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Research article

Comparative evaluation of aeration methods for municipal solid waste composting from the perspective of resource management: A practical case study in Tehran, Iran

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ABSTRACT

During four months of practical composting examination, common aeration techniques including forced aeration static pile, pile turning, natural ventilation static pile and a combination of pile turning and natural ventilation static pile were investigated to determine the most appropriate method for a full-scale composting procedure using the organic fraction of Tehran's municipal solid wastes. The results of measured parameters such as temperature, pH, electrical conductivity (EC), C/N, and main nutrients including nitrogen, phosphorus and potassium suggested that both forced aeration and pile turning have efficacy in terms of final compost quality although pile turning showed better results for agricultural applications nevertheless significant energy consumption and pollutant emissions were associated with them. The combination of pile turning and natural ventilation could solve the problem of long degradation time and concurrently guarantee the acceptable quality of finished compost for agricultural purposes. Furthermore, this combinative method showed a specific energy consumption as low as 0.218 MJ per kg-dry and had a potential to save 288.8 kg-CO2/ha by applying the achieved compost on the farm in order to replace the chemical fertilizers.

1. Introduction

The most applicable disposal method for the organic fraction of municipal solid waste (MSW) especially at large cities is considered to be biological conversion (Montejo et al., 2013; Visvanathan et al., 2005). As an attractive, low-cost method, composting may be introduced as one of the fittest methods that can treat organic wastes, increase soil organic content and protect the environment (Haug, 1993). Composting even proved its priority over incineration in case of final treating the anaerobic sludge in terms of economical consideration (Cukjati et al., 2012). However, in order to achieve a compost product with high quality, efficient composting techniques should be employed (Cukjati et al., 2012; Cezaro et al., 2015).

Nowadays, several composting methods are applicable, and selection of the method depends on the investment and operational cost, time required to reach compost maturity, the availability of land and the origin of raw materials. Among all the available composting methods, open-air pile systems are the simplest and require the lowest investment (Haug, 1993). Several aeration techniques for open-air pile composting including either forced or passive aeration have widely been investigated in the literature (Imbeah, 1998; Stentiford, 1996; Sanchez-Monedero et al., 2001; Cayuela et al., 2005; Ogunwande and Osunade, 2011; Getahun et al., 2012).

Each of the aeration methods has been shown to be suitable for a wide range of substrates. The composting process with forced aeration static pile (FAS) acts faster than the natural ventilation static pile method (NVS) in the maturation of compost (Stentiford, 1996). Furthermore, FAS has been defined as a useful method for reducing nitrogen losses by volatilization (Sanchez-Monedero et al., 2001). However, it has some disadvantages compared with pile turning (PT), regarding the limited homogenization of the pile and formation of thermal stratifications. On the other hand, the

Abbreviations: CPN, Combination of pile turning and natural ventilation; EF, Emission factor; EPA, Environmental Protection Agency (USA); FAS, Forced aeration static pile; MOE, Ministry of Energy (Iran); NVS, Natural ventilation static pile; PT, Pile turning; TWMO, Tehran Waste Management Organization.

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main disadvantages of the pile turning method are the difficulty in controlling the temperature and the loss of nitrogen during the turnings (Cayuela et al., 2005; Getahun et al., 2012). Volume reduction is predictable in different composting methods however, pile turning has shown more reduction tendencies in comparison with the others (Yue et al., 2008). A comparison between forced aeration and natural ventilation techniques was performed by Larney et al. (2000) through which, larger changes in physical properties of beef manure were observed by FAS. Passive aeration for poultry slurry showed to be more effective than FAS and NVS in nitrogen conserving and high temperature maintenance (Sartaj et al., 1997; Fernandes and Sartaj, 1997).

A wide variety of studies have been conducted on different aeration methods, but few studies have focused on a combination of such methods. A combination of composting methods, such as forced aeration with pile turning, proved to be an effective approach to an increased volume reduction (Lopez-Real, 1990).

The MSW processing facility of Tehran, the capital of Iran that receives about 7500 tons daily was selected as the investigation site for this research work. Since more than 65 percent of Tehran's MSW are putrescible materials there is a remarkably high potential for biological treatment (TWMO, 2008). The aim of the present study was to examine the effects of three different conventional aeration methods and for the first time a combination of pile turning and natural ventilation method (CPN) on the finished compost quality as well as indentifying the most suitable technique in terms of energy consumption and its associated carbon emissions. During this study several parameters were measured in monthly intervals at a real scale facility to evaluate the methods' performance and to determine the most efficient one to be used for compost production from organic fraction of municipal solid wastes (OFMSW) under the dominant conditions of Tehran.

