

Evaluation of Efficiency and Biodegradability of Lubricant Oil Treated by Sequencing Batch Reactor (SBR)

Boonchai Wichitsathian and Watcharapol Wonglertarak

Abstract—Oily wastewater is one of the most concerned pollution sources due to its consisting of toxic substances such as phenols, petroleum hydrocarbons, and polyaromatic hydrocarbons. Those substances are also inhibitory to plant and animal growth as well as mutagenic and carcinogenic to human being. Such kind of wastewater is mainly originated from crude oil production, oil refinery, petrochemical industry, lubricant and car washing. The purpose of this study was to investigate the effect of lubricant oil concentration normally used in a gas station on the performance of SBR. The experiment was performed by varying concentration of lubricant oil from 50 to 500 mg/L in SBR with HRT 24 hrs. The results indicated that the effective removal of COD was in the range of 84-87%. The oil removal efficiency was found to be in the range of 51-82%. Considering, effluent of SBR system at HRT 24 hours with the Readily biodegradable, the value percentage increase of 62.00%, 57.79%, 60.54%, 54.53%, 41.79% and 36.03%, respectively, and Slowly biodegradable hydrolysis into Readily biodegradable was to increases.

Index Terms—Oily wastewater, COD fractionations, sequencing batch reactor (SBR).

I. INTRODUCTION

Wastewater from gas stations has become a major cause of environmental pollution in urban areas. Each gas station generates an average of 20 m³ wastewater per day. Carwash operation utilizing approximately 300–600 L of water per car is a primary contributor of wastewater, which mainly consists of toxic substances such as phenols, petroleum hydrocarbons, and polyaromatic hydrocarbons. Those substances are inhibitory to plant and animal growth, as well as mutagenic and carcinogenic to human being [1]. The oil compounds in the carwash wastewater are mainly present as an oil water emulsion with the presence of emulsifier. Conventional treatment systems for oily wastewater from gas stations are parallel or corrugated plate interceptors (PPI or CPI) designed to treat only free oil and settled solid. Therefore, those treatment systems have little effect on the oil water emulsion containing about 50–100 mg/l of oil. Consequently, wastewater discharged from gas stations hardly meets the effluent standards of 15 mg/l and 120 mg/l for oil and chemical oxygen demand (COD), respectively.

Physical treatments of oily wastewater such as API gravity separator, dissolved air floatation (DAF), and ultrafiltration cannot remove the pollutants completely but just transfer to a

more concentrated waste [2]. The chemical coagulation process that usually precedes with the biological process is replaced with a more advanced process such as electrocoagulation [3]. However, the physical treatment methods are also unable to remove soluble fraction of the wastewater and these processes pose high costs and have fairly low application on an industrial scale [4].

Moreover, the conventional biological treatment techniques are mostly incapable of producing a complete elimination of hydrocarbon in the stable emulsion. Low removal efficiency of the conventional biological processes is probably due to the inhibitive effects of toxic substances and hydrophobic characteristics of oil components [2]. Therefore, it is necessary to investigate the concentration threshold of oil introduced into a biological treatment system to prevent the occurrence of a shock load in the system that adversely affects the treatment efficiency.

II. MATERIALS AND METHOD

A. Synthesis of Oily Wastewater

Synthetic oily wastewater was prepared in accordance with the survey data from various gas stations in Thailand [5]. It showed that O&G concentration and BOD of carwash wastewater were in the range of 7.8 – 280.5 mg/L and 10 – 1220 mg/L, respectively. The oil concentration in this study was varied from 50-500 mg/L. Glucose was supplemented into the feed wastewater to simulate the carbon source. The components of the synthetic oily wastewater contained glucose 98.74 mg/L, K₂HPO₄ 880 mg/L, KH₂PO₄ 440 mg/L, NH₄Cl 105 mg/L, MgSO₄·7H₂O 150 mg/L, ZnSO₄·7H₂O 5 mg/L, FeSO₄ 5 mg/L, MnSO₄ 5 mg/L, CaCl₂ 20 mg/L, CuSO₄ 0.02 mg/L, CoCl₂ 0.02 mg/L, and emulsifier 13.6 mg/L. Commercial lubricant PTT Max Speed 4T, manufactured by Petroleum Authority of Thailand (PTT), was used in this study.

