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Energy Procedia 138 (2017) 1017–1022

Energy Procedia

www.elsevier.com/locate/procedia

2017 International Conference on Alternative Energy in Developing Countries and Emerging Economies 2017 AEDCEE, 25 – 26 May 2017, Bangkok, Thailand

An Integrated Ultrasonic Membrane An aerobic System (IUMAS) for Palm Oil Mill Effluent (POME) Treatment

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Abstract

Biogas is formed naturally when palm oil mill effluent (POME) decomposes in the absence of oxygen. Unharnessed, this gas is an unwanted, potentially hazardous contributor to global climate change. Biogas is typically composed of 50–75% methane (CH_4), 25–45% carbon dioxide (CO_2) and trace amounts of other gases. To overcome POME hazardous problems and retain the methane gas, CH_4, this research introduces newly designed of an integrated technology of ultrasonic and membrane for a palm oil mill effluent treatment. To fit kinetic study, six steady states were investigated and the results have shown that the mixed liquor volatile suspended solids (MLVSS) ranges from 12,600 to 19,500 mg/l while the mixed liquor suspended solids (MLSS) ranges from 14,700 to 23,800 mg/l. Three kinetic models Monod, Contois and Chen & Hashimoto were used to evaluate the integrated system at organic loading rates ranging from 1 to 15 kg COD/m^3.d. The percentage efficiency of COD removal was from 91.6% to 98.5% and hydraulic retention time, HRT from 400 to 9 days. The influent COD concentrations of the POME ranged from 65,600 mg/l to 86,400 mg/l.

The integrated technology of IUMAS is a more attractive solution compared to the case when the palm oil mill effluent either ultrasonic or membrane technology individually.

***Keywords*: Membrane; ultrasonic; POME; methane; CO_2; IUMAS;COD**

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1. Introduction

Membrane bioreactor (MBR), which couples membrane technology and wastewater biological treatment technology has many advantages, such as high biomass in the system, small footprint, excellent effluence, and especially high removal rate for suspended solid (SS), pathogenic bacterial, and virus [1], Biogas is formed naturally when palm oil mill effluent (POME) decomposes in the absence of oxygen. Unharnessed, this gas is an unwanted, potentially hazardous contributor to global climate change. Biogas is typically composed of 50–75% methane (CH_4), 25–45% carbon dioxide (CO2), and trace amounts of other gases [2-4]. When POME collection is uncontrolled, CH_4 is

10.1016/j.egypro.2017.10.120

released directly into the atmosphere. [5], reported that, as a greenhouse gas (GHG), methane is 21 times more powerful than CO2.Biogas plant, on the other hand, takes advantage of this natural decomposition process to generate electricity. Organic liquid wastes generated during palm oil production represent a major untapped source of energy. So converting POME emissions to biogas for combustion can produce energy, as well as significantly reduce the climate change impacts of palm oil production.

Acid forming bacteria displace methanogens, and result in increasing volatile acids concentration and reducing the pH of the system. Various methods for retaining cells in the system have been developed [6]. A COD removal of 96.2% from anaerobic digestion of POME was achieved in an immobilized cell bioreactor at a volumetric loading rate of 10.6 kg COD/m3/day [7]. The organic loading rate was increased to 30 kg COD/m3/day with an overall 90% COD reduction by recirculation of the treated palm oil mill effluent in a two-stage up-flow anaerobic sludge blanket (UASB) system [8]. However, the anaerobic digestion for this system was conducted in two separated upflow anaerobic reactors for acidogenesis and methanogenesis, respectively.

The main objective of this study was to evaluate the performance of the newly designed an integrated ultrasonic membrane anaerobic system, IUMAS in treating palm oil mill effluent (POME) based on three models; Monod [9]; [10] and [11]. Table 1 shows mathematical expressions for specifics substrate utilization rate for three kinetic models (Monod, Contois and Chin & Hashimoto).

