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Methane production in simulated hybrid bioreactor landfill

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HIGHLIGHTS

- Temporary aeration into the hybrid bioreactor improved leachate quality.
- pH adjustment by the aeration boosted the formation of methane generation phase.
- The hybrid bioreactor was economically feasible by the methane quality improvement.

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ABSTRACT

The aim of this work was to study a hybrid bioreactor landfill technology for landfill methane production from municipal solid waste. Two laboratory-scale columns were operated for about ten months to simulate an anaerobic and a hybrid landfill bioreactor, respectively. Leachate was recirculated into each column but aeration was conducted in the hybrid bioreactor during the first stage. Results showed that leachate pH in the anaerobic bioreactor maintained below 6.5, while in the hybrid bioreactor quickly increased from 5.6 to 7.0 due to the aeration. The temporary aeration resulted in lowering COD and BOD_5 in the leachate. The volume of methane collected from the hybrid bioreactor was 400 times greater than that of the anaerobic bioreactor. Also, the methane production rate of the hybrid bioreactor was improved within a short period of time. After about 10 months' operation, the total methane production in the hybrid bioreactor was 212 L (16 L/kg_{waste}).

1. Introduction

Landfilling is the most common method of municipal solid waste (MSW) disposal around the world, especially in developing countries (Giusti, 2009; Mor et al., 2006). In China, landfill has been the dominant way for MSW management because it is a cost-effective MSW management option compared with other options and can treat mixed MSW without separation (Chen et al., 2010; Zhang et al., 2010). According to statistical data, in 2010, the amount of MSW disposal was 131 million tons, of which 77% was landfilled (China Statistical Yearbook, 2012). However, it is estimated that the recovery rate of landfill gas generated from traditional landfills is less than 20% (Zhang et al., 2010). One of the main reasons is the relatively slow MSW degradation in traditional landfills (Xu and Ge, 2011). MSW degradation rate and methane production from MSW are mainly influenced by microorganisms, moisture conditions, and other inhibitory factors. One of the inhibitory factors is the imbalance between acidogenesis and methanogenesis, which is often caused by the rapid hydrolysis of readily biodegradable materials in the beginning of anaerobic digestion. MSW composition in China is dominated by food waste, typically more than 50% by weight. In anaerobic conditions, the excess hydrolysis of easily biodegradable food waste can cause the accumulation of acids resulting in the decrease of pH. So, it may delay the formation of stable methane production phases in Chinese MSW landfills. In some cases, it took several years to start methane generation (O'Keefe and Chynoweth, 2000).

Bioreactor landfill technology has been developed to accelerate the biodegradation of the biodegradable fractions and to enhance the stabilization of landfilled waste. The key step to create a landfill bioreactor is water addition or leachate recirculation to increase moisture content of MSW (Townsend et al., 1996; Reinhart et al., 2002; Benson et al., 2007; He et al., 2007; Kumar et al., 2011; Bilgili et al., 2012). In general, there are four types of landfill bioreactors: aerobic, anaerobic, facultative and hybrid systems, equipped with different operating schemes to achieve optimal results (Berge et al., 2005). Among the different types of landfill bioreactors, hybrid bioreactor landfill technology is of great promise (Long et al., 2009a,b). Combination of both aerobic and anaerobic

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conditions is involved in hybrid landfill bioreactors. Aerobic conditions can facilitate degradation of organic matter and rapidly improve leachate quality (Nikolaou et al., 2010). In addition, anaerobic operation can produce methane which can be used for biogas-to-energy projects.

Research has shown that operating hybrid systems served for in situ nitrogen removal (Shao et al., 2008). However, few researchers have investigated the effect of hybrid landfill on methane generation. This research investigated a hybrid bioreactor landfill technology using leachate recirculation and temporary aeration to a part of a simulated waste landfill (the upper layer of the compacted waste). The performance of the simulated hybrid bioreactor landfill was compared to the bioreactor with simple leachate recirculation.

2. Methods

2.1. Materials

Each waste component was collected from Shenzhen University Town (Shenzhen, China) and was synthesized to represent the typical MSW composition in Shenzhen. Collected waste components were screened and shredded to reduce particle size to less than 5 cm. The initial moisture content of the synthesized waste was 49.7%. Moisture content, volatile solid (VS), and total solid (TS) of each component are listed in Table 1. The total volatile solid of biodegradable components in each bioreactor was about 3.4 kg.

