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BIOMETHANATION OF SUGARCANE WASTEWATER BY ULTRASONIC MEMBRANE ANAEROBIC SYSTEM (UMAS) TO PRODUCE METHANE GAS

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ABSTRACT
The five largest countries that produce sugar from sugarcane in 2011 were Brazil, Thailand, India, European Union, and China. The demand for sugars nowadays is high, thus, the production of sugar is increasing nowadays, and the sugarcane wastewater increased and caused more pollutions. Therefore, wastewater sugarcane was treated to produce methane by using anaerobic digestion method. But, most of the problem occurs during the treatment process is membrane fouling. Membrane fouling can cause severe flux decline that can affect the quality of the water produced, and the cost to fixed membrane fouling is expensive. Thus, Ultrasonic Membrane Anaerobic System (UMAS) is used as alternative overcome this problem. The sugarcane wastewater had to acclimatize for 5 days before running the reactor. The raw value of COD recorded was 9870 mg/L; BOD was 2480.35 mg/L, TSS 1.976 mg/L, and VSS 1.331 mg/L. The pH, pressure, and temperature were kept constant during this experiment with the value 6.5-7.5, 1.5-2.0 bar, and 32OC respectively. After 28 days of experiment, the COD removal efficiency obtained was 95%, BOD removal efficiency was 97% and the methane gas composition obtained was about 75%.The TSS and VSS removal efficiency also reached 99% of removal. Based on the results obtained after 28 days of experiment, UMAS not only can treat high strength wastewater, but also can treat low strength wastewater, avoid membrane fouling and produce methane gas from sugarcane wastewater. Nevertheless, further works are required to provide deeper understanding of the mechanisms involved to facilitate the development of an optimum system applicable to the industry.

KEYWORDS: UMAS, membrane, fouling, treatment, sugarcane, COD reducti

INTRODUCTION
The production of sugar is increasing every year in Malaysia. In Malaysia, sugarcane is produced widely at Chuping, Perlis for the production of sugar. Rapid deterioration begins when the cane is cut; Sugarcane cannot be stored for later processing without excessive deterioration of the sucrose content (Panda, 2011).Then, the juice was extracted from the cane, by crushing methods. The crushed sugarcane will be transported through conveyor to the next mill. The evaporation process takes place and is followed by crystallisation process.

From these summarized process, it can be conclude that the sugarcane waste product is generated day by day in sugar industries and sugarcane industry has significant wastewater production. . Roughly over 30 tonnes of waste sugarcane has been damped and burned to an open field. The disposal of untreated waste water from cane sugar mills to nearby water source such as the rivers is the major environmental problem which sugar industry faced. The effluent, pre-treated to correct the pH and remove oil and suspended solid, can be applied on land used for sugar cane cultivation. Inadequately, pre-treated effluent, however, gives off odours (Dick J., 1990) .The solution to this problem is by converting the waste by 'waste-to-wealth' method. From the waste of sugarcane, it can produce methane and fuel which can be a source of energy. This will increased the production of methane from the waste sugarcane as methane is the largest source for natural gas and Liquefied Natural Gas (LNG). Besides, the waste sugarcane is a renewable resource (Renewable Fuel

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Association, 2004). Inadequately, pre-treated effluent, however, gives off odours (Dick J., 1990) generally, the waste sugarcane will be stored prior for further processing.

The sugarcane waste water is a viscous brown liquid at pH ranging between 5.3 and 8.8. Averagely, the biochemical oxygen demand (BOD) for this sugarcane waste water is 180 mg/l, with the chemical oxygen demand (COD) of 591 mg/l, and 375 mg/l of suspended solid (SS). This polluting wastewater can cause several pollution problems. Anaerobic digestion is the most suitable method for the treatment of waste sugarcane. Anaerobic digestion is defined as the engineered methanogenic anaerobic decomposition of organic matter. It involves different species of anaerobic microorganisms that degrade organic matter (Cote, 2006) .In the anaerobic process, the decomposition of organic and inorganic substrate is carried out in the absence of molecular oxygen (N.H. Abdurahman, 2012). Methanogens will convert the acetic acid, ammonia, hydrogen and carbon dioxide to methane (CH_4) and carbon dioxide (CO_2). Anaerobic digestion will reduce the emission of landfill gas into the atmosphere and is widely used as a source of renewable energy (Borja, R, & Banks, C. J., 1995b). By combining the advantages of membrane treatment type and anaerobic treatment type, membrane anaerobic system (MAS) will be used to treat the wastewater of sugarcane.