Table 1: Mathematical expressions of specifics substrate utilization rates for known kinetic models

Kinetic Model	Equation 1	Equation 2	
Monod	$U = \frac{k\,S}{k_s + S}$	$\frac{1}{U} = \frac{K_s}{K}(\frac{1}{S}) + \frac{1}{k}$	[9]
Contois	$U = \frac{U_{\max} \times S}{Y(B \times X + S)}$	$\frac{1}{U} = \frac{a \times X}{\mu_{\max} \times S} + \frac{Y(1+a)}{\mu_{\max}}$	[10]
Chen & Hashimoto	$U = \frac{\mu_{\max} \times S}{Y\,K\,S_o + (1-K)\,S\,Y}$	$\frac{1}{U} = \frac{Y\,K\,S_o}{\mu_{\max}\,S} + \frac{Y(1-K)}{\mu_{\max}}$	[11]

2. MATERIALS AND METHODS

2.1 Raw POME Wastewater Preparation

The raw POME was collected from a near local palm oil mill in Lebah Hillier, Kuantan, Malaysia. The raw POME was stored in a cold room at 4 ^{o}C before use. Different dilutions of POME were prepared using tap water. The pH of the feed was adjusted to 7.0 using a 6 N NaOH solution.

2.2 IUMAS Bioreactor Operation and Experimental Set-Up

A laboratory scale, IUMAS reactor with an effective 200-Litre volume Figure 1 was used in this study. The IUMAS reactor was consists of a cross-flow ultra-filtration membrane apparatus, a centrifugal pump and an anaerobic reactor. The total volume of the reactor was 200 Litre and the working volume was 150 Litre. Six multi frequency ultrasonic transducers, operated at 25 KHz, are bonded to two-sides of the tank chamber and connected to a Crest Genesis Generator (250W, 25 KHz; Crest Ultrasonic, Trenton, NJ, USA). The maximum operating pressure on the membrane was 55 bars at 70 WC, and the pH ranged from 2 to 12.

2.3 Analytical methods

The following parameters were analyzed: COD, BOD, pH, VSS, and TSS. Methane gas was determined by gas chromatography with a stainless steel column (200 x 0.3 cm) packed with active carbon (30-60 mesh) using thermal conductivity detection). For TSS, VSS, volatile fatty acids and alkalinity were determined according to the Standard Methods [12]. The COD was measured using a Hach colorimetric digestion method (Method # 8000, Hach Company, and Loveland, CO, USA). The MLSS and MLVSS were determined by drying the sample at 105 ^{o}C and 550 -+ 50 ^{o}C.

