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Application of a recyclable plastic bulking agent for sewage sludge composting

Hai-Bin Zhou [a], Chuang Ma [a,b], Ding Gao [a,*], Tong-Bin Chen [a], Guo-Di Zheng [a], Jun Chen [a], Tian-Hao Pan [a]

[a] Center for Environmental Remediation, Institute of Geographic Sciences and Natural Resources Research, Chinese Academy of Sciences, 11A Datun Road, Beijing 100101, PR China
[b] Zhengzhou University of Light Industry/Collaborative Innovation Center of Environmental Pollution Control and Ecological Restoration, Henan Province, Zhengzhou 450001, PR China

HIGHLIGHTS

- A recyclable plastic bulking agent (RPBA) was developed.
- The RPBA improved oxygen diffusion and water removal during sludge composting.
- The RPBA could be reused to reduce the cost of the composting process.
- An optimal size and the addition ratio of the RPBA were given.

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ABSTRACT

A recyclable plastic bulking agent (RPBA) that can be screened and reused was developed to improve sludge composting and to reduce costs. Two RPBAs were developed: RPBA35 (35 mm in diameter) and RPBA50 (50 mm in diameter). The objective was to study the influence of size and quantity of RPBA on temperature, oxygen content, water removal during sludge composting, and phytotoxicity of the compost. RPBAs of both sizes improved the temperature, oxygen supply, and water removal compared with the treatment with no RPBA, and obtained phytotoxic-free compost. RPBA50 more effectively removed water than RPBA35. Oxygen diffusion rate in the composting pile containing RPBA50 was higher than in the treatment with no RPBA. When the RPBA50: sludge mixture ratio was above 1:1.5, the period over which the temperature exceeded 55 °C was insufficient to meet the harmless treatment requirement. The water evaporation rate was highest at a ratio of 1:2.

1. Introduction

Composting is a major method of sewage sludge treatment. Dewatered sewage sludge cannot be composted alone due to its high moisture content (MC, about 80%) and poor air permeability. It needs to be mixed with materials such as bulking agents to improve the final quality of the compost (Eftoda and McCartney, 2004; Yañez et al., 2009). Many researchers have reported the effectiveness of adding bulking agents such as straw, cotton wastes, sawdust and wood chips, and mature compost in improving the composting process (Cai et al., 2012; Gea et al., 2007; Haug, 1993; Iqbal et al., 2010; Yañez et al., 2009).

Bulking agents can adjust MC and free air space (FAS) of composting materials (Mason et al., 2004), and mature compost can also provide proper microorganisms to the composting mixture. The MC of different composting materials is usually reduced to approximately 50–70% following the addition of bulking agents (Richard et al., 2002). If the MC is too high, the oxygen diffusion is impeded because of poor void structure in the pile, which leads to anaerobic conditions, failure of self-heating, and poor processing (Miller, 1989). Haug et al. (1993) suggested that the optimum MC was 60%. Cai et al. (2012) adjusted the MC of sewage sludge with sawdust and bio-dried product to 66.1% to study the dewatering process, which showed that peak water generation and evaporation occurred during the thermophilic phase.

Adding bulking agents can also provide optimum FAS and void dispersion in composting piles (Iqbal et al., 2010), which permits adequate water and gas exchange between gas and solid phases, and prevents excessive compaction of the composting materials. If FAS is too low, the transfer of oxygen will be inhibited and conditions in the pile become anaerobic (Jeris and Regan, 1973; Kulcu and Yaldiz, 2007; Nakasaki et al., 1987). A FAS of above 30% was suggested in the research of Kulcu et al. (2007) and Jeris and Regan (1973). Maulini-Duran et al. (2013) adjusted the FAS to 41.8% for raw sludge to obtain stabilized compost. Studies have indicated that different sizes of bulking agents provide different void

* Corresponding author. Tel./fax: +86 10 64889303.
E-mail address: gaod@igsnrr.ac.cn (D. Gao).

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dispersion and FAS to composting piles. Higgins et al. (1986) found that shredded rubber with particles ranging in size from 12.7 to 25.4 cm was optimal for efficient sludge composting. When organic bulking agents of finer particle sizes are used, the thermophilic temperature is reached sooner and sustained for a longer period; however, collapse of the pile occurs when the MC is too high and less moisture is lost during the composting process (Raichura and McCartney, 2006; Barrington et al., 2002). Large particles contribute to low density and more void spaces for air transport (Barrington et al., 2002), which leads to higher ventilation rates in the composting pile (Raichura and McCartney, 2006).

