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# The operation of cost-effective on-site process for the bio-treatment of mixed municipal solid waste in rural areas

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ABSTRACT

The application of on-site waste treatment significantly reduces the need for expensive waste collection and transportation in rural areas; hence, it is considered of fundamental importance in developing countries. In this study, the effects of in-field operation of two types of mini-scale on-site solid waste treatment facilities on de-centralized communities, one using mesophilic two-phase anaerobic digestion combined with composting (TPAD, 50 kg/d) and another using decentralized composting (DC, 0.6–2 t/d), were investigated. Source-separated collection was applied to provide organic waste for combined process, in which the amount of waste showed significant seasonal variation. The highest collection amount was 0.18 kg/capital day and 0.6 kg/household day. Both sites showed good performance after operating for more than 6 months, with peak waste reduction rates of 53.5% in TPAD process and 63.2% in DC process. Additionally, the windrow temperature exceeded 55 °C for >5 days, indicating that the composting products from both facilities were safe. These results were supported by 4 days aerobic static respiration rate tests. The emissions were low enough to avoid any impact on nearby communities (distance <100 m). Partial energy could be recovered by the combined process but with complicated operation. Hence, the choice of process must be considered in case separately.



## 1. Introduction

Rural areas account for 90% of mainland China and are home to 65% of the Chinese population. Rural household waste refers to household solid waste (mainly food waste) generated in rural areas, which is usually mixed with some agricultural waste (wheat straw, vegetable and green waste), therefore, they have a greater easily degradable fraction than solid waste from urban areas (Chen, 2010).

Little attention has been paid to waste management and treatment systems in rural area, especially in developing countries (Zarate et al., 2008; Zurbrügg, 2003). Due to the farming manufacturing life style, most rural household waste, especially the organic components, are recycled in a variety of ways. Therefore, there was little organic rural household wastes left for integrated solid waste management in the past. However, with the economic development of China, the amounts of rural household wastes are increasing rapidly. As a result, large quantities of un-utilized solid wastes are disposed of randomly without treatment in rural areas, leading to serious environmental problems. Indeed, there were 180 million t of solid waste generated from rural China without proper treatment and disposal in 2005 (Ye and Qin, 2008).

In areas such as small, decentralized towns, villages and hilly or mountainous areas, the collection and transportation of generated solid waste is complicated and expensive (Hogg, 2005; Li et al., 2011). On-site waste treatment will significantly reduce the cost of waste treatment by decreasing the amounts that need to be transported to urban systems for treatment and/or final disposal. Hence, the application of on-site treatment is considered to be of fundamental importance (Abduli et al., 2008; He, 2012), especially in developing countries, which are sensitive to the costs of solid waste management.

Household or community-scale anaerobic digestion and composting have a long history in rural areas (Farrell and Jones, 2009; Iacovidou et al., 2012; Rajendran et al., 2012; Weiland, 2010). However, only a few assessments of the performance and product safety of mini-scale on-site biological treatment facilities (composting or anaerobic digestion, with a waste treatment capacity of <2 t/d) have been conducted to date, which is mostly focused on the lab reactor and combined with heating equipment (Lashermes et al., 2012). Moreover, due to the proximity to nearby

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communities, odors produced by such facilities need to be carefully evaluated.

In this study, two applications of on-site treatment were evaluated, two-phase anaerobic digestion combined with composting (TPAD) treatment and decentralized composting (DC), to determine the feasibility of decentralized on-site treatment in rural areas while focusing on the waste reduction rate and product safety. In addition, the influence of odor on nearby communities was evaluated.

## 2. Materials and method

### 2.1. Facilities location

A TPAD facility with a capacity of 50 kg/d was constructed in a rural area of Hangzhou, Zhejiang Province. The facility consisted of a windrow, hydrolysate collection tube, hydrolysate tank, 1 $m^3$ anaerobic digester, gas tank, recirculation tube, flow meter, and pump (Fig. 1) The windrow was located in a simple vessel, the top and the bottom of which were sealed by HDPE geotextile. The sealed HDPE geotextile created a vacuum space for the windrow in order to prevent the rainfall leaking into it. The max height of the space was 1.2 m, while the height of the windrow was 0.8 m. The aeration tube, which meanwhile was the leachate collection tube, located in the grave layer in the bottom of the windrow. Source separation of solid waste was applied in the service area, which included approximately 75 families.