B. Experimental Setup

The experiments were operated with the sequencing batch reactor (SBR) mode. Each cycle went through four main steps: filling, reacting (aeration), settling and drawing. Three liter-glass-bottles were used as model reactors. The concentrations of lubricant oil were varied for 50, 75, 100, 150, 300, and 500 mg/L in six reactors with the control HRT of 24 hrs. The reactors were mixed and aerated by the compressed air through stone air diffusers to maintain a suitable mixing condition and to supply sufficient dissolved oxygen for microorganism growth (DO = 2 - 4 mg/L). The pH of the reactors was controlled within the range of 6.2-8.0 by adding NaOH. The reactors were operated without sludge

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wastage except for a sampling purpose.

C. Biodegradability Kinetic Evaluations

The OUR experiments were conducted to determine the biodegradability kinetic coefficients of the aerobic heterotrophs via the procedure of [6]. The batch tests shown in Fig. 1 were maintained at the temperature 30 ± 0.5 °C and pH 7 ± 0.2 with suppressing nitrification of 70 mg N-ammonia/L. The sludge samples were obtained from a municipal activated sludge process. The initial mixed liquor volatile suspended solids (MLVSS) concentration (X_0) in the sludge samples was about 485 mg/L for the batch tests and the various lubricant oil initial substrate concentrations (S_0) that govern the quality of the batch respirometric tests. The OUR results were used for calculating the maximum specific growth rates (μ_{max}), substrate utilization rate (r_x), half-velocity constant (K_s), and sludge yield coefficient (Y) based on Monod kinetics by regression analysis.

D. Sampling and Analytical Methods

The influent and effluent samples of the SBR were analyzed following the standard methods for the examination of water and wastewater [7] for COD, total Kjeldahl nitrogen, and O&G. Biochemical oxygen demand (BOD) was determined with an OxiTop®-C measuring pressure head instrument (Expotech USA Inc., Houston, TX, USA). The carbonaceous materials were measured in terms of the COD parameters subdivided into a number of fractions following [8].

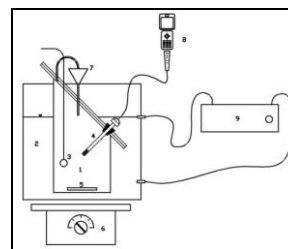


Fig. 1. Respirometer: 1) Respiration cell, 2) Water jacket, 3) Air diffuser, 4) DO probe, 5) Magnetic bar, 6) Magnetic stirrer, 7) Expansion funnel, 8) DO meter, and 9) Water bath.

III. RESULTS AND DISCUSSION

A. Removal Efficiencies of COD and O&G

Table I and Fig. 2 summarize the variation in the COD and O&G concentrations of the influent and effluent throughout the experimental runs. The results showed that the effective removal of COD was in the range of 84-87%, which is insignificant difference when increasing in the oil concentrations up to 500 mg/L, as shown in Fig. 1. The COD effluent concentrations were 30.0 ± 7.7 , 35.3 ± 8.6 , 40.8 ± 10 , 50.8 ± 9.0 , 80.4 ± 9.7 and 121 ± 4.5 mg/L for the lubricant oil concentrations of 50, 75, 100, 150, 300, and 500 mg/L, respectively. All COD effluents are all lower than the standard of COD effluent (200 mg/L) recommended by the Ministry of Science, Technology and Environment in Thailand for a gas station. Considering the oil treatment, the removal efficiencies for the investigated concentrations were found to be in the range of 51-82%.

TABLE I: WATER QUALITY AND EFFICIENCY OF LUBRICANT OIL TREATED BY SBR

Parameter		Concentration of lubricant oil (mg/L)					
		50	75	100	150	300	500
COD	inlet (mg/L)	193±3.3	243±3.4	277±3.6	361±4.1	611±6.8	946±11
	Outlet (mg/L)	30.0±7.7	35.3±8.6	40.8±10	50.8±9.0	80.4±9.7	121±4.5
	Efficiency (%)	84.78	85.48	85.11	85.99	87.07	87.34
O&G	inlet (mg/L)	155±11	173±7	203±12	261±7	396±4	537±6
	Outlet (mg/L)	59±1	74±6	86±2	119±6	165±18	184±4
	Efficiency (%)	61.9	57.2	57.6	54.4	58.3	65.7
TKN	inlet (mg/L)	14.6±1.0	16.3±0.3	16.3±0.3	17.4±1.7	17.5±0.9	17.6±0.9
	Outlet (mg/L)	5.3±0.97	5.9±0.28	5.3±0.97	5.2±0.32	5.7±0.70	3.7±0.16
	Efficiency (%)	63.7	63.8	67.5	70.1	67.4	79
BOD	inlet (mg/L)	55.40	61.60	71.90	88.80	152.00	248.00
	Outlet (mg/L)	18.60	20.40	24.70	27.70	33.60	43.60
	Efficiency (%)	66.43	66.88	65.65	68.81	77.89	82.42