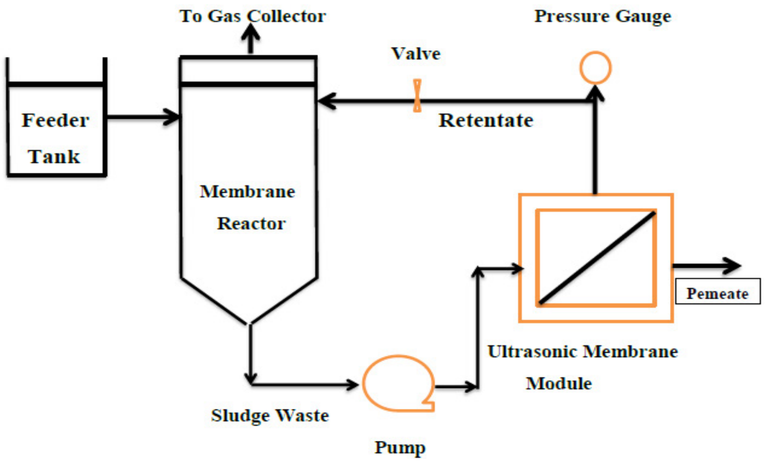

Figure 1. Experimental set-up

3. Results and Discussion

3.1. The performance of integrated ultrasonic-membrane anaerobic system (IUMAS)

The operating conditions for the integrated ultrasonic membrane anaerobic, IUMAS over the 500 day experimental are given in Table 2. The performance evaluation of the integrated ultrasonic-membrane anaerobic system, IUMAS was generated at different influent COD concentrations and Hydraulic retention times; HRTs. For the system results at influent COD concentrations from 65,600 to 86,400 mg/l and pH (6.7-7.8) UMAS was performed well. The mixed liquor volatile suspended solids (MLVSS) for the first steady state was 10,400 mg/l whereas the mixed liquor suspended solids (MLSS) was 13,800 mg/l, equivalent to 75.36% of the MLSS. This low result can be explained due the palm oil mill effluent wastewater contains very high suspended solids.

The volatile suspended solids (VSS) fraction in the reactor at sixth steady state was increased to 89.20 %. Results have shown that the long solid retention time, SRT of UMAS facilitated the decomposition of the suspended solids and their subsequent conversion to methane (CH_4); these findings found by [5] and [6]. At organic loading rate, OLR of 15 kg COD/m^3/d, the system registered the highest influent of COD 86, 00 mg/l. at this stage; the IUMAS achieved 92.8% COD removal. Figures 2-4 shown that, IUMAS can be applied and treat POME efficiently. Among the three models applied, the Monod and Chen & Hashimoto models performed better, shown that UMAS reactor performance should consider organic loading rates. These two models suggested that the predicted permeate COD concentration (S) is a function of influent COD concentration (S_o).

