Waste Management 34 (2014) 1381–1390

Contents lists available at ScienceDirect

Waste Management

journal homepage: www.elsevier.com/locate/wasman

Effects of bulking agent addition on odorous compounds emissions during composting of OFMSW

Li-Ming Shao [a,b], Chun-Yan Zhang [a], Duo Wu [a,c], Fan Lü [a,c], Tian-Shui Li [a,c], Pin-Jing He [a,b,*]

[a] *Institute of Waste Treatment and Reclamation, Tongji University, 1239 Siping Road, Shanghai 200092, PR China*
[b] *Centre for the Technology Research and Training on Household Waste in Small Towns & Rural Area, Ministry of Housing and Urban-Rural Development of PR China (MOHURD), 1239 Siping Road, Shanghai 200092, PR China*
[c] *State Key Laboratory of Pollution Control and Resource Reuse, Tongji University, 1239 Siping Road, Shanghai 200092, PR China*

ARTICLE INFO

Article history:
Received 30 October 2013
Accepted 14 April 2014
Available online 10 May 2014

Keywords:
Organic fraction of municipal solid waste
Composting
Odorous compounds emissions
Volatile organic compounds
Rice straw

ABSTRACT

The effects of rice straw addition level on odorous compounds emissions in a pilot-scale organic fraction of municipal solid waste (OFMSW) composting plant were investigated. The cumulative odorous compounds emissions occurred in a descending order of 40.22, 28.71 and 27.83 mg/dry kg of OFMSW for piles with rice straw addition level at ratio of 1:10, 2:10 and 3:10 (mixing ratio of rice straw to OFMSW on a wet basis), respectively. The mixing ratio of rice straw to OFMSW had a statistically significant effect on the reduction of malodorous sulfur compounds emissions, which had no statistically significant effect on the reduction of VFAs, alcohols, aldehydes, ketones, aromatics and ammonia emissions during composting, respectively. The cumulative emissions of malodorous sulfur compounds from piles with the increasing rice straw addition level were 1.17, 1.08 and 0.88 mg/dry kg of OFMSW, respectively. The optimal mixing ratio of rice straw to OFMSW was 1:5. Using this addition level, the cumulative malodorous sulfur compounds emissions based on the organic matter degradation were the lowest during composting of OFMSW.

1. Introduction

Odor is an unavoidable form of secondary pollution generated during composting of organic waste. Laboratory and field monitoring data have shown that odorous compounds emitted from composting process include several inorganic and organic compounds, such as ammonia, hydrogen sulfide, volatile organic sulfides, volatile fatty acids (VFAs), alcohols, aldehydes, ketones, terpenes, aromatics and amines (Komilis et al., 2004; Soupramanien et al., 2010; Sironi et al., 2007). Current methods employed to control odor emissions during composting include airtight composting reactors, gas collection with negative pressure and deodorization processes. However, these approaches are limited by aeration conditions and gas collection efficiency of the composting reactor, especially during periods of intense odorous emissions. Moreover, these approaches require wind-induced fan and other equipment, which affects the cost-effectiveness of the treatment.

The emissions of odorous compounds during composting are known to be affected by the operating conditions (Delgado-Rodríguez et al., 2011; Fraser and Lau, 2000; Müller et al., 2004). A series of monitoring data found that the emissions of odorous compounds were related to the composting stages (Eitzer, 1995; Hanajima et al., 2010; Kumar et al., 2011; Pagans et al., 2006a; Turan et al., 2007). Specifically, odorous compounds were mainly emitted in the mesophilic and thermophilic phases, while they decreased obviously in the curing phase, indicating that the odorous compounds emissions were closely related to the rapid biodegradation of organic matter. Previous studies showed that odorous compounds were mainly formed under anaerobic conditions (Homans and Fischer, 1992; Schlegelmilch et al., 2005). These findings indicated that the formation of odorous compounds was related to the oxygen content in the composting pile, which was affected by the aeration intensity, content of easily biodegradable organic matter and porosity of the composting pile (de Guardia et al., 2008; Madejón et al., 2002; Scaglia et al., 2011; Vandergheynst et al., 1998). Therefore, changing the ratio of easily biodegradable organic matter in the raw material mixtures for

---

Abbreviations: AT_4, cumulative respiration index; DM, dry matter; OFMSW, organic fraction of municipal solid waste; TN, total nitrogen; TOC, total organic carbon; TP, total phosphorus; VFAs, volatile fatty acids; VOCs, volatile organic compounds; VS, volatile solids.

[*] Correspoding author at: Institute of Waste Treatment and Reclamation, Tongji University, 1239 Siping Road, Shanghai 200092, PR China. Tel.: +86 21 65986104; fax: +86 21 65986104.

E-mail address: solidwaste@tongji.edu.cn (P.-J. He).

http://dx.doi.org/10.1016/j.wasman.2014.04.016
0956-053X/© 2014 Elsevier Ltd. All rights reserved.

composting may enable control of odorous compounds production and emissions from the source.

Many studies have been conducted to investigate the configuration of raw materials for composting. However, they have primarily been designed to accelerate the degradation of organic fraction of solid waste (Cabeza et al., 2013; Kulcu and Yaldiz, 2007; Petric et al., 2009), or to increase the stability of the compost (Doublet et al., 2010; Ponsá et al., 2009; Troy et al., 2012). To date, few studies have investigated the relationship between the configuration of raw materials and odorous compounds emissions, especially for those processes carried out in the pilot-scale composting plants.

