorganic like paper, plastic, glass, metal and others (Karak et al., 2012). As the income level of a country increases, the waste stream composition also changes and typically has lower proportion of organic waste. The proportion of organic waste in low income countries is 64% and this value reduces to 28% in higher income countries (Table 1) (Hoornweg and Bhada-Tata, 2012). Slight reduction in proportion of organic waste in low to high income countries are projected in 2025. However, the amount of the organic waste is increasing together with the total amount of solid waste. Solid waste generation rates are predicted to be exceeding 11 million metric tons per day, which are more than three times the current rate of solid waste generation using 'business-as-usual' projections by the year of 2100 (Hoornweg et al., 2013).

Current methods of solid waste managements are landfilling, incineration, recycling, reuse, source reduction and others (Wu et al., 2014). Both landfilling and incineration are characterized as waste disposals, which are the least preferred options in the waste management hierarchy. In many parts of the world, landfilling remains the dominant method for waste disposal as it is the cheapest in terms of capital costs (Laner et al., 2012). In developed countries, the landfills are equipped with a combination of waste containment systems such as leak detection and management systems for collecting leachates and biogas (Hoornweg and Bhada-Tata, 2012). On the contrary, proper landfilling is often lacking in developing countries (Hoornweg and Bhada-Tata, 2012). In recent years, controlled landfilling in these countries is increasing (Sim and Wu, 2010) but open dumping is still a common practice (Hoornweg and Bhada-Tata, 2012). Management of leachate is also a problematic issue because the raw leachate contains high organic load in chemical oxygen demand (Romero et al., 2013), which requires proper management and disposal that will add cost to the landfill operation (Závodská et al., 2014). Greenhouse gas emissions due to solid waste decomposition in the landfill is also a cause for concern (Pozza et al., 2015). In addition, most landfills in the developed countries require proper maintenance and continuous care after their closure. Therefore, extra costs are needed for landfill aftercare until no threat to the human health and environment is found (Laner et al., 2012). Furthermore, the limitation of land and the value of waste as resources are concrete reasons to move away from landfilling and shift towards more sustainable waste management strategy (Marshall and Farahbaksh, 2013). For example, European countries are doing away with the landfill owing to the EU Landfill Directive which requires its member states to reduce landfilling of biodegradable waste to less than 35% of the amount produced in 1995. Countries such as Austria, Belgium, Denmark, Germany, Luxembourg, Netherlands and Sweden have fulfilled and exceeded the targets of the EU Landfill Directive (EEA, 2009). Currently, Netherlands are landfilling only 2–3% of its total waste (Scharff, 2014). In addition, recent study done by Yang et al. (2015) also showed that over the next 10–15 years, an increase in the proportions of incineration and composting is more feasible than landfilling in municipal solid waste management.

Scarcity of land for landfilling leads to another waste disposal option like incineration. Waste incineration could be the solution for reducing the degradation of land, generation of methane gas