The wastewater of cane sugar will be treated using Membrane Anaerobic System (MAS) under anaerobic digestion method. Still, the main problem that always occurs in this system is membrane fouling (Chang, 2003). Membrane fouling is a process where solute or particles deposit onto a membrane surface or into membrane pores in a way that degrades the membrane's performance. The quality of the water produced will be affected and severe flux declined will occur when membrane fouling happens. An economic solution to overcome this problem is by adding ultrasonic-device into the MAS system. This is a new design that was proposed by NH Abdurahman et.al, in treating POME and producing methane. (N.H. Abdurahman, 2012)

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Table 1 : Optimum condition for UMAS (Abdulrahman, 2014)

Parameter	Optimum Condition
pH	6.5-7.5
Temperature (℃)	25℃ - 37 ℃
Pressures (Bars)	1.5 bar – 2.0 bar
Ultrasonic Frequency (kHz)	10kHz

This research is conducted to study the performance of Ultrasonic membrane anaerobic system (UMAS) in treating sugarcane wastewater together, to determine whether membrane fouling still occurs in the system, to evaluate the influence of retention times towards the respective parameters (chemical oxygen demand, biochemical oxygen demand, total suspended solid, volatile suspended solid, pH, and to produce methane gas from raw sugar cane wastewater. There are four scopes of this research which are to design a laboratory scaled ultrasonic membrane anaerobic system (UMAS) with an effective 100 litre volume to treat raw sugar cane wastewater, to monitor parameters such as BOD, COD, TSS, VSS, pH and color, to study the effect of organic loading rate (OLR) in the performance of UMAS and to determine the amount of methane gas produced by the volume of permeates.

MATERIALS AND METHODS

Characterization of raw material

75 liters of the raw sugarcane was collected at Central Sugar Refinery, Shah Alam. The sample was stored in a cold room at 40C to make sure the wastewater does not biodegrade due to microbial action. Some of sugarcane wastewater samples were taken and analyzed for parameters such as chemical oxygen demand (COD), total suspended solids (TSS), pH, and volatile suspended solids (VSS).

Experimental set-up

This research was done in laboratory scale by using a custom designed reactor with ultrasonic device and cross-flow ultrafiltration membrane, Ultrasonic Membrane Anaerobic System (UMAS) as shown in Figure 1 below

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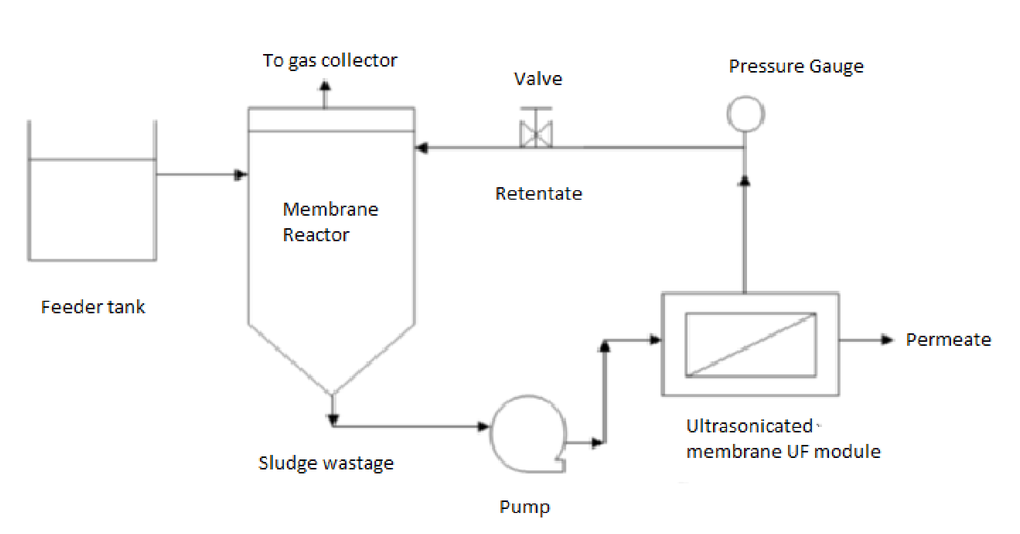

Figure 1 : Experimental Set up for UMAS (N.H. Abdurahman, 2012)

The sugarcane waste water will be treated in a 100 L reactor equipped with cross flow ultrafiltration (CUF) membrane and centrifugal pump. The reactor is made from transparent PVC. The ultrasonic frequency is set at 10 kHz. The pressure is set in the range of 1.5 bar – 2.0 bar using the gate valve after the at the retentate line after CUF unit.

