Journal of Water Sustainability, Volume 3, Issue 2, June 2013, 97–106

Treatment of Low Strength Wastewater by Rubber Granules Media AFB Reactors without Internal Recirculation

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ABSTRACT

In this research, the efficiency of wastewater treatment and biogas production by the Anaerobic Fluidized Bed (AFB) reactors using rubber granule as a media were performed under condition of no internal recirculation. A low density rubber granule is easy to form a fluidization state which beneficial conserves more energy for the process. The experiment was divide into two parts, first is a system startup, which the synthetic wastewater with a COD of 1,045 mg/L (equivalent to OLR of 30 kg COD/$m^3 \cdot d$) was continuously feed into two AFB reactors at a constant rate of 46.8 L/day and hydraulic retention time as low as 0.84 h. After those two reactors reached steady state, the step up OLR variation was performed. The OLR loading for the 1st reactor was changed to 15 and 2 kg COD/$m^3 \cdot d$ (equivalent to COD of 522 and 70 mg/L), whereas the OLR loading for the 2^{nd} reactor was changed to 5 and 2 kg COD/$m^3 \cdot d$ (equivalent to COD of 174 and 70 mg/L), respectively. The result showed that COD removal efficiency of the 1st reactor was achieved to 81.45%, 88.44% and 81.18%, while the amount of biogas was 0.17, 0.28 and 0.18 L/g COD removed. For the 2^{nd} reactor, the efficiency for COD removal was 96.49%, 91.40% and 91.02%, together with 0.08, 0.18 and 0.05 L/g of COD being removed for biogas production. This research could be concluded that the rubber granule media AFB without internal recirculation in this research has the comparable efficiency to other general AFB reactors with internal recirculation. Moreover, this knowledge reveals an advantage of this AFB reactor in terms of a shorter retention time, which can save more energy and simultaneously performed a larger amount of wastewater treatment.

Keywords: Anaerobic Fluidized Bed (AFB); rubber granule; organic Loading Rate (OLR); low strength wastewater; without internal recirculation

1. INTRODUCTION

Anaerobic fluidized bed (AFB) reactor, an alternative biological wastewater treatment reactor which has several advantages compared to other biological reactors. For instance, it can treat high organic loading rate wastewater, has proper hydraulic retention time, and is able to maintain concentration of biomass in the system (McCarty and Rittman, 2001). Besides, the byproduct is biogas which is important in terms of being used as the renewable energy source (Masud et al., 2009). The principal biogas from anaerobic decomposition in wastewater is methane gas (Metcalf and Eddy, 2004). However, this system has some disadvantages such as the startup period is long and the system consumes more energy in order to keep the inner media fluidized. In AFB reactor, the supporting materials play a very important role in treatment performance. Thus, this research chosen the rubber granule prepared from spent tire as a media in the AFB reactor. This rubber granule has a lower density; moreover, it is easier to be fluidized

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DOI: 10.11912/jws.2013.3.2.97-106

than other classical media, such as microsand, charcoal, coconut coir and sepiolite (Acharya et al., 2008; Arnaiz et al., 2006; Metcalf and Eddy, 2004). This profit also allowed wastewater to easily diffuse through biofilm layer, causing a high quantity of biomass and high COD removal. Moreover, due to its low density, the rubber granule can be used in the AFB reactor without an internal recirculation. The result from previous research showed that using the rubber granule as a media in biological treatment reactors caused no effect to microorganism activities (Park et al., 2006). In addition, the use of rubber granule from spent tire can be considered as a recycle way for waste reduction. Therefore, this research presents the efficiency of wastewater treatment and biogas production by AFB reactors using rubber granule as a media under a condition of no internal recirculation. In these experiments, the wastewaters with varying organic loading rates (OLR) of low different COD concentrations were fed in laboratory scale experimental reactors under a controlled hydraulic retention time (HRT).

