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Industrial scale garage-type dry fermentation of municipal solid waste to biogas

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HIGHLIGHTS

- Characteristics of MSW from new town are different from urban and rural waste.
- 1st industrial utilization of garage-type dry fermentation for treating MSW to biogas in China.
- The specific biogas yield of the feedstock was about 270 m^3 CH_4 t VS^{-1}.
- The volumetric biogas production of the digesters and percolate tank was 0.72 and 2.22 m^3 (m^3 d)$^{-1}$, respectively.

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ABSTRACT

The objectives of this study was to through monitoring the 1st industrial scale garage-type dry fermentation (GTDF) MSW biogas plant in Bin County, Harbin City, Heilongjiang Province, China, to investigate its anaerobic digestion (AD) performance and the stability of process. After a monitoring period of 180 days, the results showed that the volumetric biogas production of the digesters and percolate tank was 0.72 and 2.22 m^3 (m^3 d)$^{-1}$, respectively, and the specific biogas yield of the feedstock was about 270 m^3 CH_4 t VS^{-1}, which indicated that the GTDF is appropriate for the Chinese MSW. This paper also raised some problems aimed at improving the process stability and AD efficiency.

1. Introduction

With the economic development and rapid urbanization, the generation of municipal solid waste (MSW) has increased sharply in recent years in China. In 2012, 657 cities annually produced 170.8 million tons of MSW, of which was treated by landfill of 61.4%, incineration of 21%, composting of 2.3%, and still 15.2% of MSW was treated with passive way, such as unsanitary landfill and open-air dump. By 2020, the annual generation of MSW is expected to reach 200 million tons (Zhou et al., 2014).

The Chinese MSW typically contains high water content and high biodegradable organic fraction (OFMSW) (up to 50–70%), such as kitchen waste, food waste and fruit/vegetable residues, which has led to serious adverse effects in existing MSW treatment systems, such as abundant generation of leachate from landfill, and unstable burning conditions and dioxin release from incineration (Liu et al., 2012a; Cheng and Hu, 2010). The calorific value of Chinese MSW (4000–7000 kJ kg^{-1}) is lower than that in developed countries (8400–17,000 kJ kg^{-1}), thus, fresh MSW generally needs to be stored in storage bunkers for 3–7 days before incineration. (Dang et al., 2013; Yang et al., 2012), which increases the greenhouse gas emission (Liu et al., 2012b). Therefore, the proper treatment of MSW is becoming an urgent and important task for the continued development of China.

Anaerobic digestion (AD) technology, as an appropriate solution to treat waste and produce methane-rich gas energy (biogas) (Zhu et al., 2015; Li et al., 2014), can be classified by several parameters, e.g. based on the number of phases, dry matter content of the input and the operational temperature (Madsen et al., 2011). In contrast to GTDF, the more common wet AD technologies (TS < 15%) is suitable for the treatment of feedstock which can be pumped originally or after mixing with liquids (other liquid substrates, liquid digestate or sometimes water). GTDF is characterized by

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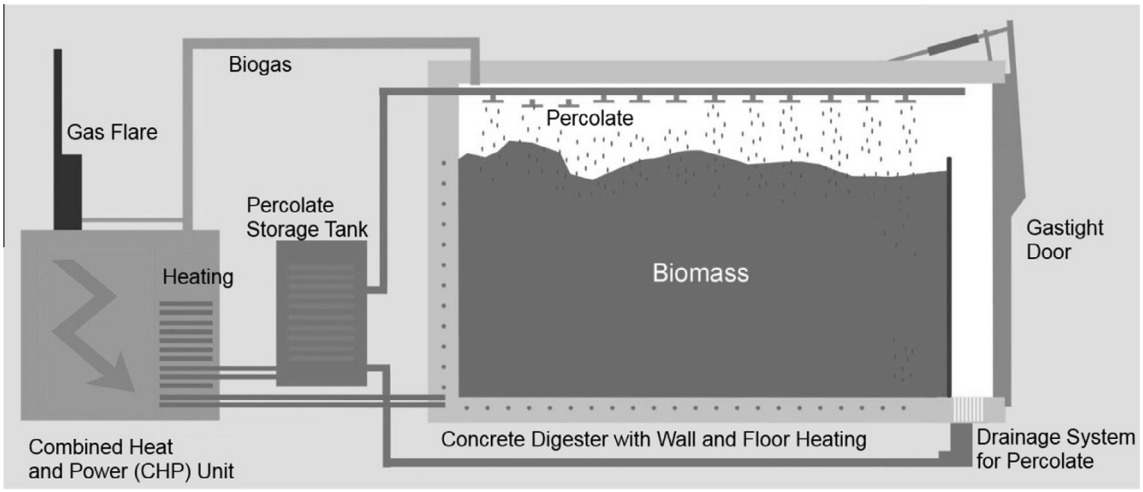

Fig. 1. BEKON GTDF process concept of a batch system with percolate.

