COD Removal of Cardboard Factory Wastewater by Upflow Anaerobic Filter

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***Abstract* – Cardboard factories have generated organic contaminated wastewater according to their using of raw materials which included starch glue in process. Wastewater usually contains of pink color with high turbidity and Chemical Oxygen Demand (COD) 1,300 – 1,600 mg/L which affected to environmental problem. In this studies, Upflow Anaerobic Filter reactors were developed to operate under anaerobic condition at room temperature (25 - 27 ^oC). Diameter and active height of reactor was 0.15 m and 1.2 m. Bio balls were introduced into the reactor which has specific surface area by 230 m^2/m^3. The reactors had effective volume of 19 liters. The operated conditions in this research were controlled at OLR 0.65 $kgCOD/m^3$.d , HRT 48 hr. and OLR 1.3 $kgCOD/m^3$.d , HRT 24 hr.**

Results showed the efficiency of COD removal that enhanced to 40.7 % and 47.4 %, for OLR 0.65 $kgCOD/m^3$.d and OLR 1.3 $kgCOD/m^3$.d respectively. Gas analysis by Shimazu GC-8A revealed that CH_4 production from the operated conditions with OLR 0.65 $kgCOD/m^3$.d and OLR 1.3 $kgCOD/m^3$.d were 61.2 % and 62.4 % ,respectively. Consequently, biochemical methane potential (BMP) can be estimated to 0.09 LCH_4/gCOD and 0.07 LCH_4/gCOD. The Upflow Anaerobic filter should be the primary wastewater treatment for cardboard factory wastewater.

Keywords – cardboard factory wastewater , Upflow anaerobic filter , COD removal , Methane production , Organic loading time.

1. INTRODUCTION

The rapid growth of industrial development in Thailand bought on numerous environmental problems which affects Thai people quality of life. Cardboard production industry is one of the industries that generate wastewater which has an impact on environment and living standard of people residing in the vicinity of the factory. The wastewater generated from cardboard process factory in Northern Thailand contains high organic pollutants resulted from glue which made from starch and unpleasant color from chemical used production processes. Henze and Harremoes (1983) defined the upflow anaerobic filter (UAF) is an original type of anaerobic digestion process which results for well operational characteristics. Song and Young (1986) , Joseph and Pohland (1992) reported upflow anaerobic filter (UAF) is usually used, because of its several advantages over other anaerobic treatment processes [e.g. upflow anaerobic sludge blanket (UASB) or continuous stirred tank reactor (CSTR)]. UAF offers exceptional benefits with providing a quiescent inlet region for high biomass retention, shorter startup period, smaller reactor volume, relatively stable operation under variable feed conditions. Moreover, Speece (1996) mention that it is also suitable for waste with low suspended solids content, and reducing electricity consumption because mechanical mixing is not required. Thus, the purpose of this study is to assess the effectiveness of the Upflow Anaerobic Filter (UAF) in the treatment of wastewater from cardboard production factory for the reduction of COD and the production of the methane gas as by-product from this treatment process.

2. MATERIALS AND METHOD

2.1 Wastewater

Figure 1 Wastewater for experiment1 (Exp1) and experiment2 (Exp2)

Daily wastewater was directly collected the discharged wastewater of the cardboard factory in Chiang Mai Province. Collection from once a week or depending on the needs of the experiments and kept at 4^oC in a refrigerated room. During this experiment, average COD of wastewater was 1,400 mg/L and the range of COD wastewater concentration was about 1,300 – 1,600 mg/L. Anaerobic digester sludge that used for seeding was obtained from Chiang Mai University's wastewater treatment plant. The sludge concentration (MLVSS) in reactors was 4,000 mg/L at seeding period. Wastewater characteristics were depicted in Table 1.

Table 1 Wastewater characteristics

Wastewater Characteristics	
pH	6.9 - 8.1
COD , mg/L	1,300 - 1,500
SS , mg/L	100 - 500
VSS , mg/L	100 - 500
Alk , $mgCaCO_3/L$	40 - 60
VFA , mg/L	100 - 600

2.2 Reactors

In this study, two UAF reactors were configured to conduct the experiments. Both reactors were made from PVC column with an inner diameter of 0.15 m height of 1.5 m which have an effective height of 1.2 m and effective volume of 19 liters. They were filled with plastic bio ball as media that was introduced into the reactor which has specific surface area by 230 m^2/m^3 as shown in figure1. The wastewater was storage in the storage tank (volume of 50 liters) with mechanical agitator. Influent was pumped from peristaltic and diaphragm pumps to the reactors.