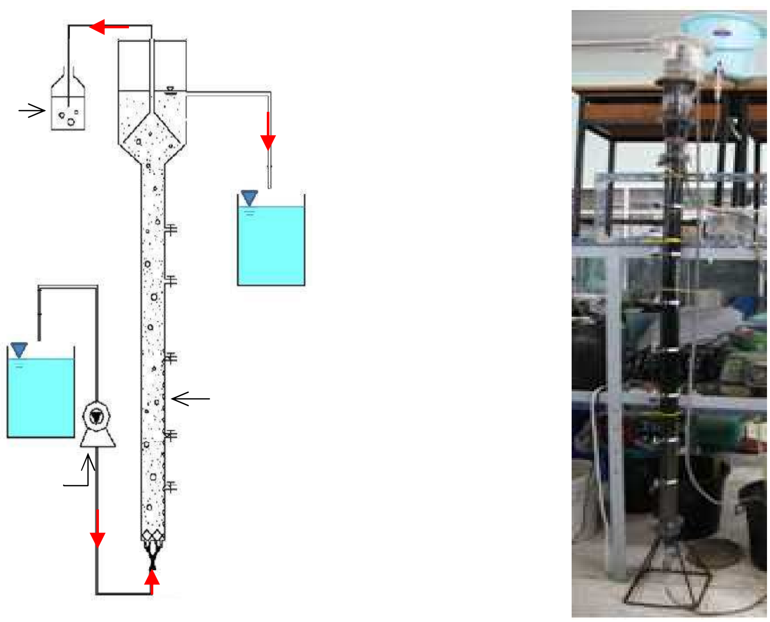
2. MATERIALS AND METHODS

2.1 Anaerobic Fluidized Bed Reactors

The anaerobic fluidized bed reactors used in this study were made from transparent acrylic resin with 2.3 m height, 0.03 m wide in diameter and 1.6 L of total volume. In this research, a diaphragm pump was used to feed the synthetic wastewater into a reactor under the controlled flow rate of 46.8 L/d, in order to keep the height of media as fully fluidized. The hydraulic retention time of the system was controlled at 0.84 hrs. The schematic diagram of AFB reactor was shown in Figure 1 (a, b) and the design aspect of this reactor was shown in Figure 2.

2.2 Rubber granule

Crumb rubber granules prepared from spent-tires with the effective size of 0.43 mm. the density of 1.2 g/cm^3 and uniformity coefficient of 1.53 was used as media in AFB reactor. The photo of the rubber granule used in this research was shown in Figure 3.



(a) (b)

Figure 1 A schematic diagram and photo of AFB reactor without internal recirculation used in this research (a, b)