Reactor operation

The sieved sugarcane waste water was fed into the membrane anaerobic reactor and was left in the reactor for 5 days. This is to make sure the microorganisms were fully acclimatized with the reactor's environment. The reactor was covered with aluminum foil to prevent algae direct sunlight in the reactor. It is also to ensure the microorganisms are not affected by extreme sunlight. After the 5 days of acclimation period, the reactor was left to operate for 5 hours. During this period, the sugarcane waste water from the digester was pressurized into the ultrafiltration membranes simultaneously. The ultrasonic device with frequency 10 kHz is also attached to the ultrafiltration membrane to determine the effect of ultrasound in treating sugarcane wastewater and methane gas produced. Parameter such as pH, COD, BOD, TSS and VSS were checked before and after the process and volume of permeate produced was recorded on each day.

RESULTS AND DISCUSSION

Table 2 shows the results obtained from 28 days of experiment,

Table 2: Results obtained fom experiment

Parameter/Days	5	7	9	12	14	16	18	22	25	28
BOD_5 removal efficiency , (%) (Permeate)	45.852	51.07	59.83	72.41	76.23	78.89	80.19	90.40	95.99	97.87201
BOD_5 removal efficiency , (%) (Reacted)	53.33	59.02	63.73	73.85	77.13	80.02	84.20	90.97	96.57	98.04
COD , (%) (Permeate)	13.56	26.72	48.33	61.25	71.98	86.58	88.67	90.76	93.39	95.62
COD , (%) (Reacted)	10.88	22.50	36.51	57.43	68.65	85.30	88.08	91.65	92.85	92.85
TSS , (%) (Permeate)	93.72	95.29	96.15	94.84	96.71	98.94	99.39	99.75	98.68	99.39

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TSS , (% (Reacted)	76.32	83.50	88.51	82.44	95.04	96.36	96.71	97.62	95.80	98.79
VSS , (%) (Permeate)	89.93	92.79	92.79	93.01	97.52	97.97	98.87	99.40	99.47	99.55
VSS , (%) (Reacted)	60.03	68.97	75.51	72.50	93.46	94.52	95.79	97.45	97.82	98.05
Methane gas compostion (%)	-	-	-	-	-	65.83	73.92	74.4	73.9	75.2

Chemical Oxygen Demand (COD) and Biochemical Oxygen Demand (BOD) Testing

Figures 2 & 3 show the BOD and COD removal efficiencies profile for UMAS using sugarcane wastewater as substrate respectively. The removal efficiency for UMAS was highest on the 28th day which achieved 97%for BOD and 95 % for COD. Significant reduction in BOD and COD indicates that reaction had occurred and leads to the reduction of soluble matters in the system. This is due to the activity of the bacteria, which uses up all the dissolved oxygen during the treatment process (Buvaneshwari., 2013)From the last 3 days, removal efficiency of BOD and COD efficiency does not change much and nearly become constant at this duration. The trends shows by UMAS performance at this time might due to the reduction of fouling on the membrane by the ultrasonic device which managed to avoid accumulation of particles on the membrane surface . Similar pattern of results was reported by Abdurahman et al. (2012) for UMAS using Palm Oil Mill Effluent (POME) as substrate.