2. Materials and methods

2.1. Experimental procedure

At the time of study, PT and FAS were being used as the predominant methods for biological treatment of OFMSW in the composting site of Tehran's waste management organization, located 10 km south-east of Tehran. Four different piles each by approximately 95 m^3 volume were built on a layer of finished compost in order to prevent leachate penetration into the ground. The experimental piles were tried to be established in most appropriate situation to the real ones in terms of pile sizes, aeration flow and turning periods according to the other scientific studies with similar scopes whilst temperature rises might not be achieved using smaller dimensions (Cezaro et al., 2015). Three piles were examined to evaluate the NVS, PT and FAS methods and the fourth pile was used to evaluate the combination of PT and NVS methods (CPN). The experimental set-up as shown in Fig. 1 aimed to scale up the results and compare the outcomes of the experienced techniques to the CPN method.

Perforated polyvinyl chloride (PVC) pipes of 90 mm diameter were laid along the beds of the piles for NVS and FAS methods in order to prepare a better air distribution. The organic fraction of MSW (OFMSW) were collected from local sources after passing through conventional sorting including drum screens by 80 and

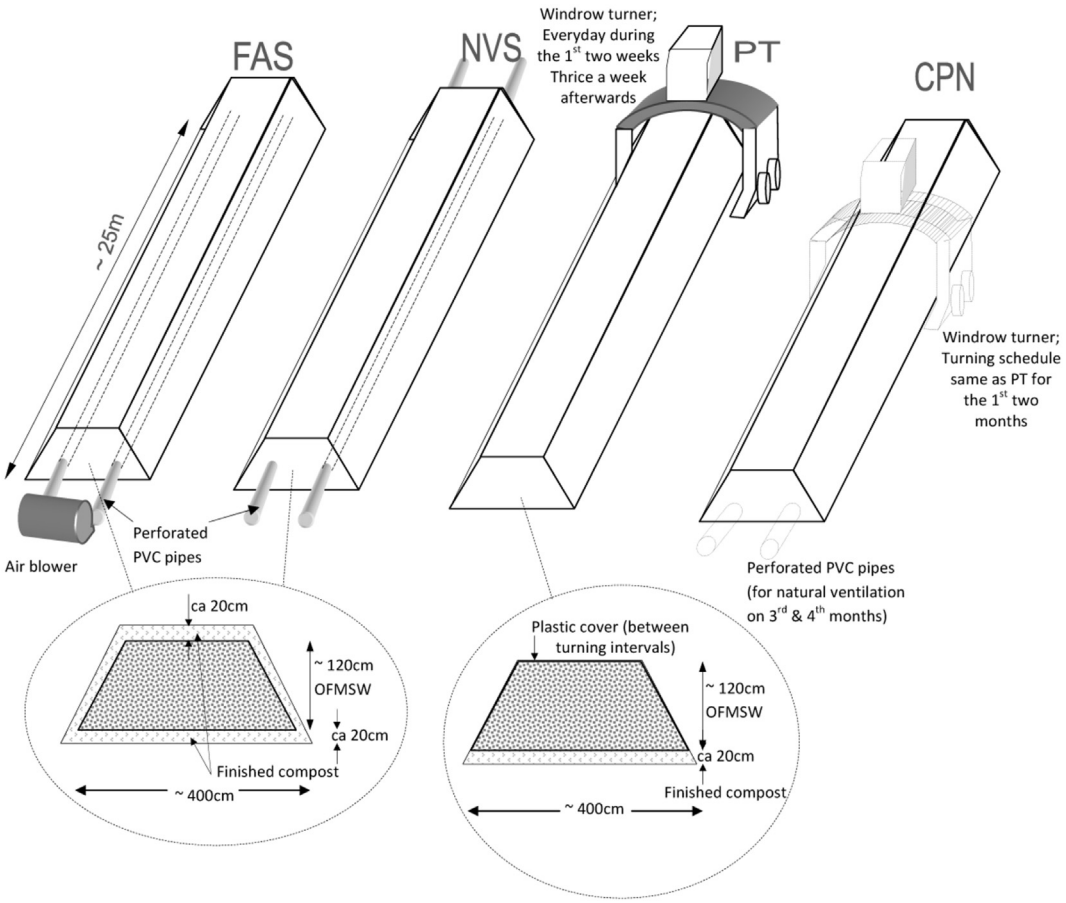

Fig. 1. Graphical description of the experimental arrangement.

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