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ORIGINAL ARTICLE

Identification of Biogas Production by Bio Methane Potential (BMP) Test During the Anaerobic Digestion Process of Organic Wastewater from Polyester Manufacturing Processes

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Abstract

Organic wastewater generated from polyester manufacturing processes was selected from H company to investigate the feasibility of anaerobic digestion that produces gases including methane. Bio Methane Potential (BMP) tests were conducted to measure the gas production and methane concentration for 7 process wastewater and 2 kinds of sludges from the H company. Also, along with monitoring pH and alkalinity during the anaerobic digestion process, the concentrations of COD and 1,4-dioxane were measured with 4 different operating conditions for N Emulsion (NE) and Ethylene Glycol (EG) wastewater. The BMP tests showed that 65% of methane was produced from NE and EG wastewater. This suggests that the organic wastewater from H company can be effectively treated by an anaerobic digester by which more than 90% of COD was removed.

Key words : Anaerobic digestion, Biogas, Organic wastewater, BMP

1. Introduction

As the process of manufacturing polyester uses terephtalic acid (TPA) and Ethylene Glycol (EG) as raw materials, involving esterification and condensation polymerization, the process wastewater contains high-level organic matter generated from unreacted monomers and polymers as well as 1,4-dioxane from ethylene glycol ($HOCH_2$-CH_2OH). The wastewater is usually treated by using conventional processes such as physio-chemical and biological wastewater treatment(Cho et al., 1993; Han et al., 2008; Woo and Han, 2010). As the treated wastewater quality, however, exceeds permissible wastewater discharge standards and the generated sludge needs to be treated properly, this kind of wastewater has complicated issues in relation to treatment process improvement and process development for sludge treatment (Safarzadeh et al., 1997; Wang et al., 2016; Ziganshina et al., 2017).

Considering that there have been no stable and demonstrated treatment methods domestically as well as globally, it is important to present alternative plans for sludge treatment at this point of time(Stefan and

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Table 1. Characteristics of wastewater and thickened sludges from each unit process

Contents	Oil	NE	PE	HT	T319	T316	EG	SA	SB
Production (m^3/d)	73	18	4	5	177	213	118	288	200
pH	4.10	5.89	5.55	10.12	9.11	1.31	4.31	7.23	7.22
Alkalinity(mg $CaCO_3$/L)	-	1,900	1,050	4,450	1,550	-	-	2,440	2,400
BOD_5 (mg/L)	921	752	296	2,621	248	26	373	882	767
$TCOD_{Cr}$ (mg/L)	10,840	96,530	27,084	314,840	684	679	11,060	9,379	7,471
$SCOD_{Cr}$ (mg/L)	10,568	76,738	10,142	132,460	386	235	10,980	88.9	82.4
SS (mg/L)	13	16,255	873	43,117	1,730	730	15	10,723	10,610
VSS (mg/L)	10	15,750	867	42,916	490	325	13	5,790	5,540
NH_4^+-N (mg/L)	825.2	75.75	33.29	5,050	2.32	3.77	9.96	13.68	5.77
NO_3^--N (mg/L)	0	24.01	13.44	1,910	2.20	0.00	4.15	4.36	2.59
TN (mg/L)	1,108	152.00	88.50	7,060	4.88	6.44	10.40	15.14	6.23
TP (mg/L)	1.10	16.60	3.45	65.00	0.20	0.30	0.90	1.24	0.56

Bolton, 1998). Accordingly, a number of research has provided improved methods on reduction of sludge production and reusing sewage sludge as a resource(Burback and Perry, 1993; Parales et al 1994; Heo and Chung, 2005; Mohan et al., 2007; Anjum et al., 2017). Most of them are, however, limited to treatment process improvement, process technology for sewage sludge or composting technology via biological treatment(Kaparaju et al., 2009; Lee et al., 2014). Thus, it is of importance to investigate the operating conditions of the anaerobic digestion processes to make best use of high-level organic wastewater. In this study, organic removal efficiency and its reduction effect using anaerobic digestion were evaluated to treat high-level organic wastewater generated from the process of manufacturing polyester in H company who has been applying physio-chemical pre-treatment followed by aerobic treatment. Also, this study presents optimum operational parameters by evaluating the feasibility of anaerobic treatment for each manufacturing process wastewater.

