Methane Generation from Landfill Waste as a Resource Recovery Strategy

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Abstract

Engineered landfills are becoming popular as waste management areas in developing countries and therefore it is import to recover value from landfills so that the cost of operation is reduced. In this study, the potential to harness methane from landfill waste was investigated. Landfill waste with organic waste composition ranging from 70-90% was investigated for varying moisture content between 15-60%, mesophilic temperatures of 30-40°, thermophilic temperatures of between 50-60 °C. Anaerobic digestion was conducted in 1L digesters over a digestion period of 70 days. Landfill waste from various cells with different ages from 5-10 years was used. Highest methane composition of around 70% was obtained under mesophilic conditions, for moisture content of 30-40% and aging waste which was compacted for more than 5 years.

Keywords: Biogas, landfill waste, methane, process conditions.

1. Introduction

Landfills present an opportunity for potential biogas generation which is a renewable source of energy at the same time prevention of uncontrolled fires on landfills due to uncontrolled or untapped methane emissions (Karapidakis et al., 2010; Asgari et al., 2011). Landfill biogas, like any other biogas from organic waste digestion can be used for electricity generation, combined heat and power generation or can be used directly as compressed gas for cooking and heating purposes (Rada et al., 2015). The product of biogas from landfills is dependent on various process factors such as substrate temperature, available nutrients, and symbiosis of bacteria, pH, retention time, inhibitory factors, nitrogen inhibition and the carbon to nitrogen ratio (Karapidakis et al., 2010). Landfill biogas is produced in the following phases: Phase 1-Aerobic decomposition, Phase 2-Anoxic, non methanegenic, Phase 3-Anaerobic, methanegenic and Phase 4-Anaerobic, methanegenic (Kaufman et al., 2004; Verma and Themelis, 2004; Themelis and Ulloa, 2007).

This study focused on assessing the potential to generate methane from landfill waste with a main focus on the effect of the waste composition, waste moisture content, waste anaerobic digestion temperatures as well as the age of the waste utilized.

2. Materials and methods

2.1 Materials

Landfill waste of different ages was obtained from a local landfill. An AND moisture analyzer from Sigma Aldrich was used for moisture content determination. A Biogas 5000 analyzer was used for biogas composition determination.

2.2 Methods

Landfill waste was manually sorted for its organic waste composition and other waste to determine its composition. The waste was allowed to anaerobically digest in 1L lab scale reactors for a digestion period of 70 days. The digestion temperatures were ranged between mesophilic conditions of 30-40°C and thermophilic temperatures of 50-60°C. Temperature of the digesters was maintained by a water bath. Moisture content was varied between 15-20 °C for low conditions, 30-40% for medium conditions and 40-60% for high moisture content and was varied either by addition of water or by sun drying. The pH in the digesters was maintained around 7.0 by a Mettler Toledo pH meter.

3. Results and discussion

3.1 Landfill gas characteristics

The landfill gas had a composition ranging from 50-70% depending on the temperature used, moisture content, and age of the waste as well as the composition of the landfill gas. The itemized landfill biogas composition is shown in Table 1.

Table 1. Landfill gas composition

Gas	Composition

Methane	50-70
Carbon dioxide	20-30
Oxygen	<4
Nitrogen	<12
Traces	500 ppm

3.2 Process factors affecting landfill gas production

Waste composition

Landfill waste with high organic municipal waste composition of 90% resulted in biogas with methane composition of around 70% which was 20% higher in comparison to landfill waste which had 70% organic municipal waste composition (Figure 1). Highly biodegradable organic waste can be digested easily to biogas unlike other type of waste that maybe available in the landfill.

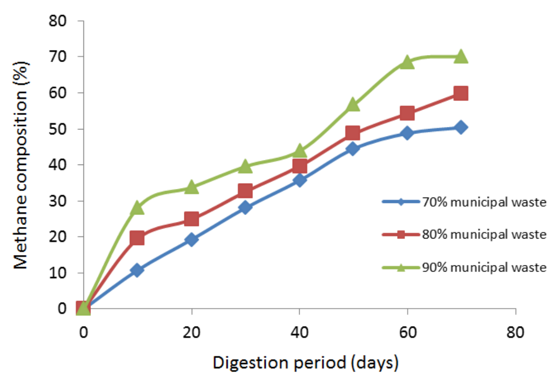

Figure 1. Effect of waste composition on methane production

Moisture content

Moisture content of 30-40% was ideal for anaerobic digestion of the landfill waste to methane (Figure 2). Low moisture content results in more digestion being required for digestion of the waste hence lower methane compositions of around 50%.