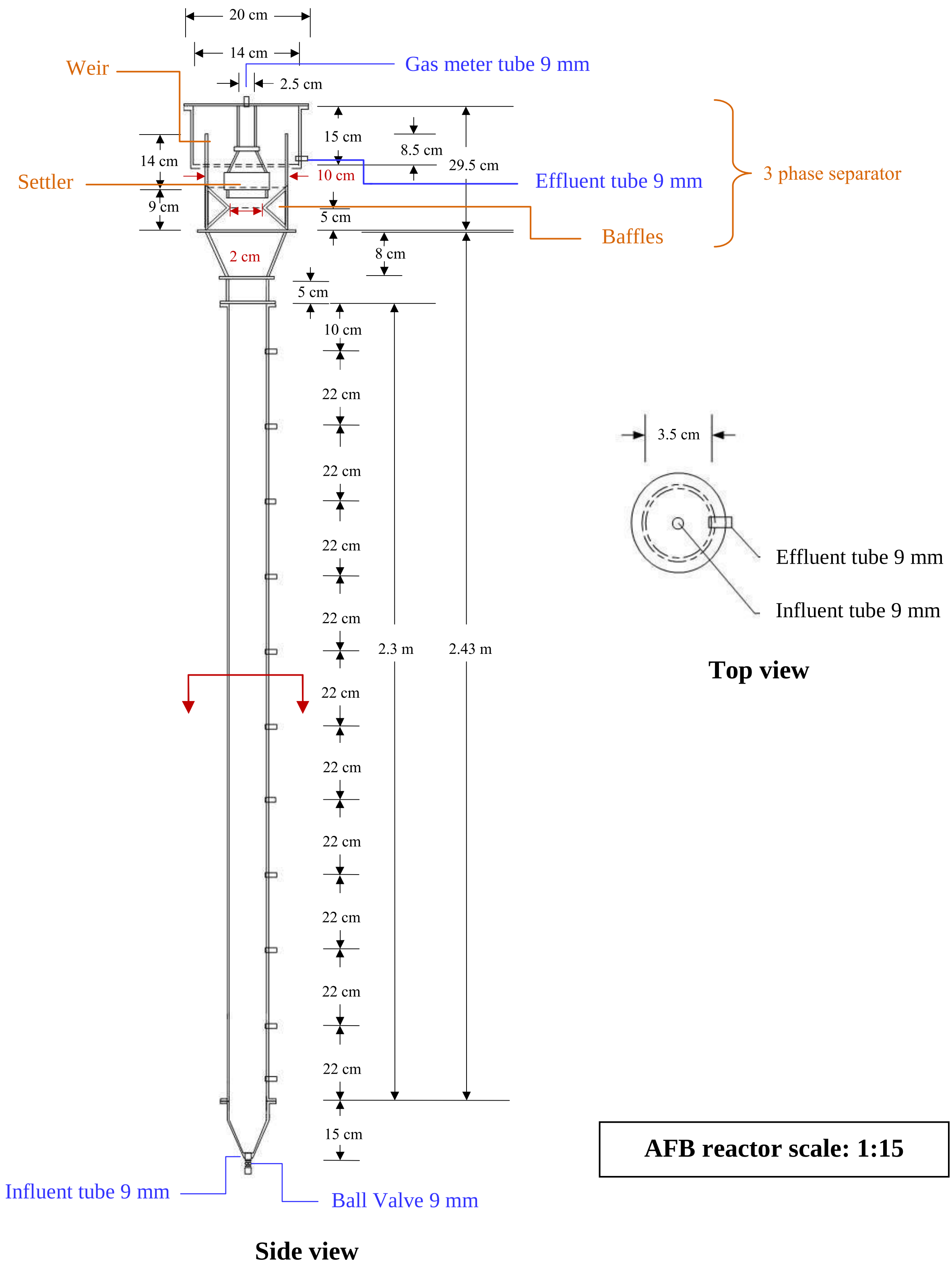


Figure 2 The design aspect of AFB reactor without internal recirculation used in this research