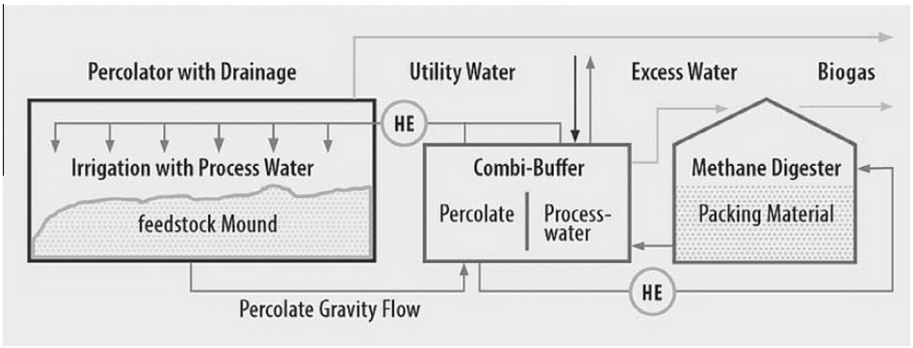

Fig. 2. GICON GTDF process concept of a batch system with external methanization.

greater acceptance of input materials with higher dry matter content, containing impurities which can be harmful for stirrers and pumps, and lower energy consumption (Li et al., 2011; Brown and Li, 2013). Because of these advantages, GTDF is widely used for the treatment of stackable non-free flowing materials like MSW or energy crop in Europe.

During the last decade, numerous GTDF plants were built and approved for operation in Germany and other European countries. Fig. 1 shows the concept of a batch process as carried out by BEKON Energy Technologies GmbH & Co. KG. The feedstock is inoculated with digestate before each feeding cycle and the percolate is run in circuit. The inoculum contains methanogenous bacteria which supports the conversion of organic acids to methane mainly in digester. Fig. 2 shows the process implemented by GICON Holding GmbH, which is operated without inoculation by digestate, but by recirculation of percolate. The percolate is stored in a percolate tank that is connected to an external digester where most of the acids are degraded into biogas. This two-phase system of separating the acetogenesis and methanogenesis provides a better process stability as the risk of process acidification is reduced (Shen et al., 2013), and allows a better process control as the methanogenesis process can be disconnected if problems occur (Nkemka and Murto, 2013).

Since 1980s, China has started the research about dry fermentation, and the research on large scale utilization was started from 2008 (Liang et al., 2013). The objectives of this study was the monitoring of the 1st industrial scale GTDF MSW biogas plant in China, to investigate its anaerobic digestion (AD) performance and process stability to provide baseline data for the adaptation of GTDF in China.

2. Methods

2.1. Site and process description of the GTDF biogas plant

The 1st industrial scale GTDF MSW biogas plant in China is located in Bin County (127.48E, 45.75N) about 100 km away from Harbin City, Heilongjiang Province. The plant is in operation since 2014 with a designed daily capacity of 100 tons of waste and 8000 m^3 of biogas production. This plant includes two parallel treatment lines, and each line has six garage-type digesters with about 400 m^3 each (cubic shape with L: 24 m, W: 4 m and H: 4.2 m) and one percolate tank with about 600 m^3 (cubic shape with L: 24 m, W: 4 m and H: 6.2 m). The MSW is collected from households and transported to the plant by truck, and further simply pretreated by a jointly mechanical and manual sorting, including bag opener, drum sieving and manual sorting. Only the recyclables and the big-sized bulking materials are separated for selling and avoiding damage of equipment. The other impurities, such as paper, glass, textile and agricultural waste, etc., cannot be separated efficiently. The pretreated MSW are stored in the bunker temporarily and fed into the digester by wheel loader. The digesters are isolated by rigid polyether polyurethane foam with a thickness of 20 cm, and the digesters are heated by hot water through the heating pipe installed inside the concrete wall and floor, to