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Performance of different systems for the composting of the source-selected organic fraction of municipal solid waste

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Performance of three pile composting systems at field-scale were studied and compared in the composting of source-selected organic fraction of municipal solid waste (OFMSW): turned pile (TP), static forced-aerated pile (SAP) and turned forced-aerated pile (TAP). Routine parameters such as temperature, oxygen content, moisture and porosity were monitored. Temperature was found to be higher in turned systems whereas oxygen content was higher in forced-aerated systems. Although the initial air-filled porosity (AFP) for all mixtures was high, around 70%, the material tended to compact in the static system. A high degree of heterogeneity was found in the non-turned system. Extent of biodegradation was measured by respiration techniques (from 5.3 to 1.1 mg [O_2] g [organic matter {OM}]$^{-1}$ h^{-1} in TP and from 4.7 to 0.7 mg [O_2] g [OM]$^{-1}$ h^{-1} in turned forced-aerated pile). The non-turned compost showed a low level of stability (3.6 mg [O_2] g [OM]$^{-1}$ h^{-1}) and the lowest maturity grade (I) measured by the self-heating test. In forced-aerated systems a low intermittent aeration rate of 1 l kg [volatile solids {VS}]$^{-1}$ min^{-1} (5 min on, 30 min off) proved to be excessive, causing major water losses and hampering moisture control. Comparison of the results obtained for TP and TAP demonstrated that the investment cost in a forced-aeration system is not necessary for this waste. Hence, turned systems are recommended for OFMSW pile composting.

1. Introduction

According to European legislation (Directive 99/31/EC) the total amount of organic matter (OM) disposed in landfills must be gradually reduced. Many studies have shown that municipal solid waste (MSW) contains a high proportion of organic materials, from 50 to 65% (Tchobanoglous *et al.*, 1993). The source-separated organic fraction of municipal solid waste (OFMSW) presents 80–95% of organic material. This fraction can be treated and managed instead of being sent to landfills or incinerated. Composting and recovering of organic material is an available technology which redirects a significant fraction of the organic wastes stream from landfills.

Composting is an aerobic thermophilic process, which requires oxygen to stabilize the organic wastes and optimal moisture content for the microorganisms' development (Haug, 1993). The common control variables at compost facilities are temperature, oxygen and moisture. The final product, the compost, is a stable, sanitised and humus-like material (He *et al.*, 1995; Chefetz *et al.*, 1996).

Composting stages are common for all composting systems. Initially high microbial activity produces heat which causes

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Nomenclature

AFP	air -filled porosity
MSW	municipal solid waste
OFMSW	organic fraction of municipal solid waste
OM	organic matter
OUR	oxygen uptake rate
SAP	static forced-aerated pile
SRI	static respiration index
TAP	turned forced-aerated pile
TP	turned pile
VS	volatile solids

temperature within the compostable material to rise rapidly into the thermophilic range (above 45 °C). Usually temperature increases up to approximately 60 °C and remains there for several weeks depending on the size of the system and the composition of the raw materials (Finstein *et al.*, 1980). After the rapidly degradable components are consumed, heat generation gradually declines during the maturation stage (Kaiser, 1996). At the end of this stage, the material is no longer self-heating, and the finished compost is ready for use (Barrena *et al.*, 2006a).

Nowadays, several composting methods are applicable, and the selection of the method is dependent on the investment cost, operation cost, time required to reach compost stability and maturity, the availability of land and origin of raw materials. Among all the available composting methods, open-air pile systems are the most simple and require the lowest investment (Haug, 1993).

Several methods have been used to provide oxygen to composting material. In the passive aeration method, oxygen supply is achieved by means of the natural convective movement of the air through the pile (Mason *et al.*, 2004). The size and porosity of the pile should be adequate to enable the aeration (Szanto *et al.*, 2007). Turned composting methods are passively aerated but additional turning is used to maintain the proper porosity, to provide oxygen, to mix the material and to release excessive heat, water vapour and other gases (Haug, 1993). This method is the most common method to produce compost from organic wastes (Avnimelech *et al.*, 2004). In static forced-aerated pile (SAP) composting, forced aeration is applied through air ducts, and aeration is provided by blowing or sucking air through the composting material (Haug, 1993).

Forced-aeration systems are claimed to enhance the process, and the active decomposition period can be reduced by almost 50% in the aerated static pile system compared to a turned system (Epstein *et al.*, 1976, 1978; Finstein *et al.*, 1980). This reduction in active composting time is not only due to the aeration method used but it also depends on the other interactive factors controlling the composting process. Some studies have been published on the biological treatment of mechanically separated OFMSW (Norbu *et al.*, 2005). However, there are only few systematic works on the comparison of composting systems for source-selected OFMSW published (Castaldi *et al.*, 2008), which is an emerging material in European countries according to Directive 99/31/EC. In this work, a global biological tool such as respiration index was used to measure the extent of biodegradation and to compare the composting systems.

The main physical factor affecting the oxygen distribution in the organic matrix to be composted is its porosity. Porosity depends on the particle size, the structure of the particle and the water availability (Agnew & Leonard, 2003; Richard *et al.*, 2004). Different authors suggest different values for minimum air-filled porosity (AFP) requirements within 30–60% (Haug, 1993; Annan & White, 1999). Also, mechanical strength must be adequate to reduce compaction over the process. The loss of material porosity during the process and the formation of preferential air path flows have been reported (Veeken *et al.*, 2002; Cayuela *et al.*, 2006). Pile turning can help to reduce compaction (Alburquerque *et al.*, 2006).

The main objective of this work is to systematically analyse and compare the three pile composting configurations most widely used at composting facilities, i.e. turned pile (TP), static forced-aerated pile (SAP) and turned forced-aerated pile (TAP), in terms of evolution of temperature, oxygen concentration, moisture content, OM content, AFP and time required for material stabilization measured according to the respiration index.

2. Materials and methods

2.1. *Composted materials and operation performance*

Three different piles were built in two composting plants: the TP was located at the Jorba composting plant (Barcelona, Spain), while the SAP and the TAP were processed at the La Selva composting plant (Girona, Spain). The volume of the three piles was approximately 200 m^3. They were built according to the windrow method with a trapezoidal shape of the following approximate dimensions: base: 4 m; height: 2 m; length 30–40 m. The piles were built on a slightly sloped concrete floor. Both plants were covered to avoid the effect of rainfall on the piles.

Each pile was built using 70–80 tonnes of OFMSW collected from surrounding municipalities during a week. OFMSW presented a 12–15% (by weight) of non-compostable fraction. The main characteristics of the used feedstock are presented in Table 1. In both composting plants, the OFMSW was mixed with wood chips from shredded pallets used as bulking agent at a volumetric ratio of 1.5:1 (OFMSW: bulking agent), as this is the optimised ratio used in the facilities were the trials took place for source-selected OFMSW composting.

In both turned pile systems (TP and TAP) turning was performed daily in the first two weeks, and every 2–3 days after two weeks and until the end of the process. This is a high turning frequency which is normally used in highly heterogeneous materials such as OFMSW (Barrena *et al.*, 2006b). Turning was carried out by using a Backhus turner Model 15.5 (Edewech, Germany).

Forced air in both aerated piles (TAP and SAP) was provided in cycles of 5 min on and 30 min off (fixed rate) during the first 50 days of process and 5 min on and 60 min off during the remaining period (total composting time was 90 days). Air