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PRELIMINARY STUDY ON BIOGAS PRODUCTION OF BIOGAS FROM MUNICIPAL SOLID WASTE (MSW) LEACHATE

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Abstract

Laboratory-scale digesters were operated to study the effect of leachate chemical oxygen demand strength on biogas (methane) production. Three sets of experiment were performed using municipal solid waste leachate slurry with two different chemical oxygen demand strength strengths namely 3000 and 21000 mg/L (referred as low and high strength, respectively). The experiments were conducted at a controlled temperature of 35°C and pH ranging from 6.8 to 7.3 over 20 days period. The process performance was evaluated based on the biogas production and pollutants removal efficiencies. Results showed that the high and low strength samples performed quite similarly but with different biogas production rate observed. The biochemical oxygen demand in the effluent removed up to 80%, but the performance of other parameters such as chemical oxygen demand, total suspended solid and volatile suspended solid was slightly decreased which contributes 33 to 46%, 21 to 37% and 20 to 35%, respectively. From this study, it can be concluded that this method not only contributed to renewable biogas production but also improved the effluent quality.

Keywords: Leachate, anaerobic digestion, Biogas, Municipal solid waste (MSW)

1. Introduction

Municipal solid waste (MSW) management becomes global issues concern worldwide including middle income countries like Malaysia. With generation rate 1.5 kg/capita/day of MSW, Ministry of Housing and Local Government (MHLG) currently facing big problems dealing with MSW wastewater or so-called leachate. Thus, the "Waste-to-Energy (WTE)" concept is gaining more interest in

Nomenclatures

P	Pressure, mmHg
T	Temperature, °C
V	Volume, L

Abbreviations

BOD	Biochemical oxygen demand
COD	Chemical oxygen demand
HRT	Hydraulic retention time
MHLG	Ministry of housing and local government
MSW	Municipal solid waste
TS	Total solid
TSS	Total suspended solid
VS	Volatile solid
VSS	Volatile suspended solid
WTE	Waste-to- energy

exploring this alternative renewable energy resource. In addition to being renewable and sustainable, this type of energy resource must be environmentally friendly [1]. Anaerobic digestion is one of the promising technologies to accommodate this requirement due to the advantage of producing fuel gas (methane) as well as generating odor-free residues rich nutrients, which can be used as fertilizers [2]. MSW leachate, described as liquid percolated through solid, contains high concentration of organic materials and amendable biodegradation. Franklin et al. [3] reported that MSW leachate could contain up to 50,000 mg/L of organics (measured as COD), which is very desirable for standard rate anaerobic process.

The biogas production from this anaerobic digestion process of high organics samples is primarily affected by its organic loadings, temperatures, retention time in the reactors, pH and the degree of contact between incoming substrate (feed slurry) and a viable bacterial population [4]. The authors suggested that organic loading should be in between 0.5-1.6 kg/m^3/day of Volatiles Solids (VS) for standard rate digester and 1.6-4.8 kg/m^3/day of VS for high rate digester. In addition, many previous researchers have suggested that the gas production was linearly correlated with temperature from 25 to 44°C which is in the mesophilic temperature range [5-7]. Furthermore, there was no significant effect of the retention time on biogas production. Van Der Vlugt and Rulkens [8] in 20 litres laboratory digesters indicated that reduced hydraulic retention time (HRT) from 40 to 20 days did not effect the biogas production. In contrast, in 200 L farm scale digester Kiely [9] found that cattle slurry of higher VS produced higher amount of biogas over the total 66 days digestion period. Optimal pH for digestion was suggested between pH 6.8 to 7.3. Also, Karim et al. [2] suggested that an intermediate mixing was found to be optimal for substrate conversion which helps digester to distribute the organism in the mixture and to transfer heat. Additionally, Toprak [10] discovered that the COD removal efficiency correlates inversely with the organic loading.

The objective of this paper is to study the effect of leachate chemical oxygen demand (COD) strength on biogas (methane) production and their pollutants removal using anaerobic digestion method. For this purpose, the anaerobic digestion of MSW leachate was performed at optimal conditions (pH 6.8-7.3, temperature 35°C and intermediate mixing rate) with different COD loading (300 mg/L and 21000 mg/L) in a closed 1 L anaerobic digester.

