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Biostabilization of municipal solid waste fractions from an Advanced Waste Treatment plant

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Abstract Controlling the safe disposal of Municipal Solid Waste (MSW), especially the biodegradable fraction, is an important goal of waste management. This study reports the effects of using composting to biostabilize the biodegradable fraction of MSW sourced from an Advanced Waste Treatment plant in Australia. The impact of biostabilization on the initial aerobic degradation of the material showed a reduction in oxygen consumption of 30% (230 g O_2/kg loss of ignition (LOI)) in immature compost and 45% (181 g O_2 kg^{-1} LOI) in mature compost when compared with the input material (330 g O_2/kg LOI). Anaerobic tests showed a reduction in biodegradability of 40% in the immature compost with biogas production 250 L/kg LOI compared with 50% in mature compost with biogas production of 218 L/kg LOI. The results confirm that the biostabilization of the biodegradable fraction of MSW diverted from landfill can result in a significant reduction of greenhouse gas emission.

1. Introduction

Modern landfills have been the principle method for disposing of Municipal Solid Waste (MSW) in many countries for over a century. However, recent decades have seen a change in attitudes towards landfills, caused by environmental issues surrounding the use of a landfill, including the production of landfill leachate, odour and methane (Ying et al., 2012; Farombi et al., 2012; Mor et al., 2006; Cossu et al., 2003). In addition, MSW disposal and treatment processes release substantial amounts of greenhouse gases which are considered as one of the most important anthropogenic sources of green-

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house gases (Tian et al., 2013). For example, in the United States, landfills contribute 17.5% of total methane gas emissions, representing the third-largest anthropogenic source of CH_4 emissions (USEPA, 2014).

Although, the issues associated with landfill are generally historic (Christensen and Kjeldsen, 1995), the legacy of the environmental issues from non-sanitary landfills has resulted in the development and use of alternative methods for the utilization of waste (Adani et al., 2000; Zhen-Shan et al., 2009). The aim of waste management of MSW has therefore been refocused to further reduce the environmental and health impacts of MSW. Legislation and regulations have reinforced the development of techniques for appropriate waste disposal, centred on waste minimization, recycling and recovery of materials, resulting in the minimization of MSW entering landfills (Leao et al., 2001). For example, decreasing allowances for landfilling the biodegradable fraction of the MSW (BMW) have been set in the UK under the National Landfill Allowance Schemes (DEFRA, 2006). Controlling the safe disposal of MSW, especially the biodegradable fraction, is an important goal of waste management. As leachate, odour and methane production represent the main environmental impacts of landfilling of MSW, studies have focused on the applications of processes such as composting that reduces these impacts. Compositing therefore represents an important component of an Advanced Waste Treatment (AWT) facility.

Composting has been proposed as a cost effective method that minimizes waste landfill impact using biological processes (Mohee and Soobhany, 2014; Ball et al., 2000b; Bernal et al., 2009). In AWT plants, waste minimization through recovery and recycling are capable of diverting around 80% of MSW away from landfills; composting of the BMW plays an important role in this diversion, typically converting around 10–15% (w/w) of the incoming MSW to compost and plant nutrient products. Generally in AWT plants, the initial shredding, mixing and composting is carried out in-shed or in-vessel in order to control odour and other environmental impacts while also maintaining optimal compost temperatures (55 °C) over the first 3–4 weeks; the maturation phases (typically lasting 8–12 weeks) normally occur outside due to decreased impacts and space restrictions.

During composting, aerobic biological treatment occurs resulting in a biostabilized product; the degree of the impact will depend on the level of stability reached (Scheelhaase and Bidlingmaier, 1997). To assess the potential impact of composting and the biostabilization process on the reduction in gaseous emissions such as carbon dioxide, respiratory measurements have routinely been used (Ball and Drake, 1998; Ball et al., 2000a). However, aerobic respiratory measurements do not provide information on any residual anaerobic biogas production which remains a key environmental factor associated with the landfilling of MSW. Therefore, residual biogas production tests have been developed, such as the Biochemical Biomethane Potential Test (BM100) (Wagland et al., 2009; Godley et al., 2005). These tests allow the measurement of biogas production that can potentially be produced from a known quantity of BMW (Godley et al., 2007).

The aim of this study was to assess the impact of biostabilization of the organic waste fraction through composting of MSW at a full scale AWT plant in Australia. Respiration and residual biogas production were determined during the process to provide a measure of the potential impact of the biostabilized products compared to the incoming material thereby assessing the environmental benefits of this treatment. To the best of the authors' knowledge, this is the first study which examines the impact of biostabilization of organic waste under both aerobic and anaerobic conditions using material from a full scale commercial Advanced Waste Treatment Plant.

2. Materials and methods

2.1. Sampling

Samples were collected, screened, weighed and prepared on-site at an Advanced Waste Treatment Facility in Australia. Advanced Waste Treatments are integrated systems designed to take the complex and varying mix of materials that make up what we know as waste and do three things: (1) recover useful products from the waste, (2) stabilize the waste to minimize environmental impacts, and 3) reduce material to landfill.

Fig. 1 shows the outline of the process for the conversion of MSW through to mature compost. The incoming MSW arriving on site was sampled immediately after the waste had passed through the pre-sort/bag opener, by random grab sampling. Unsuitable material (e.g. batteries, electronics) was manually removed during sorting prior to sampling. Immature compost was sampled from the end of the conveyor leaving the in-vessel composting tunnel, again using multiple grab sampling. Mature compost material was similarly taken from the most mature compost material (samples taken at 10–30 cm depth in the windrow) that was ready for screening in the outside compost rows. The volume of material collected at each stream varied from 14 kg (immature compost) to 26 kg (mature compost) (Table 1). Samples were transported to the laboratory via courier overnight on the day of sampling in sealed containers.

2.2. Analysis of sieved MSW material

Upon arrival samples were screened through 5 mm sieves and the contents separated according to the composition of the material (Table 1). The moisture content of each sample was determined following overnight drying in an oven at 70 °C. Loss on ignition was determined by placing dried material in a muffle furnace at 550 °C for 3 h. Total Kjeldahl nitrogen and total organic carbon content of dried and ground samples (using a pestle and mortar > 2 mm particles) of the three substrates were analyzed using standard laboratory protocols to provide additional data regarding the C:N ratio of the material (Table 1). All analyses were carried out in triplicate.

2.3. Testing of aerobic biostabilization

The aerobic biostabilization (DR4) test was adapted from the standard compostability ASTM D 5975–96 test (ASTM, 2004). Test organic waste material (BMW fraction from input MSW, immature compost and mature compost; 100 g dry matter) was mixed with commercially sourced mature compost (RICHGRO Organic Compost, used as a microbial inoculum; 100 g dry matter). The moisture content was adjusted and maintained at 50% (w/w) (Environment Agency, 2005). Ammonium chloride and sodium dihydrogen