2. Materials and methods

2.1. Characteristics of organic wastewater

To evaluate the possibility of anaerobic digestion to treat organic wastewater generated from each unit process for polyester manufacture, 7 different organic wastewater and 2 kinds of thickened sludge were selected and their characteristics were analyzed as listed in Table 1. The selected organic wastewater includes water separated from oil mixture (Oil), N Emulsion (NE), P Emulsion (PE), heat-treatment wastewater (HT), two aramid wastewater (T319 and T316) and Ethylene Glycol (EG). The thickened sludges were denoted as SA and SB.

2.2. Biological Methane Potential (BMP) test

An anaerobic digester was operated at 35°C by loading the selected organic wastewater and thickened sludges. A Biological Methane Potential (BMP) test method was used to measure the amount of gas production(Dague et al., 1992, APAH 1998, Siman et al., 2004, Kang et al., 2011). Based on the injection volume ratio, COD loading was varied

Table 2. Operating conditions of BMP test

Contents	Blank	Oil	NE	PE	HT	T319A	T316A	EG	SA	SB
Injection volume (mL)	N.D	13.84	1.55	5.54	0.48	21.93	21.93	13.56	15.99	20.08
COD loading (mg/L)	N.D	150	150	150	150	15	15	150	150	150

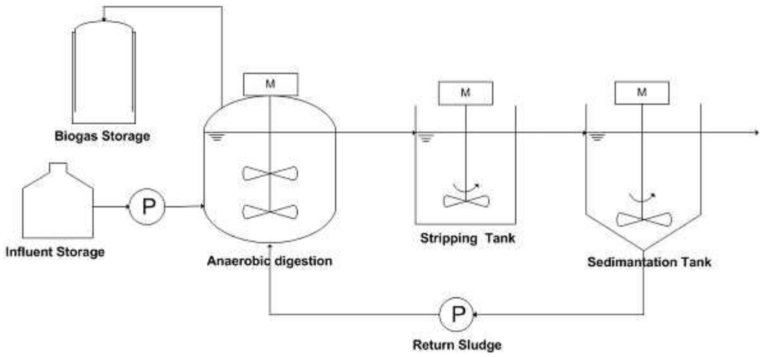


Fig. 1. Schematic diagram of the lab-scale anaerobic contact process.

widely (0, 15 and 150 mg/l) as listed in Table 2.

2.3. Continuous operation of an anaerobic contact process

Two sets of a lab-scale anaerobic contact process were manufactured and operated as shown in Fig. 1.

With EG and NE wastewater, the anaerobic digester was operated at 35˚C by varying organic loading and HRT to investigate their effects on the anaerobic contact process(Jeong et al., 2007; Jeong et al., 2008). For convenience, the operating conditions are denoted as A1 - D1 and A2 - D2 for EG and NE wastewater, respectively as listed in Table 3.

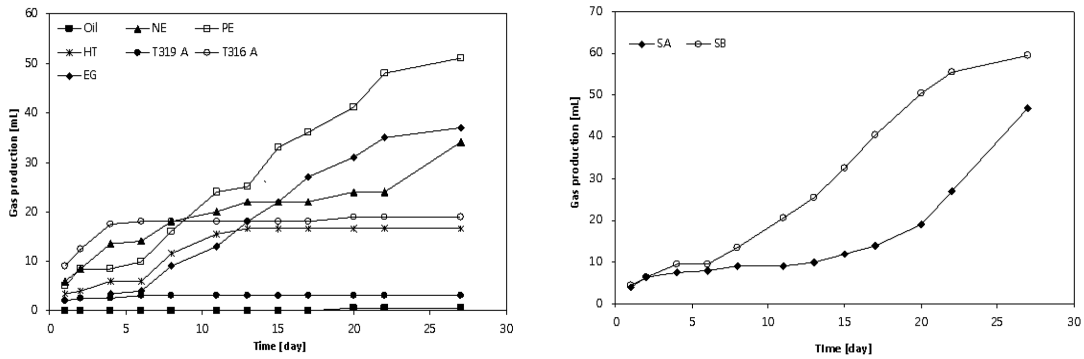
3. Results and discussion

3.1. BMP test results and influent wastewater selection

From the BMP tests with each process organic wastewater and thickened sludge, the cumulative gas production during the operation period of 27 days was obtained, as shown in Fig. 2. The total cumulative gas production was found to be 0.5 - 51.0 mL and 47.0 - 59.5 mL with unit process organic wastewater and thickened sludges (SA and SB), respectively and the average being about 23.0 mL. P Emulsion (PE) yielded the highest cumulative gas production (51 mL). NE and EG wastewater yielded

Table 3. Operating conditions of the lab-scale anaerobic contact process at 35˚C

Conditions	A1	A2	B1	B2	C1	C2	D1	D2
	EG	NE	EG	NE	EG	NE	EG	NE
COD_{Cr} loading rate ($kg/m^3 \cdot day$)	0.625	0.625	1.25	1.25	2.5	2.5	5.0	5.0
HRT (days)	12.5	20.8	6.25	10.42	3.12	5.21	1.56	2.60



(a) Unit process organic wastewater (b) Thickened sludge

Fig. 2. Cumulative biogas production obtained from BMP tests.