This study was conducted to investigate in a pilot-scale OFMSW composting plant using the rice straw as a bulking agent. The rice straw was mixed with OFMSW in different proportions to form raw mixtures with different porosity and initial content of easily biodegradable organic matter, which were then used as raw materials in the composting experiments. According to the sampling and analysis of the odorous compounds in the exhaust gases during the forced aeration process, the comparative analysis was then conducted to evaluate the emission fluxes of odorous compounds from the composting piles with different mixing ratios of rice straw to OFMSW during composting. The present study will contribute to the understanding of the mechanism for the formation of odorous compounds and the development of a new method for controlling the emissions of odorous compounds during composting.

2. Materials and methods

2.1. Experimental equipment

The experiment was carried out in an OFMSW composting treatment plant located in Shanghai, China. The plant contained 20 separated concrete chambers used for composting, each of which was 3 m long and 1.2 m wide. Perforated ventilation pipes were installed below the composting chambers, and a gravel layer was provided to form a ventilation layer. Additionally, the top of each composting chamber was equipped with an exhaust gas collection cover. An air blower provided oxygen via the aeration pipes, while the gas collection cover was equipped with an induced draft fan that actively collected and pumped the exhausted gases from the composting piles to biofilters composed of mature compost for deodorization. The air blower pump and the induced draft fan were run coordinately by means of intermittent operation. The aeration rate of each composting chamber was set at 0.45 m^3/min.

2.2. Experimental materials

The OFMSW used in this experiment was separately collected from the residential area of the town. The average content of the OFMSW was food waste (87% w/w), napkins (about 8% w/w), and stems and leaves of plants (about 5% w/w). The main component of the waste were easily biodegradable organic matter (Table 1). The rice straw used as a bulking agent was mixed with OFMSW in different proportions. Before mixing, the rice straw was crushed to a length of 2–5 cm. The characteristics of the OFMSW and rice straw are listed in Table 1.

2.3. Experimental design

Three treatments were established, with wet mass ratio of rice straw added to OFMSW being 10%, 20% and 30%, respectively. The composting duration was set at 20 days. The operating parameters are shown in Table 2. The porosity of the composting pile was calculated by Eq. (1).

$$\text{Porosity} = \left(V_m - \left(\frac{M_w}{D_w} + \frac{M_s}{D_s}\right)\right) \Big/ V_m \tag{1}$$

where V_m is the initial total volume of the composting pile (m^3); M_w is the initial total weight of water of composting mixtures (kg); M_s is the initial total weight of dry solids of composting mixtures (kg); D_W and D_s are the density of water and dry solids, respectively, which are assumed to equal 1.0×10^3 and 0.5×10^3 kg/m^3, respectively.

The amount of OFMSW collected and treated differed to some extent each day, which led to the different aeration rates and heights of the three composting piles. Nevertheless, the aeration rate and height of each composting pile were still within the suitable scope of operating conditions for composting (Ministry of Construction of the People's Republic of China, 1993).

2.4. Experimental monitoring

The temperature of the composting piles was measured and recorded automatically through the electrical resistance thermometer located in the center of the piles. The oxygen content of the composting piles was measured using a sampling tube inserted in the center of the pile and a manually operated suction sampler with an oxygen content determinator (CYS-1, Xuelian Co., China). Temperature and oxygen content were recorded prior to each aeration operation.

2.5. Sampling and analytical methods

2.5.1. Solid samples

About 1 kg of raw materials was placed in each mesh bag and placed in the center of the piles. The bag was then removed at various composting times and their contents were analyzed. The cumulative respiration index (AT_4) was determined as previously described by He's method (He et al., 2006), which was expressed as g of oxygen consumed per kg of dry composting mixtures (g O_2/kg dry composting mixtures). The moisture content was determined by air-drying at 70 °C for 48 h. After air-drying at 70 °C for 48 h, the rice straw and OFMSW in the composting mixtures samples were separated by manual sorting, and then the VS was measured for individual fractions, respectively. VS was analyzed by loss on ignition at 550 °C to the constant weight. The degradation rate of VS for the samples was calculated by Eq. (2) (Haug, 1993).

$$\text{VS degradation rate} = \frac{(VS_m\% - VS_p\%) \times 100}{VS_m\% \times (100 - VS_p\%)} \tag{2}$$

where VS_m is the VS content at the beginning of the process; VS_p is the VS content at the end of the process.

Table 1
Characteristics of OFMSW and rice straw.

Parameters	TOC (% DM)	TN (% DM)	TP (‰ DM)	Protein (% DM)	Polysaccharide (% DM)	Moisture content (%)
OFMSW	30.7–33.7*	2.54–2.84	5.89–6.00	18.3–19.5	9.9–10.9	79.21–81.22
Rice straw	41.2–42.4*	1.02–1.14	0.18–0.20	3.2–3.6	24.2–25.0	6.73–7.04

Abbreviations: TOC: total organic carbon; DM: dry matter; TN: total nitrogen; TP: total phosphorus.

* The number indicated the range index of the OFMSW and rice straw used for composting in three consecutive days. There were no statistically significant differences in all the indexes of the OFMSW collected in the three consecutive days in this study ($p > 0.05$).