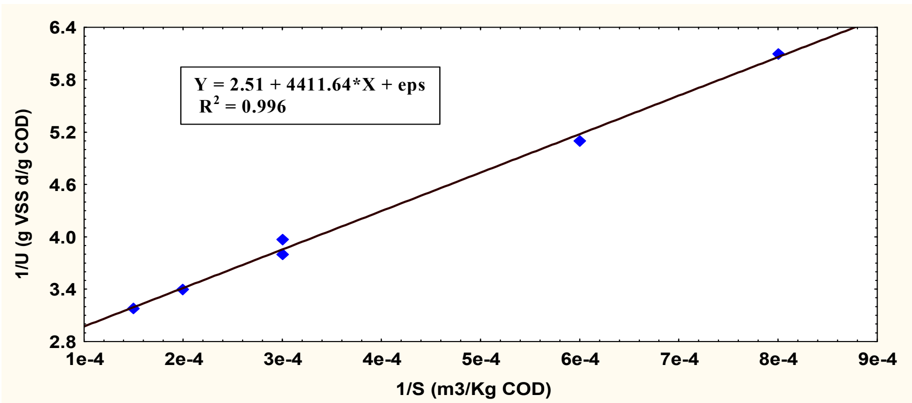

Figure 2. The Monod model

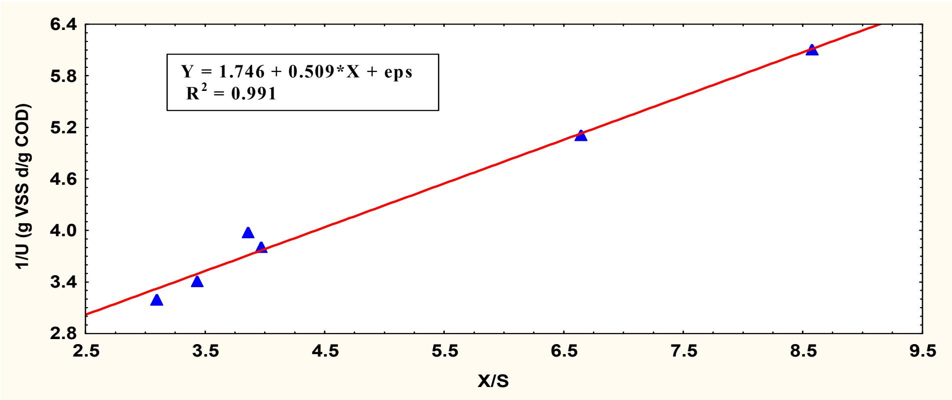

Figure 3. The Contois model

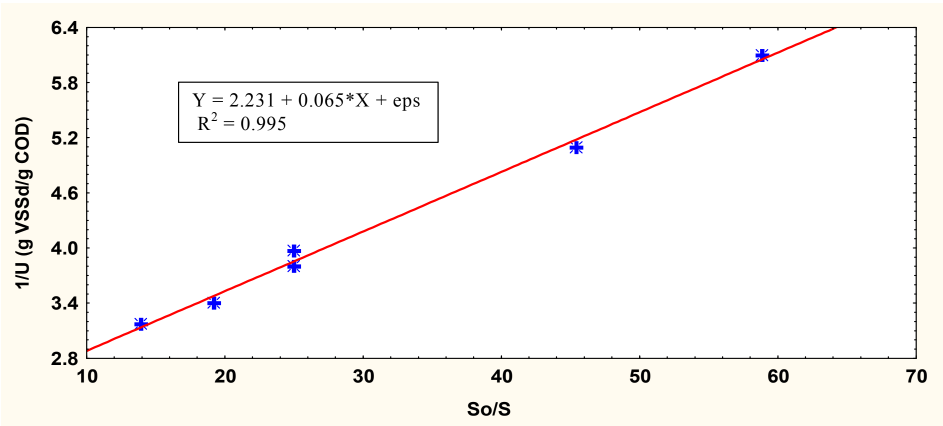

Figure 4. The Chen and Hashimoto model

The percentage removal of COD by IUMAS at various solid retention times, SRTs was shown in Figure 5, it might be noted that the process fails when the microorganism removal rate as evidenced by SRTs exceeds the rate at which the microorganisms can produce themselves. From Figure 5 it observed that the substrate removal efficiency was stable, when the SRTs was between 300 to 30.5 days, but when the SRTs is below 20.3 days, the efficiency was rapidly decreased until SRTs reached 15.8 days which gives the minimum allowable SRTs [5].

4. Production of methane (CH_4) and carbon dioxide (CO_2) gases

To verify the reliability of the experimental results obtained in this study, the steady state conditions of IUMAS were achieved, the average daily methane production for the digester was determined from the measured volumes of the produced gas and percentage of methane. In this study, the influent COD concentration was increased from 65,600 to 86,400 mg/l. (for the six steady states). Figure 6 illustrates the steady state % CH_4 composition, and total gas yield against the designated OLR. While Figure 7 shows the % CH_4 composition, methane yield and total gas yield against the solid retention time, SRT. It was clear that composition the methane CH_4 yield decreased with increasing OLRs. Methane gas contents were varied from 64.6% to 81% and the methane yield varied from 0.39 to 0.70 CH_4/g COD/d. The decreased CH_4 yield with increasing OLR was also noted in many previous studies [13]; [14]; [15; 16; 17].

