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Research paper

Assessing the potential of coal ash and bagasse ash as inorganic amendments during composting of municipal solid wastes

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ABSTRACT

This study investigates the potential of incorporating inorganic amendments such as coal and bagasse ashes in different composting mixes. 10 different composting mixes were assessed as follows: A-20% bagasse ash (BA) with unsorted municipal solid wastes (UMSW); B-40% BA with UMSW; C-UMSW; D-20% BA with sorted municipal solid wastes (SMSW); E-40% BA with SMSW; F-SMSW; G-20% coal ash (CA) with UMSW; H-40% CA with UMSW; I-20% CA with SMSW and J-40% CA with SMSW. The composting processes were carried out in rotary drum composters. Composting mixes D, F, G and I achieved a temperature above 55 °C for at least 3 days, with the following peak temperatures: D-62 °C, F-57 °C, G-62 °C and I-58 °C. D resulted in the highest average net Volatile solids (VS) degradation of 68.6% and yielded the highest average volume reduction of 66.0%. The final compost from D, G, I, C and F were within range for electrical conductivities (EC) (794–1770 μS/cm) and pH (6.69–7.12). The ashes also helped in maintaining high average water holding capacities within the range of 183–217%. The C/N ratio of sorted wastes was improved by the addition of 20% coal ash and bagasse ash. Higher germination indices, above 0.8 were obtained for the ash-amended compost (D, G, I), indicating the feasibility and enhancement of using bagasse and coal ash as inorganic amendment in the composting process. Regarding heavy metals content, the chromium concentration for the composting mix G was found to be the highest whereas mixes D and I showed compliance with the MS (Mauritian Standards) 164 standards.

1. Introduction

The deposition of combustion ashes in water bodies and on waste lands has raised the risks and hazards to which people are exposed with regards to the environmental health complications (Earth Justice, 2009). In Mauritius, two types of combustion ashes are generated– coal ash and sugar cane bagasse ash emerging from the combustion of coal and sugar cane bagasse, respectively, for the production of electricity. The sugar factories in Mauritius co-generate electricity from bagasse and coal for use in the factories itself and the excess electricity is sold to the national grid. Sugar cane bagasse is the fibrous residue left after the crushing and extraction of juice from sugar cane stalks during the manufacture of raw sugar. With fossil fuels reserves starting to dwindle, it has been become more sustainable to reutilize this residue as biomass fuel for energy supply. Mauritius has always promoted the incineration of bagasse for the production of electricity during the crop season, and this process usually results in the yearly generation of about 20,000 tons of bagasse ash from sugar industries (Oogathoo, 2012). Coal, on the other hand, other than being utilized by sugar industries during the intercrop season, is also the major fuel used whole-year round by other electricity production facilities.

According to the The Outlook For Energy (2012) electricity generation will make up 40% of the world energy consumption. Mauritius experienced an increase of 43.7% in energy import bills from the year 2009–2010 and expects an annual energy growth of 6% (Statistics, 2010). Planned economic activities will continue to stimulate the demand for more energy (Elahee, 2012) and as a result induce increased consumption of coal and bagasse as fuel input. While the use of these energy resources is increasing, the task of securing the repository of the resulting wastes, i.e. the ashes, has become an urgent task (Mehta, 1984; Yeon and Kim, 2011).

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Dumping in landfills has long been a common practice. However, considering the hazardous characteristics of ashes, such act is now being restricted by regulations through a rise in landfill disposal costs (Nurmesniemi et al., 2005). The combustion ash can also be used in road construction, reclaiming of acid mine sites and in the reduction of acid mine drainage. However, leaching from improperly lined surface is very probable (Bruder-Hubscher et al., 2001; Dick et al., 1999; Tedesco et al., 1999). While innovative uses including the use of ashes to adsorb heavy metals from contaminated soil and water also emerged, the disposal of the used adsorbents remained a problem leading back to the same initial issue of ash management (Balsamo et al., 2011; Gupta et al., 2012; Lin et al., 2008).