Traditional organic compost bulking agents such as woodchips and wheat straw are degradable and easily lost, therefore are not likely to be reused, which leads to high costs of sewage sludge composting, and they contribute to the final mass of compost. Additionally, straws are collected seasonally, which makes it difficult for composting plants to operate in areas where other supplementary bulking agents such as sawdust are difficult to collect. Researchers have tested bulking agents that can be screened and reused to reduce the cost of the composting process. Additionally, there have been researches done on bulking agents of which the sizes and porosity can be precisely controlled, including shredded rubber (Higgins et al., 1986), synthetic plastic bulking agents (Das et al., 2003; McGuckin et al., 1999) and CTB bulking agents (Zheng et al., 2007). Other inert bulking agents, including coal ash and zeolite, are used to inactivate heavy metals in sewage sludge, and the effect of these inert bulking agents on microbial activity has been researched (Wong et al., 1995; Zorpas and zLoizidou, 2008). Some of these bulking agents have the capacity to absorb water, and can adjust the MC of sewage sludge (Zheng et al., 2007). However, some are capable of adjusting only the structure, and therefore, parts of bulking agents such as sawdust and mature compost need to be added to adjust the MC and C/N ratio (Higgins et al., 1986; McGuckin et al., 1999). McGuckin et al. (1999) used three kinds of non-organic bulking materials in food waste composting in a laboratory scale experiment; the bulking agents were approximately 3–10 times more effective than pine bark, but they were fragile if used in field composting facilities where the mature compost was mixed and screened. Therefore, a strengthened recyclable bulking agent need to be developed, and the influence of its diameter, its size, and addition ratio on the structure of the composting materials and the composting process need to be studied.

In this study, a novel recyclable plastic bulking agent (RPBA), which could be screened and reused, was developed, and the influence of the diameter of the bulking agent and the ratio in which it was added to the sewage sludge was evaluated. The objectives of this study were to: (1) examine the influence of RPBA on temperature and oxygen concentration change during forced aeration composting; and (2) identify the optimal diameter of the RPBA and ratio of RPBAs to sewage sludge for composting.

2. Methods

2.1. Materials

The sewage sludge was taken from a wastewater treatment plant (WWTP) in Beijing, China. The RPBAs were made from plastic cement using an injection molding method, and the RPBA was spherical and porous. Two sizes of RPBA were developed: RPBA35 (35 mm in diameter) and RPBA50 (50 mm in diameter). The compression strengths were 226 KN and 223 KN for RPBA35 and RPBA50, respectively. Fine sawdust (less than 2 mm) and mature compost were used in this research to adjust the C/N ratio and MC. Sawdust was purchased from a furniture plant in Beijing. The mature material was taken from Lvgang Sewage Sludge Treatment Plant, in Qinhuangdao, Hebei. The initial characteristics are listed in Table 1.

2.2. Compost devices

A bench-scale composting bioreactor (Fig. 1) was constructed of polymethyl methacrylate (PMMA). The outside diameter was nominal 800 mm, and the wall thickness was 200 mm. The

Table 1
Chemical characteristics of the initial materials.

Material	Moisture content (%)	Bulk density (kg/m^3)	Particle size (mm)	Volatile solid (%)
Sewage sludge	80.7	1015.2	–	62.3
Sawdust	6.23	112.4	⩽2	90.2
RPBA35	–*	319.2	35	–
RPBA50	–	370.2	50	–
Mature compost	7.36	416.8	3–5	60.6

* : not detected.

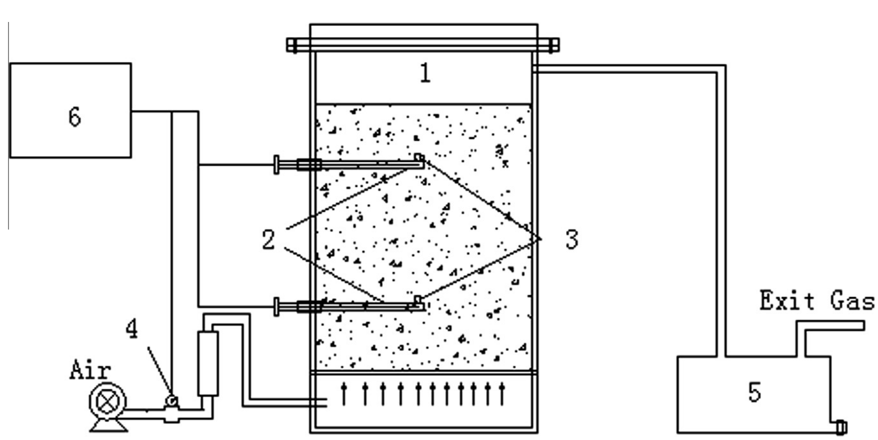

Fig. 1. The composting device and its components: 1. reactor, 2. temperature sensors, 3. oxygen sensors, 4. air volume flow meter, 5. evaporated water collection device, and 6. control system.