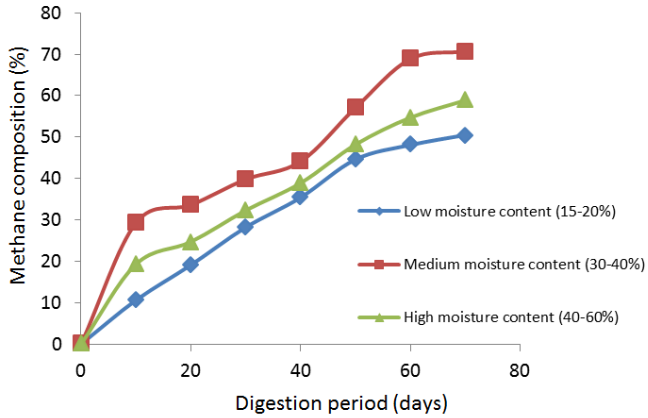

Figure 2. Effect of moisture content on methane production

Effect of digestion temperature

Methane production was higher in mesophilic conditions of temperatures between 30-40 °C with methane composition as high as 30% in comparison to thermophilic conditions of 50-60 °C (Figure 3). Mesophilic conditions which enhance the methanogenesis process thrive best at temperatures of less than 40 °C hence the optimal methane production.

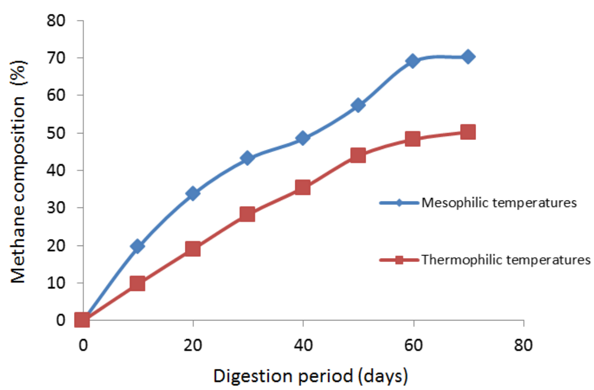

Figure 3. Effect of digestion temperature on methane production

Age of waste

The amount of methane gas produced was high for waste that was 5-10 years old unlike in cases where the waste was 5 years old or more than 10 years (Figure 4). As the landfill waste becomes older, after 5 years of compaction, it becomes easier to digest unlike when it is still young and heavily compacted in the landfill cells. However, as the waste continues to age, its permeability increases allowing biogas to escape to the environment.

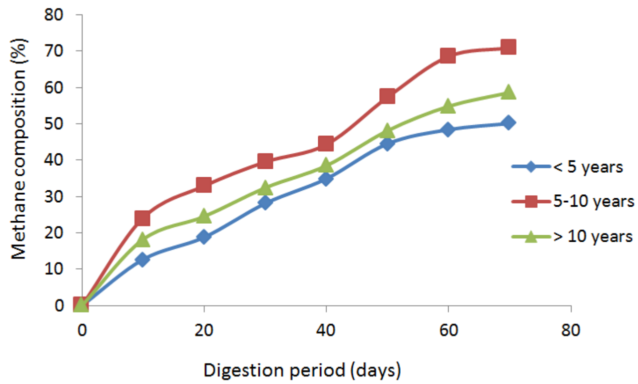

Figure 4. Effect of waste age on methane composition

The landfill site presents an opportunity for biogas production, in engineered landfills; it is recommended that pipes be perforated into the wells so that the biogas can be harnessed.

4. Conclusion

Landfills waste provides a raw material for methane generation. Methane composition of 50-70% is realized from landfill waste that is highly organic. Mesophilic conditions are ideal for methane generation and the highest concentration is obtained when the age of the waste is more than 5 years.

References

Asgari, M. J., Safavi, K., and Mortazaeinezahad, F., *Landfill biogas production process*. International Conference on Food Engineering and Biotechnology, IPCBEE vol.9 (2011), IACSIT Press, Singapore, 2011.

Karapidakis, E. S., Tsave, A. A., Soupios, P. M., and Katsigiannis, Y. A., Energy efficiency and environmental impact of biogas utilization in landfills, *International Journal of Environment Science and Technology*, vol. 7, no. 3, pp. 599-608, 2010.

Rada, E. C., Ragazzi, M., Stefani, P., Schiavon, M., and Torretta, V., Modelling the potential biogas productivity range from a MSW landfill for its sustainable, *Exploitation. Sustainability*, vol. 7, pp. 482-495, 2015 doi: 10.3390/su7010482.

Themelis, N. J., and Ulloa, P., Methane generation in landfills, *Renewable Energy*, vol. 32, pp. 1243–1257, 2007.

Verma, S., and Themelis, N. J., *Anaerobic digestion of organic waste in MSW*, Waste Management World, 2004; Jan. –Feb, 20–4.

Kaufman, S. M., Goldstein, N., Millrath, K., and Themelis, N. J., The state of garbage in America, *BioCycle*, pp. 31–41, 2004.

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