2. Material and Methodology

2.1. Feed characterisation

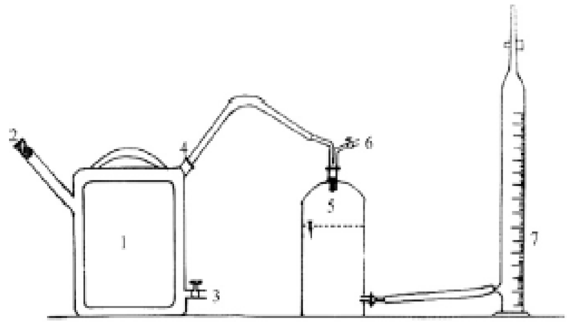
The raw municipal solid waste (MSW) leachate was collected from the leachate treatment system in the Taman Beringin Transfer Station, Kuala Lumpur. It occupies an area of more than 16 ha. This transfer station receives approximately 1800 tons of MSW per day which containing about 50-60% of organic matter. The sample were collected, delivered to the laboratory and stored at 4°C. The techniques used for sampling analyses were in accordance with the Standard Method for the Examination of Water and Wastewater [11]. The compositions of the feed for leachate sample are summarized in Table 1.

Table 1. Characteristics of the Prepared Feed Leachate Slurry.

	Digester 1	Digester 2
pH	4.07	6.97
COD (mg/L)	21056	2912
BOD(mg/L)	12878	373
TS(mg/L)	11450	690
TSS(mg/L)	515	30
VSS(mg/L)	440	10
$NH3^+$-N (mg/L)	205	0.01

2.2. Experimental

The purpose of this study was to obtain preliminary design criteria: mainly biogas yields of different leachate COD strength at controlled pH. In addition, the pollutants removal was also examined. The configuration of the batch experiments is shown in Fig. 1. For this study, the batch reactors (working volume 1.0 L) were filled with fresh prepared leachate (i.e. COD 3000 mg/L and COD 21000 mg/L). The digesters were flushed with N_2:CO_2-80:20 for 3 min to minimize air contamination, tightly closed with butyl rubber stoppers and plastic caps, and subsequently incubated at 35°C for 20 days. The digester was maintained in anaerobic conditions and it was allowed to stabilize for 1 week. During this stabilization period, digester temperature of 26 to 36°C was monitored and pH was maintained in the range of 6.5 to 7.5 by adding sodium hydroxide and COD, TSS and VSS reduction were also monitored. Steady-state condition was identified when the COD value of the effluent and the daily biogas production were measured to be the same for two or three consecutive days. A magnetic stirrer was introduced for vigorous mixing. Each experiment was performed in duplicate to determine experimental errors.



1. Digester (V=1 L) capacity
2. Feed inlet
3. Liquid sampling point
4. Gas opening
5. Water displacement jar
6. Gas outlet
7. Measuring jar

Fig. 1. Anaerobic Digestion Experimental Set-up.

2.3. Analytical methods

A complete analytical characterisation was carried out according to the Standard Methods [11]. The volume of biogas produced was measured using a gas sampling bag and the methane production rates were estimated by analysis of the methane contents in the biogas using gas chromatography (GC, Hewlett Packard 5890N series). Additionally, in order to calculate the theoretical biogas yield of MSW leachate, an elemental analysis was conducted using an LECO CHNS -932 analyzer.

3. Results and Discussion

3.1. Theoretical Biogas yield

The exact expectation of the producible biogas amount and its methane content is one of the most important aspects of an anaerobic digester. The chemical compositions of a feedstock determine the potential biogas yields, as well as the gas composition. The results of elemental analyses showed the chemical composition of feed used in this study to be $C_{14.25}H_{28.80}O_{4.43}NS_{0.03}$. An empirical equation, Eq. (1), was used to calculate the biogas production in the anaerobic digestion. As a result, the theoretical biogas and methane yields of feed fresh leachate at standard temperature and pressure (STP, i.e., 0°C, 760 mmHg) were 1.12 L biogas /g VSS destroyed and 0.72 L CH_4/g VSS destroyed, respectively. The theoretical methane was estimated to be 65%.

$$C_nH_aO_bN_cS_d + [A]H_2O \rightarrow [B]CO_2 + [C]CH_4 + [D]H_2S \quad (1)$$

where

$$[A] = (n - a/4 - b/2 + 3c/4 + d/2)$$
$$[B] = (n/2 - a/8 + b/4 + 3c/8 + d/4)$$
$$[C] = (n/2 + a/8 - b/4 - 3c/8 - d/4)$$

$$CH_4(\text{STP, mL/gVS}) = CH_4(T^\circ\text{C, mL/gVSS}) \times \frac{273}{273+T} \times \frac{760-P}{760} \quad (2)$$