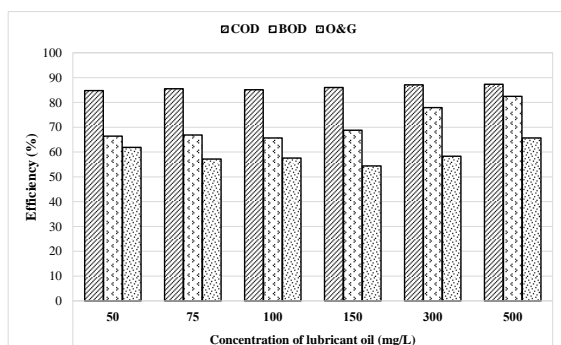


Fig. 2. Organic and O&G removal of various lubricant oil treated by SBR.

B. Biodegradability and COD Fractionations

Potential biodegradability was evaluated with the results illustrated in Fig 3. The BOD/COD ratio of oily wastewater was very low, which was in the range of 0.25-0.29 for the investigated oil concentrations of 50-500 mg/L. The ratio of BOD/COD is often used as an index to evaluate a biodegradability of wastewater. BOD/COD > 0.45 indicates that the biodegradability is very good; for BOD/COD=0.45, the biodegradability is good; for BOD/COD = 0.2–0.3, the biodegradability is poor; for BOD/COD < 0.2, the biological

treatment is unsuitable [9]. After treated by the SBR system, the BOD/COD ratio was increased to be in the range of 0.36-0.62. The 50 mg/L oil concentration provided the highest ratio.

The COD fractionations were evaluated and the results are illustrated in Fig 4 and 5. It showed that the slowly biodegradable organic matter was hydrolyzed to readily biodegradable organic matter and inert soluble organic matter. Readily biodegradable organic substrate (S_s) increased, and the hydrolysis from X_s into S_s and S_i after treated by the SBR was observed. Considering the effluent of SBR system at HRT 24 hours, the Readily biodegradable (S_s) increased in percentage of about 60%, 58%, 60%, 55%, 42% and 36% for the oil concentrations of 50mg/L, 75mg/L, 100mg/L, 150mg/L, 300mg/L and 500mg/L, respectively. Plus, an increase of slowly biodegradable hydrolysis into readily biodegradable was observed.

X_i , calculated from the difference between the soluble COD fraction (CODsol) and X_s , was about 428 mg/L or

50.05% of the total COD in case of the 500 mg/L oil influent, and was found to decrease to about 36.25 mg/L or 29.96% of the total COD after treating by SBR. The X_i fraction (inert particulates) exits the plant and bounds up in sludge flocs [10]. Although the X_i fraction is inert, it can be removed by a biological treatment [11].

C. Effect of S_0/X_0 Ratio on the Biodegradation

The ratio of initial substrate concentration (S_0) to initial biomass concentration (X_0) indicates the availability of a carbon source and inhibition for microbial growth. The oily wastewater showed a significant inhibitory effect on decreasing the specific growth rate of microorganisms at a higher concentration (Fig. 6) [12]. The sole carbon source for maximum specific growth rate was found to be with a maximum S_0/X_0 ratio 0.020-0.389.