34.0 and 37.0 mL, respectively whereas the water separated from oil mixture (Oil) and aramid wastewater T319 resulted in very low cumulative gas production (0.5 and 3.0 mL, respectively). Heat-treatment water (HT) and aramid wastewater T316 (T316A) also yielded low gas production, being less than 20 mL. As indicated Table 1, it was found that the difference in gas production was associated with COD loading in the influent. Methanogenesis is sensitive to pH and can lose its activity in the presence of organic acids generated from the anaerobic decomposition process. The thickened sludges (SA and SB) produced 53.3 mL of gas, which is more than double times, compared to the process wastewater. This result can be explained as follows:

1. The thickened sludges are weak alkaline (pH of 7.2) and thus suitable for anaerobic digestion(Antwi et al., 2017; Maragkaki et al., 2017). Their alkalinity is about 2,400 mg $CaCO_3$/L, which can play as a buffer for pH fall.

2. Also, unlike the organic wastewater, the thickened sludges themselves had pre-existing microorganisms to facilitate anaerobic digestion.

After 27 days of BMP tests, COD removal efficiencies were obtained and shown in Fig. 3.

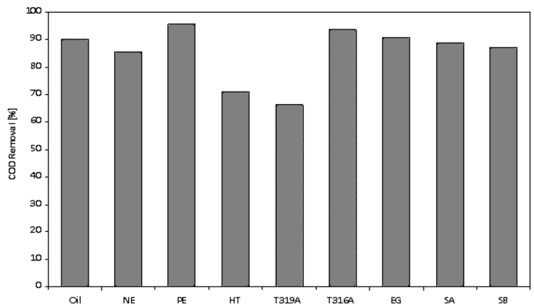


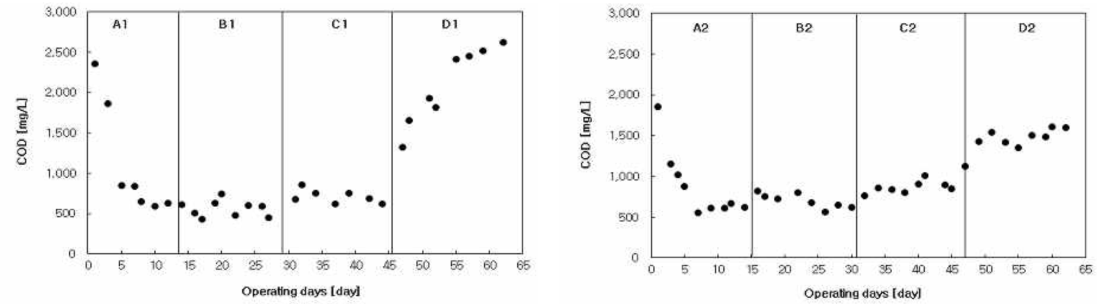
Fig. 3. COD removal efficiency obtained from BMP tests.

3.2. COD removal in the anaerobic contact process

Fig. 4 depicts COD concentration changes in the anaerobic contact process for (a) EG and (b) NE wastewater. For EG wastewater, the COD removal ratios were found to be 90.7, 92.4, 90.5 and 72.0% with the conditions of A1, B1, C1 and D1, respectively. The average effluent COD concentrations were 693.1, 568.1, 711.6 and 2,087.8 mg/L, respectively. Stable operation with COD removal efficiency of more than 90% was obtained with the first three conditions (A1, B1 and C1).