3.2. Effect of COD strength

All gas production data at different leachate strength are represented as the dry gas production at STP to eliminate the effects of water vapor pressure as seen in Eq. (2). The results from the batch experiments are summarized in Table 2. The daily biogas production for the two set of digesters has been shown in Fig. 2. The biogas production rate data shows that digester 1 produced slightly more biogas than digester 2, but the corresponding methane content was found to be significantly lower in comparison, probably due to infiltration of air [2]. The influence of the feed load on methane yield is shown in Fig. 3. Methane yield, calculated as the volume of methane produced per unit of VS added for respective digesters was observed to be 9 to 11 ml/gVS added and 182.3 to 215.7 ml/gVS added (Table 2). The results for digester 1 significantly compared to digester 2 due to the inhibition caused by a high ammonia nitrogen concentration of 205 mg/L (Table 1). This may also contributed by incomplete degradation within 20 days period. These were fairly short due to the removal of the large particles prior to feeding into reactors. Therefore, approximately 15 to 20 days seems to be the minimum for optimal digestion of MSW leachate for a digester in which somewhat larger particles can be fed occasionally. However, both results were relatively low compared to the reported methane yield normally achieved from other feedstock, i.e., 220 to 350 ml CH_4/g VS from swine manure [5,12] and 620 ml CH_4/g MSW [13].

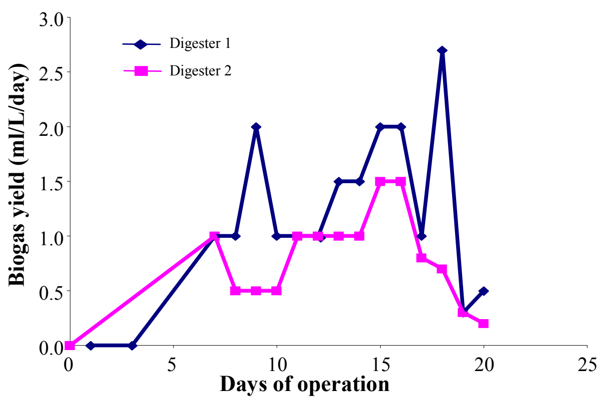


Fig. 2. Daily Biogas Production for Digesters 1 and 2.

Table 2. Average Biogas Production Rate and Methane Yield.

	Biogas production (ml biogas/ml leachate/day)	Methane yield (L CH_4/g VS added)	COD_i (mg/L)	COD_f (mg/L)
Digester 1	1.5 ± 1.2	0.001 ± 0.0100	21056	7369
Digester 2	0.6 ± 0.4	0.199 ± 0.017	2912	582.4

i = Initial value, *f* = final value

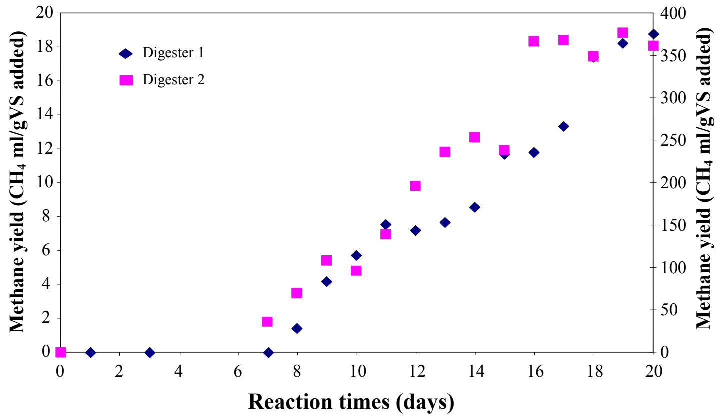


Fig. 3. Methane Yield versus Time at Different COD Strength.

3.3. Pollutants removal during anaerobic digestion treatment

Anaerobic digestion not only produced biogas but increased pollutants removal from the leachate sample. Table 3 shows the percentage of removal of COD, BOD, TSS and VSS due to microbial activities during anaerobic treatment.

Table 3. Percentage Removal of COD, BOD, TS, TSS and VSS of Anaerobic Treatment.

	Digester 1	Digester 2
COD (% removal)	33	46
BOD (% removal)	60	80
TSS (% removal)	21	37
VSS (% removal)	20	35

In this experiment, the COD and BOD reduction is the maximum at 46% and 80% for digester 2. However, lower percentage removals were observed for high strength sample in digester 1 (i.e. 33 and 60%, respectively), which corresponds to high purification efficiency of COD in diluted leachate sample. This may be due to the stable degradation of the substrate in diluted sample to stabilize the anaerobic degradation. Furthermore, the reduction of TSS and VSS measured is an important parameter for measuring biodegradation, which directly indicates the metabolic status of some of the most delicate microbial groups in the anaerobic system. The reduction of TSS and VSS denotes the process stabilization.

4. Conclusion

As a conclusion, it was found that there was a potential of biogas production from the MSW leachate. Relatively, leachate COD strength has significant effect on the ultimate amount of biogas yield, as well as the methane content. In the mesophilic temperature range, 25 to 35°C, the biogas production rates is inevitably dependent upon the VSS content of the feed, as methane comes from degradation of VSS.

Also, quite low percentage of COD, TSS and VSS removal for both cases were observed. Thus, longer digestion period was suggested or higher pollutants removal efficiency.

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