The gas collectors were made of the cylindrical clear acrylics 700 ml volume connected with rubber tube to the top of each reactor and contained acid liquor with pH 4 for preventing the dissolved of CO_2 gas.

Figure 2 Utilized upflow anaerobic filter system in the Experiments

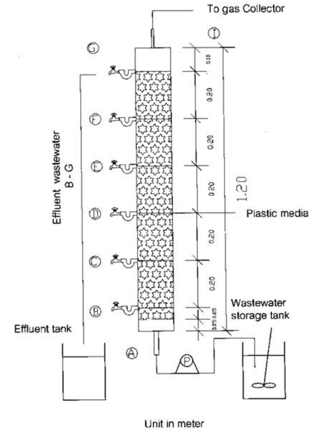

Figure 3 Schematic diagram of the model of upflow anaerobic filter(UAF) for experiment 1 and experiment 2

2.3 Experiment set-up

The setting up of experimental apparatuses was started by adding 6.65 liters of anaerobic digested sludge (35%) into both UAF reactors. Then, treatment investigations were started by feeding non-diluted wastewater until the effective volume in reactor was defined at 19 liters. The experiments has been conducted over a period of 5 months with Organic loading rate(OLR) of 0.65 $kgCOD/m^3.d$ at 48 hours HRT (Exp1) and OLR of 1.3 kg $COD/m^3.d$, at 24 hours HRT(Exp2). Details of operating conditions are shown in table 2.

Table 2 The operation used in the experiments.

Experiment	Influent COD (mg/L)	OLR ($kgCOD/m^3.d$)	HRT (hours)	Q (L/d)
1	1,400	0.65	48	9.5
2	1,400	1.3	24	19

2.4 Analytical Method

Influent and effluent pH , temperature , suspended solid (SS), volatile suspended solid (VSS) , volatile fatty acid (VFA) , Alkalinity as $CaCO_3$ and chemical oxygen demand (COD) were analyzed according to the Standard Methods for the Examination of Water twice a week during initial state and three times a week when experimental reach the steady state. Gas composition was analyzed by a gas chromatograph (Shimazu GC-8A) for CH_4 and CO_2.

3. Results and Discussions

The results from laboratory experiments with UAF cover a period of 135 day of continuous operation. The start-up of the reactors was run at the room temperature (25 - 27 ^{o}C) and approximately HRT of 48 and 24 hr at OLR 0.65 kgCOD/m^3.d (Exp1) and 1.30 kgCOD/m^3.d(Exp2) respectively. Under these conditions a quick start-up of UAF was obtained with in less than 2 weeks. In the initial state, the influent COD concentrations were fluctuate because of the inconsistency of wastewater properties when they were collected from wastewater plant at various time. The treatment process was observed to reach a steady state when the COD concentration in both conditions following the same pattern after 101 days of operation as shown in figure4. It was also observed that the COD concentration reduction in Exp2 with higher OLR rate was greater than the COD concentration reduction in Exp1 with lower rate.

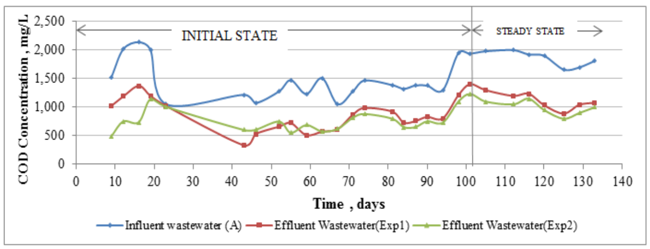

Figure 4 COD concentration in influent and effluent wastewater of Exp1and Exp2 with times

Figure5 and figure6 showed the percentage of COD removal and the production of methane gas from the treatment process with time. The results indicated that the COD removal and methane production in both experiments reached a steady state at the same time (after 101 days), the percentage of COD removal and the amount of methane production follows the same pattern. From these results , it can be summarized that the time required to reach a steady state for COD reduction and methane production is independent on the OLR .