TABLE II: BIOKINETIC EXPERIMENTAL DATA OF OILY WASTEWATER INFLUENT

S mg/l	F/M	r_x mg COD/mg MLVSS	Y mg MLVSS/mg COD	μ d^{-1}	μ_{max} d^{-1}	K_s mg COD/l
9.3750	0.0200	0.0426	0.1692	0.1730	5.2264	40.6700
10.5000	0.0216	0.0553	0.2829	0.3752		
11.6250	0.0239	0.0554	0.4421	0.5874		
20.6250	0.0424	0.0937	0.4521	1.0172		
26.2556	0.0540	0.1142	0.5043	1.3815		
31.8750	0.0655	0.1594	0.5121	1.9589		
43.1250	0.0887	0.2156	0.5680	2.9393		
96.4554	0.1983	0.3445	0.6034	4.9883		
99.6528	0.2049	0.3322	0.6165	4.9152		
189.3750	0.3893	0.2594	0.6296	3.9197		

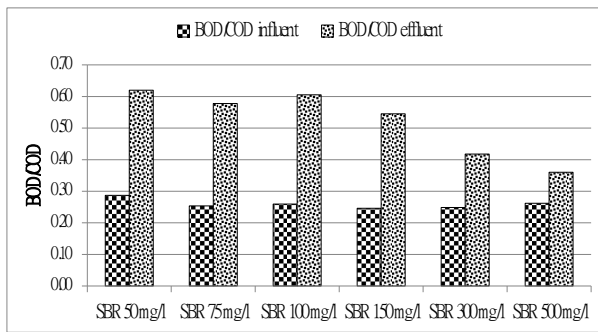


Fig. 3. BOD/COD of influent and effluent oily wastewater.

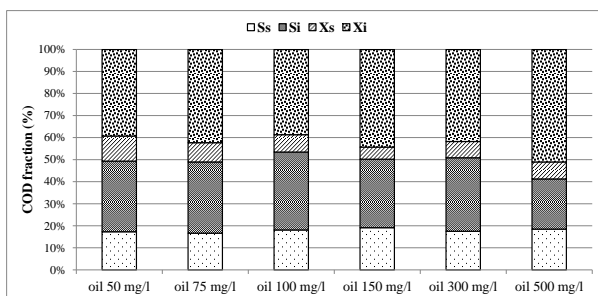


Fig. 4. COD fractionations on influent oily wastewater.

Results of biokinetics experiments show that a SBR have the higher potential for organic removal of oily wastewater. Moreover, it can also be observed that the yield (Y) of the bacterial culture is high. This indicates that high excess sludge would be produced from the bacterial system.

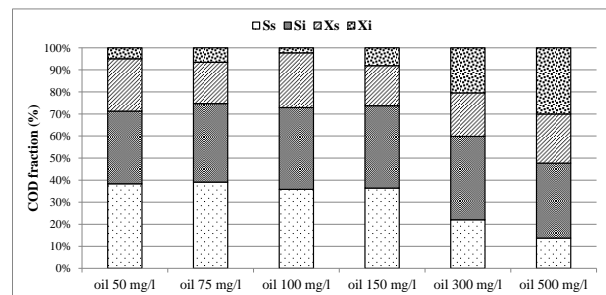


Fig. 5. COD fractionations on Effluent oily wastewater.

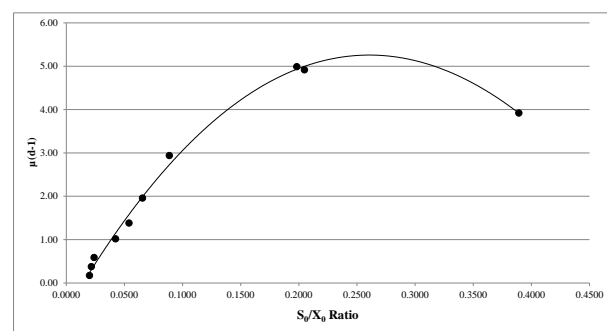


Fig. 6. Relation between μ and S_0/X_0 ratio.

Values of biokinetic coefficients of oily wastewater treated by SBR shown in Table II indicated that substrate utilization rate (r_x) and maximum specific growth rate (μ_{max}) were increased when substrate concentration increased, which explained the highest organic removal in SBR.

IV. CONCLUSIONS

The results indicated that the effective removal of COD was in the range of 84-87%. The oil removal efficiency was found to be in the range of 51-82%. Considering the effluent of SBR system at HRT 24 hours, the Readily biodegradable (S_s) increased in percentage of about 60%, 58%, 60%, 55%, 42% and 36% for the oil concentrations of 50mg/L, 75mg/L, 100mg/L, 150mg/L, 300mg/L and 500mg/L, respectively. Plus, an increase of slowly biodegradable hydrolysis into readily biodegradable was observed.

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