Past studies have indicated the possibility of incorporating ashes in composting processes. The aerobic composting process is a proven technically and economically viable technique for the treatment and sanitization of biodegradable solid wastes fractions (Gajalakshmi and Abassi, 2008; Bhattacharya and Chattopadyay, 2004). Wong et al. (2009), Komilis et al. (2011), Zhou et al. (2014), López et al. (2015) and Mancebo and Hettiaratchi (2015) have equally performed extensive experimental analysis and assessment of the composting dynamics of different organic residues consisting of food wastes, dewatered sludge, food wastes/sawdust/herbal residues and final composts, respectively. By overriding the option of waste incineration, the adoption of composting technology itself reduces the amount of ash being produced (Beffa, 2012). Belyaeva and Haynes (2009) studied the potential of composting the green fraction of municipal solid wastes with coal ash to produce top soil for landscaping and observed that coal ash had improved the water holding capacity of the end product. According to Kuba et al. (2008), nutrients and micronutrients in ashes can be used as fertilizers, either in its pure or pelleted forms, or in combination with other materials. Koivula et al. (2004) found that the presence of coal ash in the composting of source-separated catering waste improved the extent of mineralization of the organic matter in compost and enhanced the formation of humic acids. Wong and Fang (2000), Ravikumar et al. (2008) and Fang et al. (1997, 1998, 1999) suggested that coal ash may reduce the metal stability of the composting mass. Zeng et al. (2003) emphasized on the rough porous nature of coal ash that helped to improve ventilation. Ravikumar et al. (2008) and Punjwani et al. (2011) observed an increase in the content of macro and micro-nutrients with addition of coal fly ash in the composting of organic residues. Jameel et al. (2004) investigated the application of bagasse ash in calcareous soils and noted a positive impact on the soil structure and an enhanced nutrient availability.

Composting recently emerged as an appropriate technology to alleviate solid waste management in Mauritius (Mohee et al., 2012). The national composting plant in Mauritius is projecting to compost around 180,000 tons of Municipal solid wastes (MSW) per year by 2014 (Mohee et al., 2012). In that context, the amount of coal and bagasse ashes can be reduced by incorporating these ashes as amendments in MSW composting process so as to improve the compost quality and stabilization time. Hence, in line with the actual situation and the future targets of the composting facility, this study investigated the effects of coal ash and bagasse ash additions on the composting process of sorted and unsorted wastes.

2. Materials and methods

2.1. Substrates

100–200 kg of bagasse fly ash and coalfly ash and 50 kg of bagasse bottom ash and coal bottom ash were collected from thermal power plants in Mauritius. Fly ash is the powdery portion of ash captured in the thermal power plants' emission control systems while bottom ash is the coarse granular material collected in a hopper at the bottom of the furnace.

Municipal solid wastes were obtained from the composting facility of Solid Waste Recycling Limited. Two types of MSW were utilized:

1 **Unsorted MSW** which is the state in which the composting station receives the wastes and usually consist of a mixture of organic wastes (food remnants, vegetable & fruit wastes, paper, yard wastes etc) and inorganic wastes (plastics, gravels, textiles, metals, glass, cans, dirt, debris etc). Typical composition of MSW in Mauritius is represented in Fig. 1 below (Mohee and Rughoonundhun, 2006):
2 **Sorted MSW** which comprises of the organic fraction of MSW only.

All preliminary tests on samples were carried out at Solid Waste Recycling Limited over 2 months.

2.2. Ash application rates

Table 1 gives details on the ratio of the ashes and wastes used for the 10 composting setups. The coal ash and bagasse ash comprised 80% fly ash and 20% bottom ash on a dry mass basis, respectively.

2.3. Ash characterisation

The ashes were characterized for moisture content, volatile solids content (VS), nitrogen content, bulk densities, pH and electrical conductivity (EC). Since the ashes were being tested for their composting properties, the standard methods for monitoring composting parameters (Table 2) were utilized.

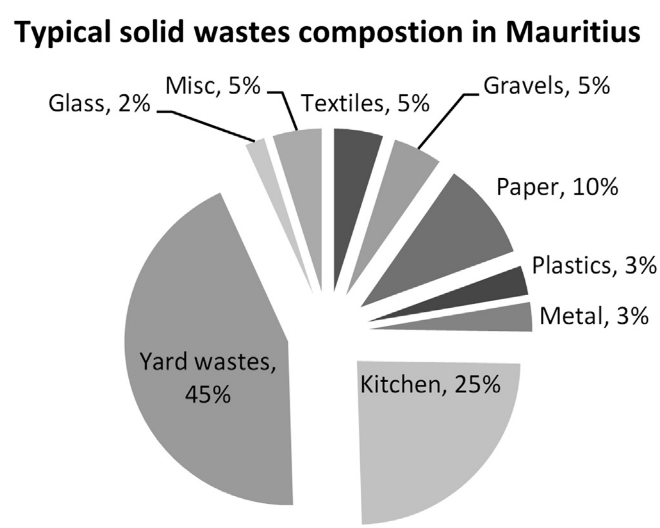

Fig. 1. Typical solids wastes composition in Mauritius.

Table 1
Application rates of bagasse and coal ash.

Main substrate	Control	Application of bagasse ash		Application of coal ash	
	(0% ash)	(20%)	(40%)	(20%)	(40%)
Unsorted MSW	C	A	B	G	H
Sorted MSW	F	D	E	I	J