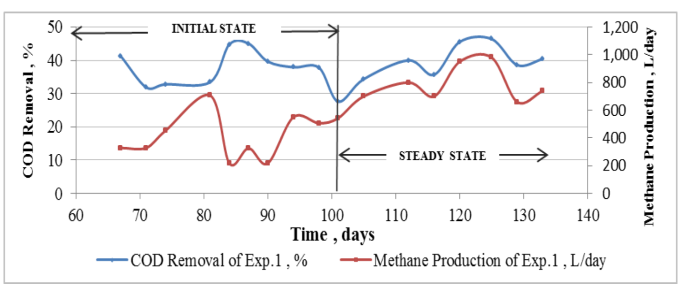

Figure 5 COD removal efficiency and methane production of Exp1

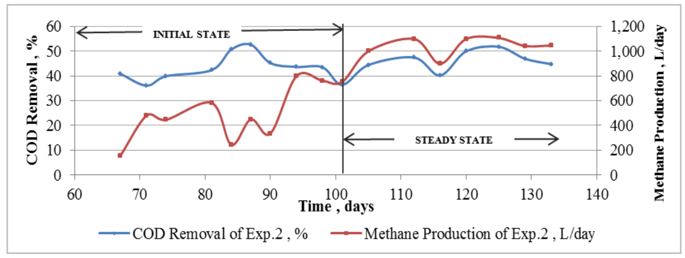

Figure 6 COD removal efficiency and methane production of Exp2

In addition, figure5 and 6 also indicated that the average of COD removal efficiencies under anaerobic conditions in this study were 40.7% and 47.4 % in the Exp1 and Exp2, respectively. In comparison , Prasad and Joyce (1993) explored the efficiency of a combined treatment consisting of fungal and anaerobic treatment in a rotating biological reactor for 2 days HRT achieved 45% COD reduction which consistent the result from Exp.1 at the same HRT in this study.

Rintala and Lepisto (1993) studied thermophilic treatment of kraft mill. The effluent wastewater was fed to anaerobic followed by aerobic reactors. Heated air was supplied to the aerobic reactors. The feed COD was 1,000–1,100 mg/l. The average COD removal was 39.7% to 44.9% in the anaerobic process at loading rates of 1.3–2.5 kgCOD/m^3.d, corresponding to hydraulic retention times of 17.6–30 h and Yu and Welander (1994) also found that anaerobic fixed film process could efficiently remove variety organic compounds. Overall COD removal was 20% and BOD removal was 70%. The results of COD removal efficiency on different operating conditions were depicted in table 3

The comparison of total amount of biogas production from both experiments was investigated. It was found that at the steady state, Exp1 average gas production rate was 870 ml/d while Exp2 average gas production rate was 1,200 ml/d. The production of total biogas during steady state related directly to OLR, which OLR in Exp2 is higher than Exp1, thus, the total gas quantity becomes higher as mention of Eddy M. a. (2004). In addition, methanogenic activity has increased with increasing OLR.

Figure7 reported the composition of biogas which consist of CH_4 , O_2 , N_2 and CO_2 the initial methane production of Exp1and Exp2 were 50 ml/d and 130 ml/d then increase steadily in the subsequence month until reaching equilibrium at 490 ml/d for Exp1 and 855 ml/d for Exp2 after 3 months experimental. Methane content in production of biogas produced were 61.2 % and 62.4 % for Exp1 and Exp2 , respectively. The biochemical methane potential (BMP) can be estimated to 0.09 LCH_4/gCOD and 0.07 LCH_4/gCOD for Exp1 and Exp2 , respectively.

Table 3 Results of COD removal efficiency on different operating conditions from various resources.

Reference	Resource	Process	OLR kgCOD/m^3.d	HRT hr.	Percentage of COD Removal
Milstein et al. (1991)	Bleaching plant	flocculation			59
Prasad and Joyce (1993)	Softwood kraft mill bleach plant	anaerobic rotating biological		48	45
Rintala and Lepisto (1993)	Kraft mill	anaerobic followed by aerobic reactors	1.3–2.5	17.6–30	39.7 to 44.9 in anaerobic process
Yu and Welander (1994)	Kraft bleaching plant	anaerobic fixed film			20
Ben and Kesentini (2008)	Cardboard industry	coagulation–electroflotation			95
Experiment 1	Cardboard factory	Upflow anaerobic filter	0.65	48	41
Experiment 2			1.3	24	46.6