Figure 3 Photos of Crumb rubber granule used in this research

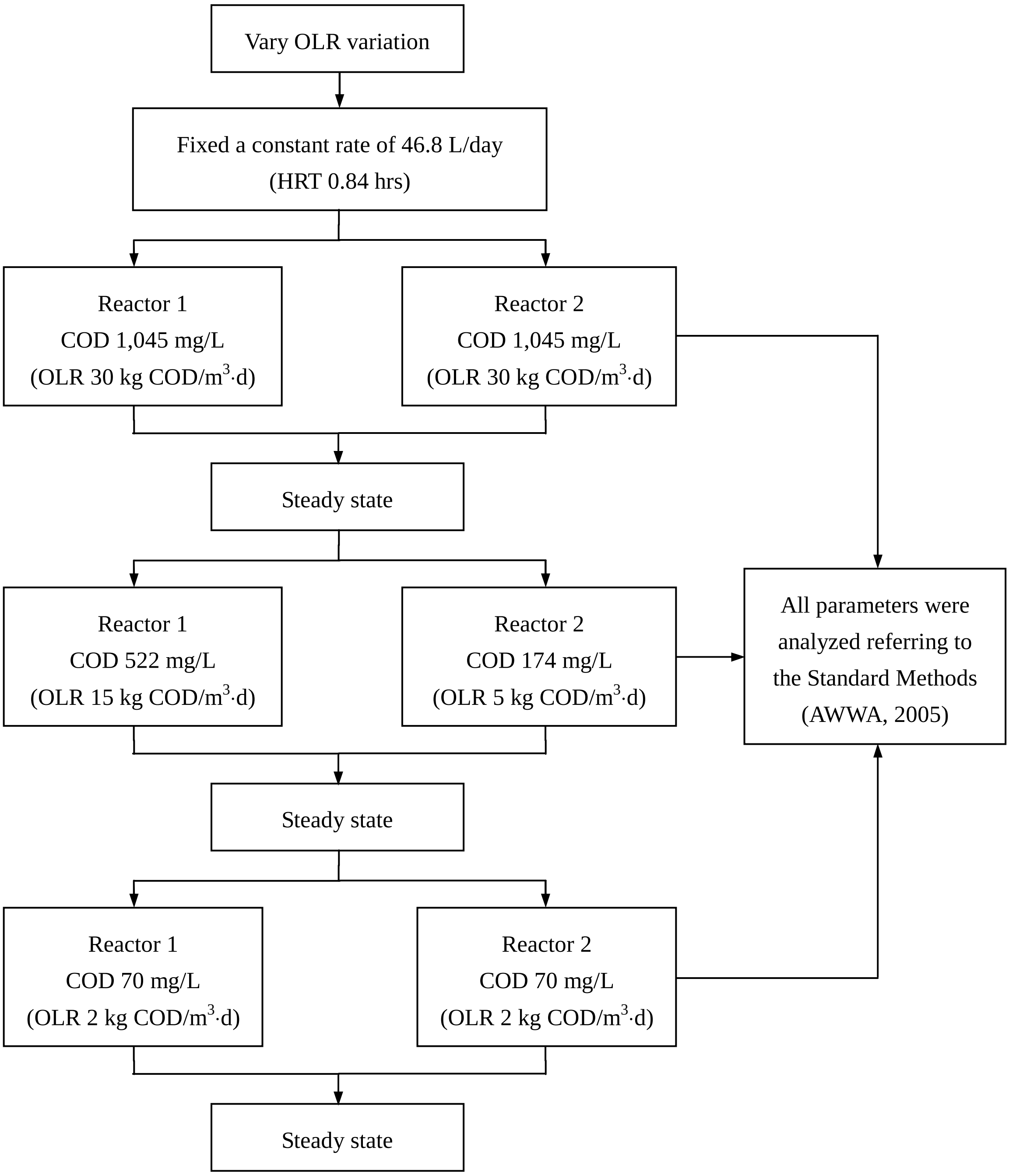


Figure 4 The diagram of the system operation in the influent from AFB reactor 1 and 2

Table 1 The experimental parameters performed in this research

Experimental parameters	Value
Varied parameter	
Organic Loading Rate (OLR)	2, 5 and 15 kg COD/$m^3 \cdot$ d
Controlled parameters	
Feed flow rate	46.8 L/d
Hydraulic Retention Time (HRT)	0.84 h
COD concentration	70, 174 and 522 mg/L (equivalent to OLR of 2, 5 and 15 kg COD/$m^3 \cdot$ d)
Volatile fatty acid / Alkalinity ratio	0.4
Uncontrolled parameter	
Temperature	Room temperature
Measuring parameters	
Effluent COD concentration Effluent Suspended Solid Biogas production pH Volatile fatty acid, VFA Alkalinity	Analytical method followed in Standard Methods for the Examination of Water and Wastewater (AWWA, 2005)

2.3 Synthetic wastewater

Synthetic wastewater was prepared from tap water using sucrose as carbon source in order to be degraded easily. Besides, the sufficient supplement nutrients such as nitrogen, phosphorus, and other trace elements, providing a ratio of COD:N:P as 150:1.1:0.2 were added into the synthetic wastewater. Moreover, sufficient $NaHCO_3$ was added as a pH buffering agent to control the pH inside a reactor in a range of 6.5-8.2 (Speece, 1996).

2.4 System operation

The experiment was divided into two parts, the system startup and the OLR variation. In the start-up period, sludge from anaerobic filter process and rubber granule was added into AFB reactors. Then synthetic wastewater at a fixed OLR of 30 kg COD/$m^3 \cdot$ d (equal to COD concentration of 1,045 mg/L) was continuously fed into two AFB reactors at a constant rate of 46.8 L/day and hydraulic retention time as low as 0.84 h. It must be noted that this system was operated under a condition of no internal recirculation in order to save more energy and to decrease the detention time compare to the classical one. The influent was fed into the reactors until they reach their steady state, which was mainly indicated by a steady COD removal efficiency and biogas production rate. After the steady state, the step up OLR variation was performed by changing the COD concentration in the influent feed. The OLR loading for the 1st reactor was changed to 15 and 2 kg COD/$m^3 \cdot$ d (equivalent to COD of 522 and 70 mg/L), whereas the OLR loading for the 2nd reactor was changed to 5 and 2 kg COD/$m^3 \cdot$ d (equivalent to COD of 174 and 70 mg/L), respectively. The diagram of the system operation was shown in Figure 4. All reactors were controlled in term of 1.5

times bed expansion compared to the normal bed height (McCabe et al., 1993). The soluble COD and other operating parameters were analyzed referring to the Standard Methods (AWWA, 2005) in order to be used as signal that prevents failure of the process. Biogas volume was collected continuously by gas counter equipment. All experimental parameters can be summarized in Table 1.