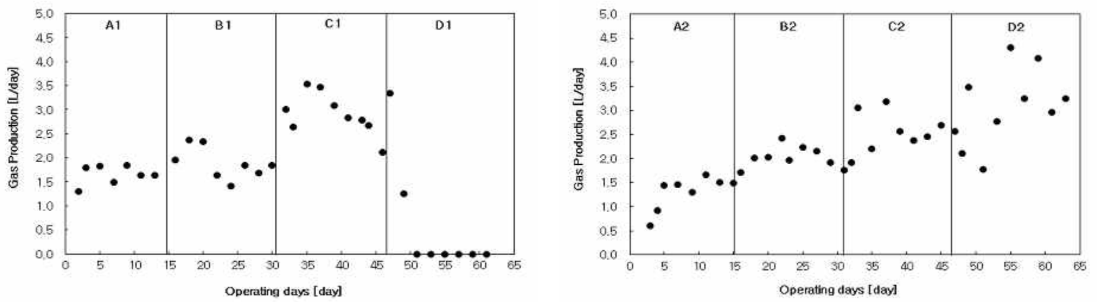
3.3. Biogas production in the anaerobic contact process

Biogas production in the anaerobic contact process was converted as dry gases at standard conditions (0℃ and 1 atm) and is plotted against operating



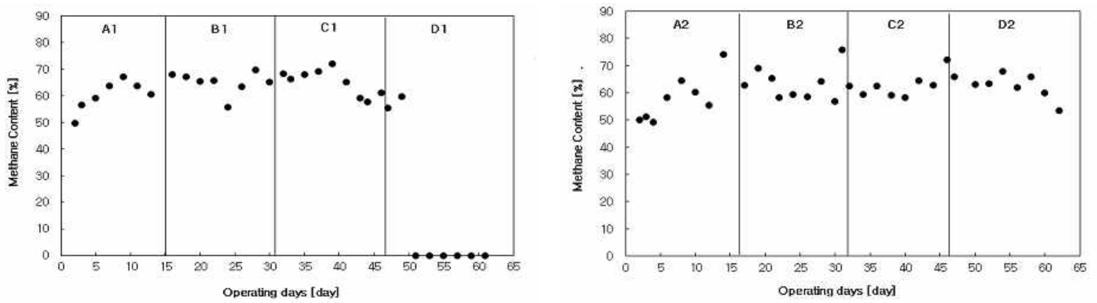
(a) EG (b) NE

Fig. 4. COD changes with operating conditions for (a) EG and (b) NE wastewater.



(a) EG (b) NE

Fig. 5. Biogas production with operating conditions for (a) EG and (b) NE wastewater.



(a) EG (b) NE

Fig. 6. Methane content changes with operating conditions for (a) EG and (b) NE wastewater.

conditions in Fig. 5. According to each operating condition in Table 3, gas production with EG wastewater was found to be 1.65, 1.89, 2.90 and 0.57 L/day, and it was 1.34, 2.05, 2.64 and 3.11 L/day with NE wastewater. This result is consistent with observations that methane production from heat treatment processes of sludge in anaerobic digesters is proportional to the amount of organic content removed. In addition, for both EG and NE wastewater, the gas production was found to increase with loading. With D1 condition, pH was dropped rapidly, deteriorating anaerobic digestion and thus yielding no gas production whereas for NE wastewater, stable gas production was obtained with D2 condition (5 kg COD/m3・day). Along with pH neutralization from 10 times dilution, HRT was longer for NE wastewater (2.6 days) than EG wastewater (1.5 days), providing longer reaction time for methanogens.Methane concentrations in the biogas produced from anaerobic contact digestion of EG and NE wastewater are plotted in Fig. 6.

4. Conclusions

In this paper, high-level organic wastewater, which was generated from the process of manufacturing polyester in H company, was treated using an anaerobic digester, resulting in the following conclusions.

1. From the BMP test results with high-level organic wastewater generated from the polyester processes, most wastewater except for aramid process wastewater was found to be suitable for anaerobic digestion. As EG and NE wastewater resulted in high methane yield and organic removal efficiency, they can be used as process influent for lab-scale anaerobic contact digesters.

2. With D1 condition, high loading of EG wastewater, whose initial pH was 4.3, reduced pH during the anaerobic contact digestion process, deteriorating active anaerobic digestion. Also HRT was too short (1.5 days), allowing no transition of acid formation to methane formation stage. Consequently, the organic acids produced by acid formers were not utilized by methanogens.

3. For NE wastewater, stable gas production was observed even with a high-loading condition (D2). As NE wastewater was diluted 10 times, its pH was neutralized and HRT with D2 condtion was 2.6 days which is longer than that for EG wastewater (1.5 days). Thus, enough reaction time was allowed to produce methane. Therefore, for stable treatment of high-level organic wastewater from H company with anaerobic digestion, pH needs to be neutralized by adding more alkalinity and HRT should be kept for more than about 2.5 days.

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