2.2. Experiment set-up

Two laboratory-scale columns were constructed to simulate an anaerobic landfill bioreactor and hybrid landfill bioreactor. Fig. 1 shows the structure of the laboratory bioreactors. The bioreactor was constructed using 20-cm-diameter polyacrylic plastic pipe with a total height of 100 cm. A 5-cm thick gravel layer was placed at the bottom of each column as a drainage layer. A total 13.2 kg of synthesized MSW was loaded into each column. The bulk density of the compacted waste was 600 kg/m^3. A layer of gravel was placed on the top of the loaded waste to facilitate the even distribution of recirculated leachate. In the hybrid bioreactor, a 10-cm thick aeration layer (gravel) was placed at the middle of the waste layer. To channel air into the aeration layer, a 0.5-cm diameter of

Table 1
Composition of the MSW in simulated bioreactors.

Waste component	% By wet weight				
	Mass	Moisture content	Volatile solid (VS)	Total solid (TS)	VS/TS*
Food waste	55.0	80.9	18.6	19.1	0.96
Inert	20.0	21.7	–**	78.3	–
Paper	10.0	8.5	7.0		0.83
Plastics	10.0	0.4	–	99.6	–
Glass	4.5	–	–	100	–
Metal	0.5	0.01	–	99.9	–
Total	100	49.7			

* The ratio of volatile solid to total solid.
** Not measured.

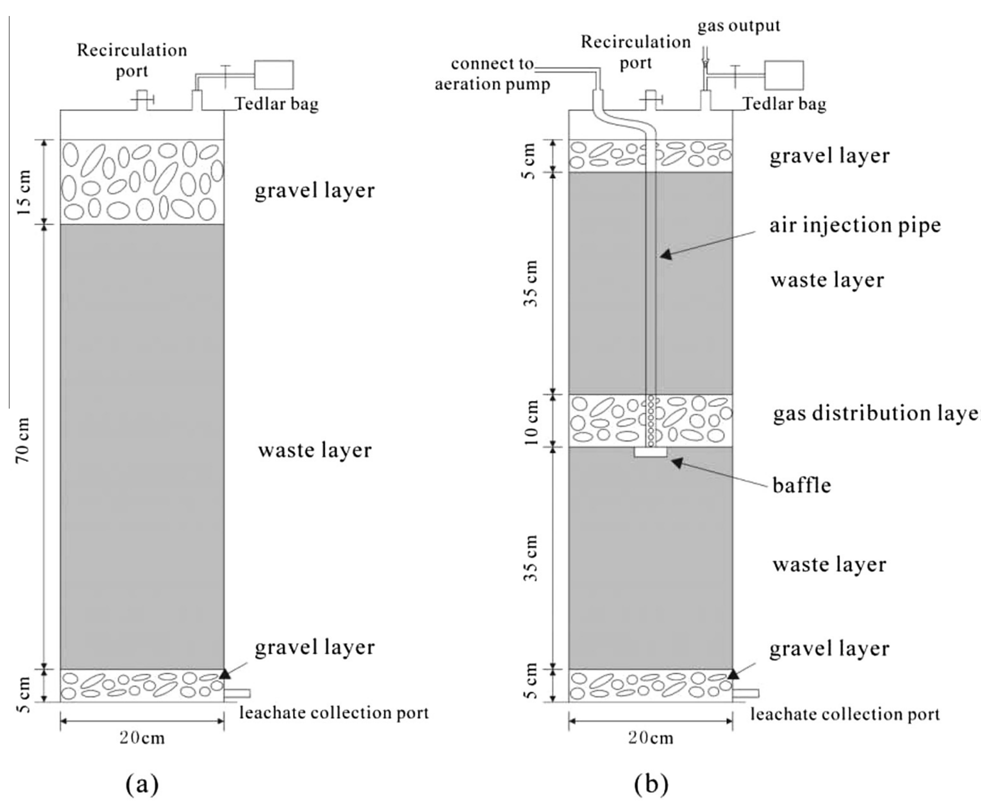

Fig. 1. Schematic of bioreactor landfills (a) anaerobic bioreactor and (b) hybrid bioreactor.