3. RESULTS AND DISCUSSION

3.1 Operating parameters

The overall result of operating parameters in the influent and effluent from two AFB reactors during the startup period and OLR variation period were shown in Figure 5.

The experimental results showed that AFB reactor without internal recirculation used 76 days since the system start up to reach the steady state. This period of time was shorter than that of general AFB reactor with internal recirculation or Upflow Anaerobic Sludge Blanket (UASB) which was around 3-6 months (Metcalf and Eddy, 2004). The average COD removal efficiency of the 1st reactor was 81.45%, 88.44% and 81.18% at OLR 30, 15 and 2 kg COD/$m^3 \cdot$ day respectively, while the average COD removal efficiency of the 2^{nd} reactor was 96.49%, 91.40% and 91.02% at OLR 30, 5 and 2 kg COD/$m^3 \cdot$ day respectively. In case of Suspended Solid (SS) results, the average effluent SS concentration for the 1st reactor were 31.90, 19.64 and 7.69 mg/L at OLR 30, 15 and 2 kg COD/$m^3 \cdot$ day respectively, while the effluent SS concentration of the 2^{nd} reactor were 21.61, 9.88 and 5.31 mg/L at OLR 30, 5 and 2 kg COD/$m^3 \cdot$ day respectively. The results in Table 2 showed the comparison between calculated values of SS concentration from anaerobic suspended growth yield and the effluent SS concentration.

The results from Table 2 revealed that the effluent SS concentration tended to decrease when OLR decreased. It is noticeable that these effluent SS concentration were a bit too high when compared with cell mass calculated from anaerobic suspended growth yield (0.08 g VSS/g COD eliminated) (Metcalf and Eddy, 2004). These high values of effluent SS concentration, which was higher than calculated cell mass in some case, were probably come from rubber granules that were washed out by the stream. However, this high effluent SS concentration did not state any negative effect on the system. It could still work well, and also the COD removal efficiency of the system could be treated as the usual average of 81-96%. By the means of this result, it was clearly assure that the AFB reactor without internal recirculation can keep the appropriate amount of SS in the system which makes the reactor properly perform.

For all OLR, pH values in the effluent stream lied in a range of 8.15-8.40, which was higher than the optimum of pH for the growth of microorganisms (6.5-8.2). This condition might be caused by the addition of alkalinity as 6 g per 1 liter of water in the form of Sodium bicarbonate. This was to control pH of environment in the reactor. The alkalinity values of the effluent stream in those two reactors lied in a range of 935-2,473 mg/L (in terms of Calcium carbonate), which was too exaggerate for the system. Furthermore, the volatile fatty acids (VFA) of the reactors in the effluent stream lied in a range of 26-391 mg/L (in terms of Acetic acid), which was slightly more than the optimum concentration of VFA in the reactor (100-300 mg/L) (Speece, 1996). The results showed that the VFA were accumulated into the reactors because methanogens could not be used immediately. Nevertheless, the system could work effectively which indicated by VFA/ALK ratio of the effluent stream. The VFA/ALK values in the effluent stream lied in a range of 0.03-0.17.

3.2 The COD removal efficiency and biogas production

After those two reactors reached steady state at day 76th, the step up OLR variation was performed. The experimental result in Figure 6 showed that the COD removal efficiency for the 1st reactor was achieved at 88.44% and 81.18%, whereas the amount of biogas production was about 0.28 and 0.18 L/g COD eliminated at OLR 15 and 2 kg COD/m^3·d (equivalent to COD of 522 and 70 mg/L), respectively. Thus, the COD removal efficiency in the 2nd reactor were achieved at 91.40% and 91.02%, while the biogas production was about 0.18 and 0.05 L/g COD eliminated at OLR 5 and 2 kg COD/m^3·d (equivalent to COD of 174 and 70 mg/L), respectively. Also, the experimental result reveals that the efficiency of AFB reactor without internal recirculation was comparable to the UASB and general AFB reactors with internal recirculation. For instance, the COD removal efficiency was about 81-98% which was comparable with general AFB reactors with internal recirculation (about COD 45-2,010 mg/L) (Shin et al., 2012) or the COD removal efficiency was about 74-98% which was comparable with UASB (about COD 58-1,647 mg/L) (An et al., 2009; Barbosa and Sant'Anna JR., 1989; Espinosa et al., 2010; Singh et al., 1996; Soto et al., 2011). In addition, the COD removal efficiency of general AFB reactor lied in a range of 60-90% (Balaguer et al., 1992; Borja et al., 1995; Jewell et al., 1981; Metcalf and Eddy, 2004).