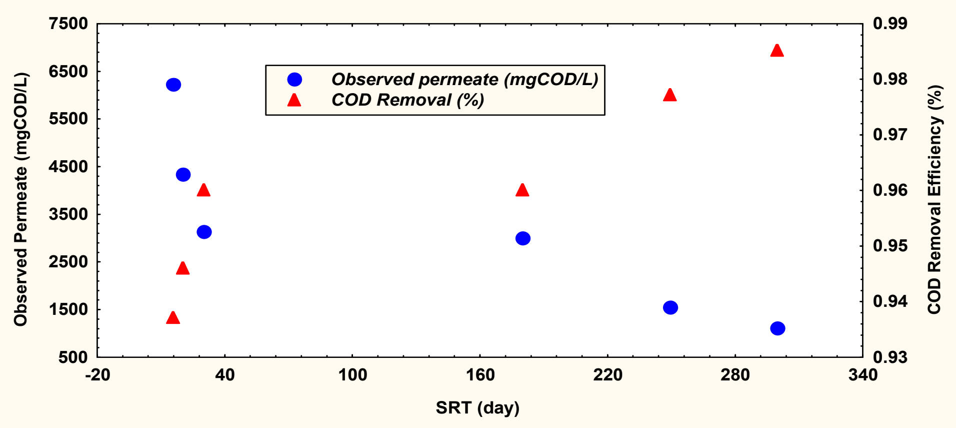

Figure 5: Observed permeate, COD removal vs. SRT

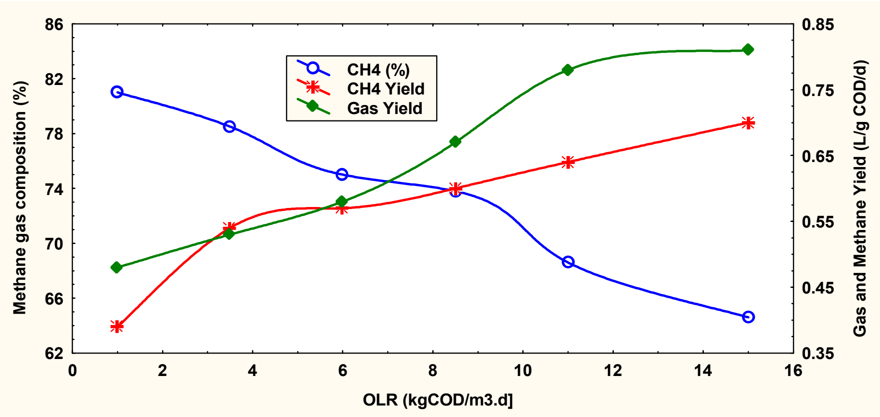

Figure 6: % CH_4, Gas and Methane Yield vs. OLR

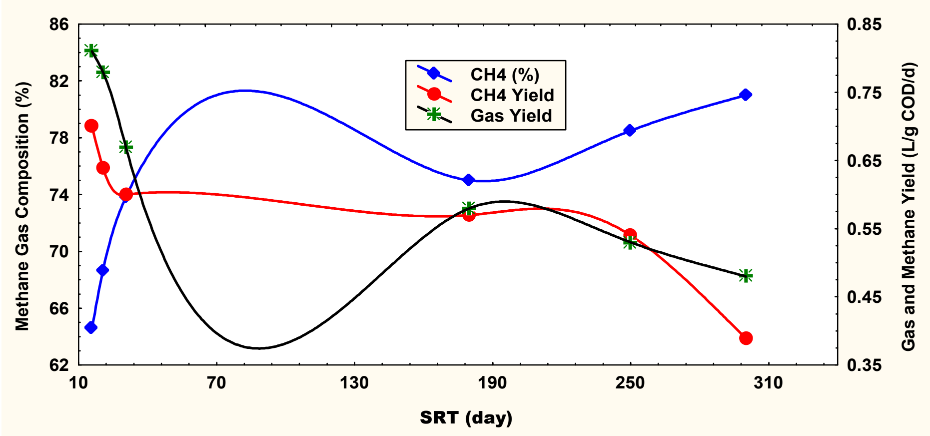

Figure 7: % CH_4, Gas and Methane Yield vs. SRT

5. Conclusions

An integrated ultrasonic membrane anaerobic system, IUMAS which operates as a single treatment unit for the removal of organic matter from POME was developed in this study. POME is always regarded as a highly polluting wastewater generated from palm oil mills. However, reutilization of POME to generate renewable energies in commercial scale has a great potential especially when coupled with wastewater treatment process.

Efficient performance of the IUMAS at steady state condition up to an OLR of 15 Kg COD/m^3/day was demonstrated, where overall COD, BOD and TSS removals of more than 98%, with biogas production containing 81% of methane and methane yield of 0.7 L CH4/g COD removed were achieved.

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