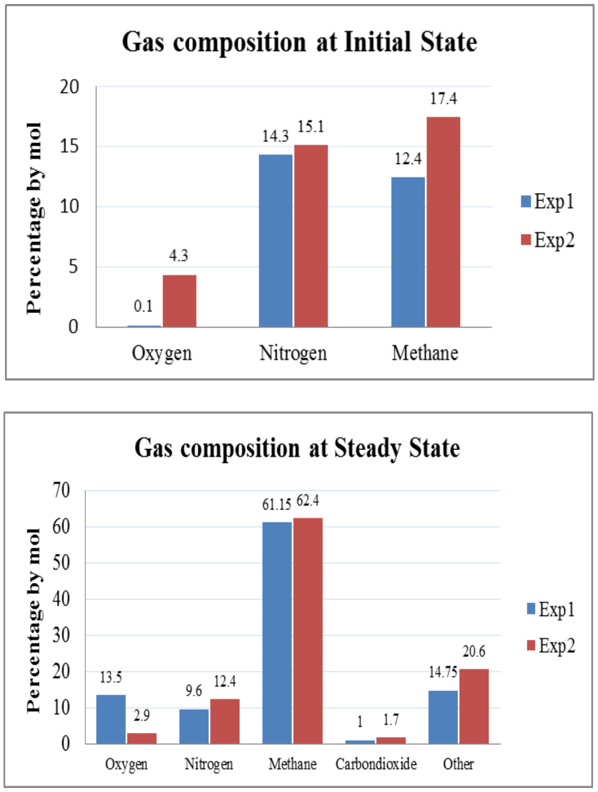

Figure 7 Biogas compositions of Exp1 and Exp2

From the results of Exp1 and Exp2 were summarizes in table 4. Methanogens prefer nearly neutral pH in the range of 6.5 to 8.2 (Speece, 1996). pH values of influent wastewater was in the range of 6.9 – 8.1 and effluent wastewater of all experiments was in range of 6.9 – 8.1 therefore, pH did not affect to the acclimatization of microorganism . Due to the fact wastewater usually contains of several solid materials varying. Generally, SS and VSS are supposed to be organic material in the water. In table4, the results show alkalinities in effluent wastewater were higher than alkalinity in influent wastewater, because changing of carbon dioxide in the form of bicarbonate. The concentration ratio of volatile fatty acid to alkalinity should be lower than 0.4, which can be implied the buffer capacity is adequate, otherwise the increasing of volatile fatty acid will affect to stability of system. In this study, the concentration ratios of volatile fatty acid to alkalinity are more than 0.4 but volatile fatty acid was not increase larger. Consequently, all experiments were studied without system failure.

Table 4 The results of the experiments

	Parameters	Unit	Exp1	Exp2
Operations	OLR	kgCOD/m^3.d	0.65	1.30
	HRT	hour	48	24
	Flow rate	L/day	9.5	19
	pH		6.9 - 8.1	
	Volatile fatty acid	mg/L	80 - 670	
	Alkalinity	mg/L as $CaCO_3$	38 - 65	
	SS	mg/L	306.25	
	VSS	mg/L	285.30	
	COD	mg/L	1,570	
Results	pH		7.04-8.03	6.94-8.10
	Volatile fatty acid	mg/L	72 - 382	13 - 287
	Alkalinity	mg/L as $CaCO_3$	69 - 95	65 - 97
	SS	mg/L	113.25	144.23
	VSS	mg/L	109.23	140.40
	COD	mg/L	931.31	835.53
	%COD removal	%	40.69	47.43
	Total Biogas	ml/day	870	1,200
	CH_4 content	%	61.15	62.4
	CO_2 content	%	1	1.7
	BMP	LCH_4/gCOD.d	0.09	0.07

4. CONCLUSION

From this study, it can be concluded that the UAF can be applied in the treatment of wastewater from cardboard production factories. The process can reduced COD concentration to an acceptable level (more than 40% removal) with approximately 3 months after start-up period. The anaerobic process also produces biogas with high methane content (more than 60% of total biogas) which can be utilized as an alternative energy resource. In addition, recirculate should be studied, in order to improve the efficiency of COD removal.

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