However, the hydraulic retention time of the system was 0.84 hrs. (about 50 minutes) whereas the hydraulic retention time of general AFB reactor was 3-24 hrs (Metcalf & Eddy, 2004). It could be concluded that the system was able to treat wastewater more effectively than general AFB reactor with similar performance. Furthermore, because a use of low density rubber granule was easy to form a fluidization condition, it helped conserve energy in the process. Moreover, this knowledge reveals a remarkable advantage in terms of a shorter retention time in AFB reactor without an internal recirculation. The reactor footprint was also small and the internal recirculation pump was no longer need. This can save more energy and treat larger amount of wastewater. Therefore, it will be beneficial to apply this technique, especially to the treatment of high volume of wastewater with low COD, such as domestic wastewater.

Table 2 The comparison results between calculated values of anaerobic suspended growth yield cell mass and effluent cell mass

Reactor	OLR (kg COD/m^3·day)	Cell mass (mg/L), calculated from Anaerobic suspended growth yield	Effluent cell mass (mg/L)
1	30	24.98 ± 13.11	31.90 ± 22.25
	15	14.31 ± 2.28	19.64 ± 8.25
	2	1.88 ± 0.02	7.69 ± 5.58
2	30	31.45 ± 3.35	21.61 ± 9.90
	5	5.02 ± 0.17	9.88 ± 2.70
	2	1.96 ± 0.01	5.31 ± 2.57