A DC facility with a capacity of 0.6–2 t was set in Chongming Island, Shanghai, China. This facility consisted of windrow compost bins, aeration tubes, suction tubes, pumps, and odor removal tank (Fig. 2). The compost bins had glass roof tightly connected on cement wall, creating an in dependent room. The aeration tube was buried in the gravel layer in the bottom of the windrow. The suction tubes were connected to the roof of the compost bins. The shutter door was used to seal the compost bin, which was opened only while the waste was fed into or discharged from the bins. During the ventilation, the air was pumped in from the bottom of the windrow. Meanwhile, the exhausted odor gas was vacuumed from the top of the bin to the odor removal tank. The service area was a 4000 resident community that was 100 m away from the facility.

### 2.2. Operation

Both TPAD and DC facilities were operated for more than 6 months, The TPAD facilities was operated from late summer to next year's early spring, while the DC facility was operated from late spring to early autumn.

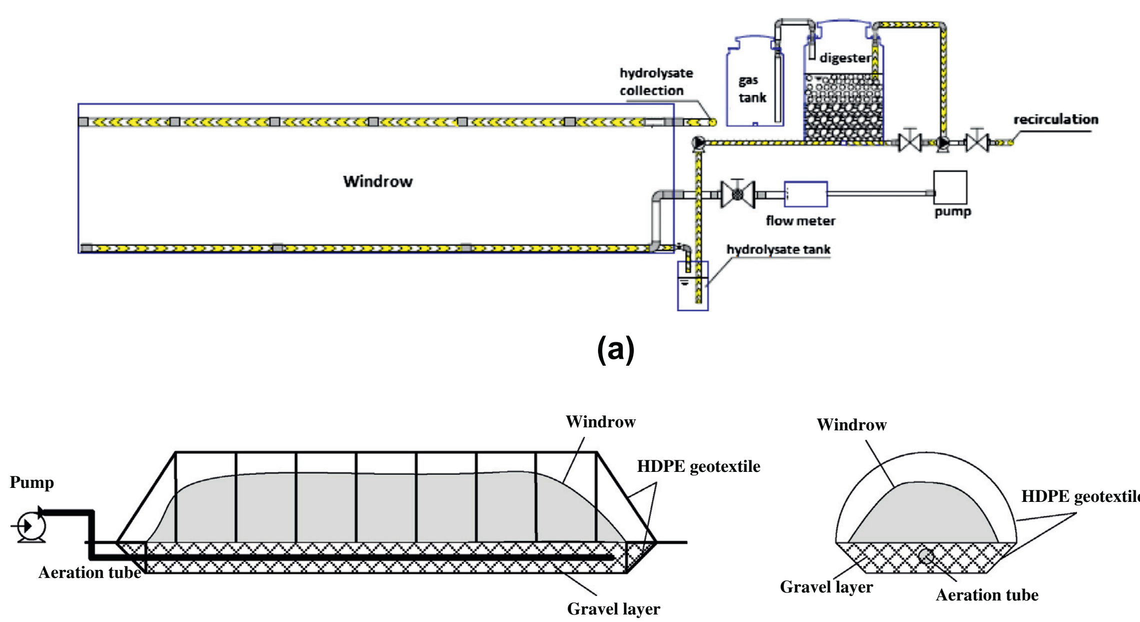
#### 2.2.1. Source separated collection

Both TPAD and DC facilities treated the organic waste in rural household waste. In DC process, the waste separation was conducted in the facility, while the source separation collection was applied on the service area of TPAD process. During the six-month operations, the composition analysis on the waste (on a wet basis) was intermittently conducted. During each analysis, 20 kg of mixed waste was separated into seven categories, including organic waste, plastic, paper, glass, metal, textiles and others. The weight of each waste category was measured to calculate the waste composition.

In the TPAD facility, local residents separated the waste before collection and the source sorting efficiency was calculated every 15 days by dividing the weight of organic waste (kitchen waste and fruit/vegetable waste) by the total amount of collected waste. In the DC facility, the operators conducted source separation in the special area of the facility before composting.

#### 2.2.2. TPAD process

The TPAD operation was divided into hydrolysis, anaerobic digestion and composting steps. In the hydrolysis step, the collected organic waste was stacked in the windrow for 48–72 h without aeration, in order to generate the hydrolysate. In the anaerobic digestion step, the hydrolysate was pumped into the anaerobic digester for methane production, and the anaerobic effluent of the digester was recirculated to the waste in the hydrolysis step to improve hydrolysis with a hydraulic loading of




(a)

(b)

**Fig. 1.** The flow chart and the windrow schematic diagram of TPAD process. (a) flow chart and (b) windrow schematic diagram.