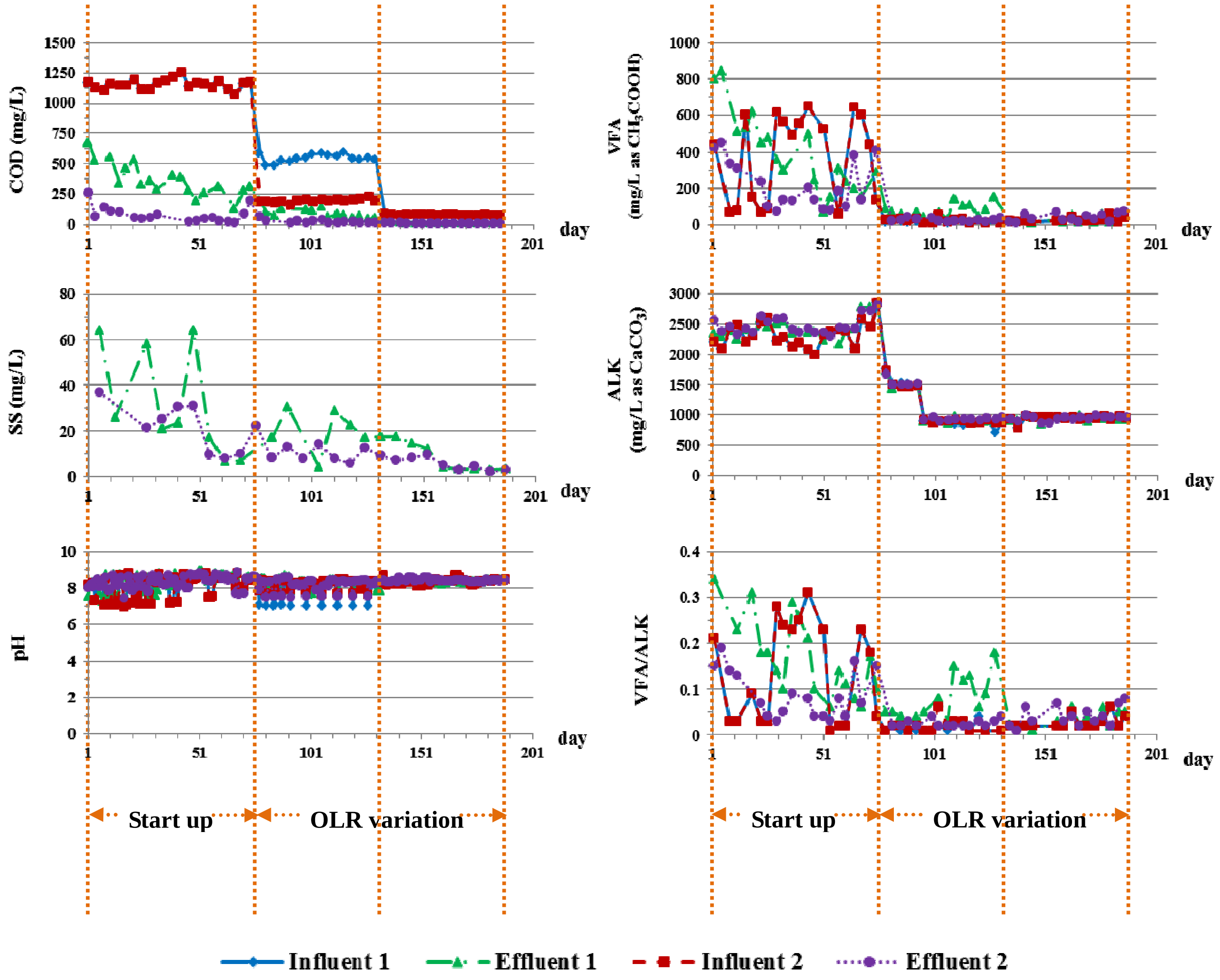


Figure 5 The result of operating parameters in the influent and effluent from AFB reactor 1 and 2

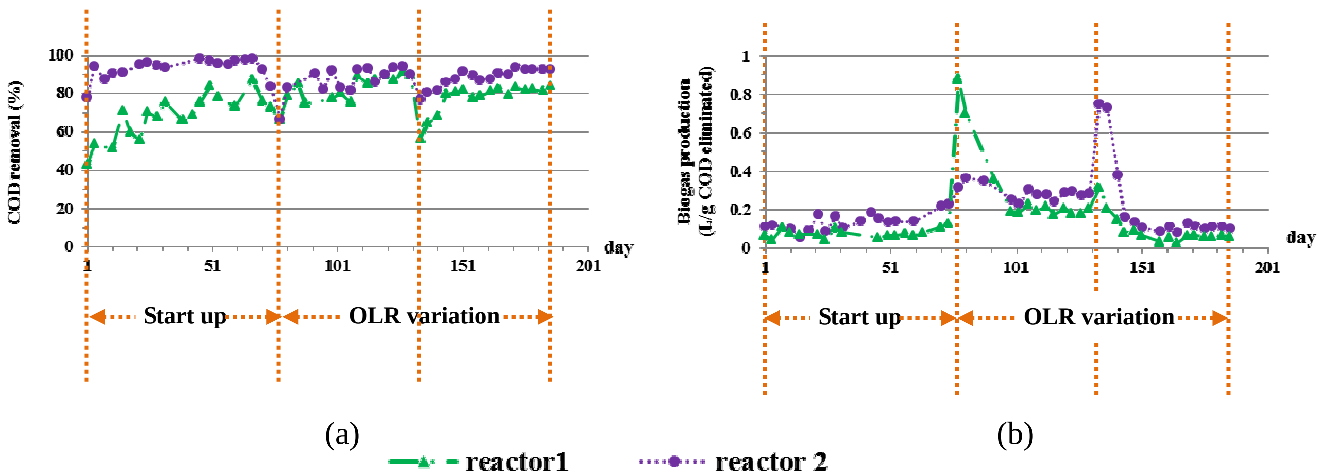


Figure 6 The COD removal efficiency (a) and Biogas production (b) in AFB reactor 1 and 2

CONCLUSIONS

The COD removal efficiency of AFB reactor without internal recirculation was about 80%. This was comparable to the other general AFB reactors with internal recirculation and UASB in term of high COD removal efficiency and keeping SS concentration within the reactor. In addition, this system has a shorter retention time from using the low density rubber granule as a media which can save the energy consume, as well save the cost of wastewater treatment. Therefore, it confer the high feasibility to apply this system, especially to treat the high volume of wastewater with low strength COD such as domestic wastewater.

ACKNOWLEDGEMENT

This research was supported by The National Research Council of Thailand, received a partially financial supported by the graduate thesis grant, Chulalongkorn University and received the additional fund from Ratchadaphiseksomphot Endowment Fund Part of the "Strengthen CU's Researcher's Project". All the equipments and facilities in this research were provided by department of Environmental Engineering, Faculty of Engineering, Chulalongkorn University, Thailand.

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