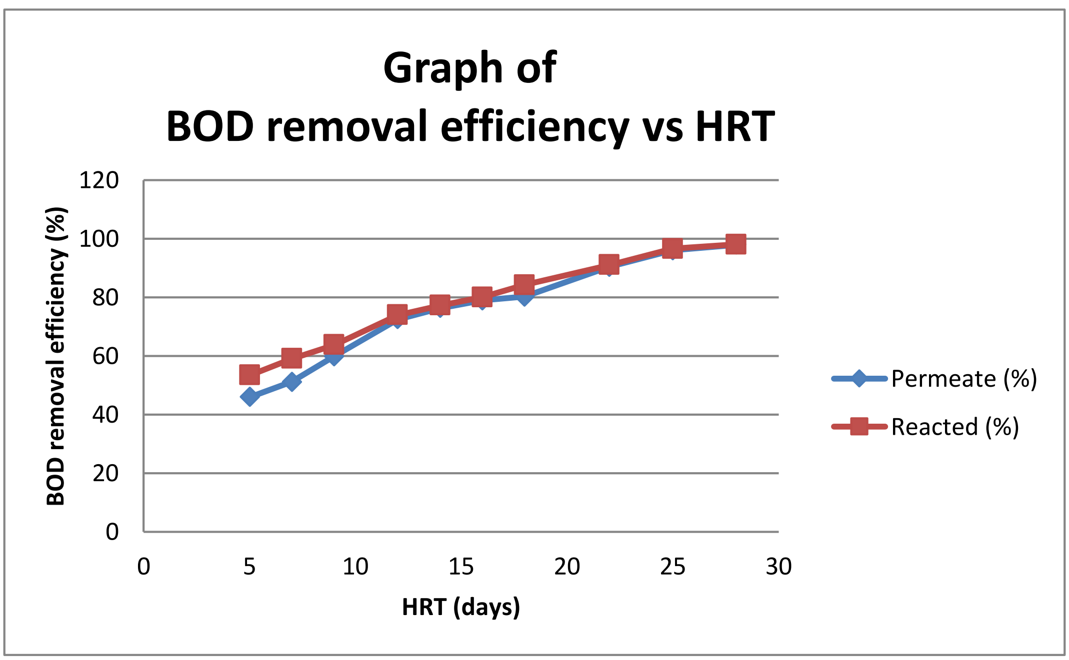

Figure 2 : Graph of BOD removal efficiency vs HRT

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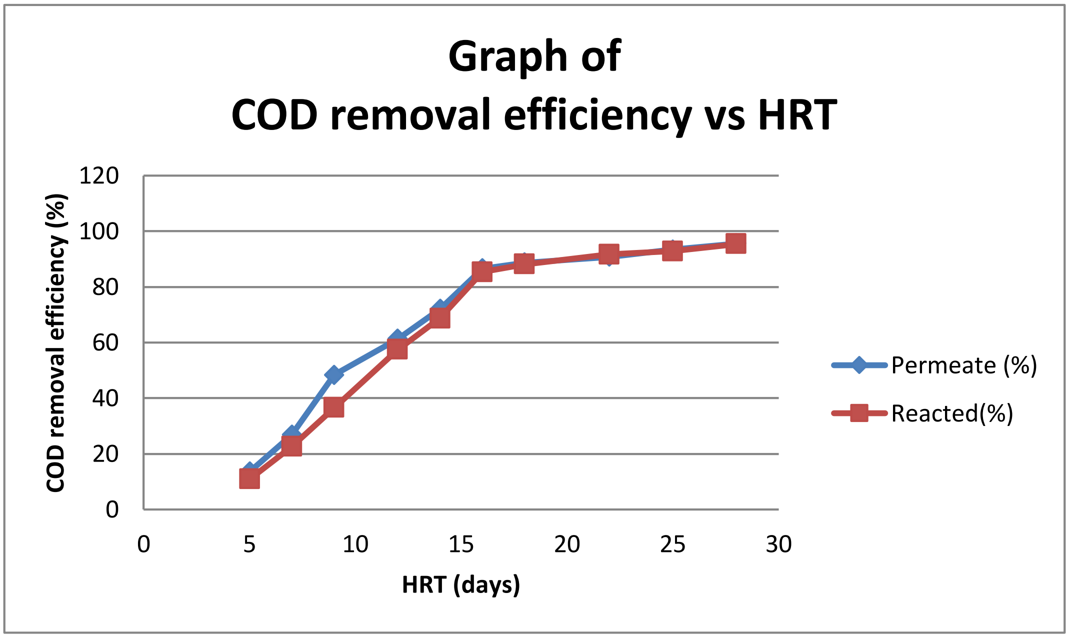

Figure 3 : Graph of COD Removal efficiency vs HRT

Total Suspended Solid (TSS) and Volatile Suspended Solid (VSS) Testing

Figures 4 & 5 show the TSS and VSS removal efficiency for UMAS using sugarcane waste water as substrate. Basically the TSS and VSS efficiency's profile trends follow the trend obtained from COD and BOD removal shown previously in Figures 2 & 3. This corresponds to the report done by Basri et al, which claimed that high concentration of suspended solid leads to the high removal rate of COD and BOD. About 98% removal was achieved for both TSS and VSS during the treatment (Basri, 2010). This might due to the clogging of inorganic particles on the membrane surface that inhibit smooth filtration process. In the research done by Abdurahman et al. (2012), 99% of TSS removal using POME as substrate was achieved during the same UMAS treatment. Removal in this study should be higher because sugarcane wastewater has lower TSS value compared to POME but the result obtain is a bit lower. This might due to some error during the process of analyzing TSS and VSS.

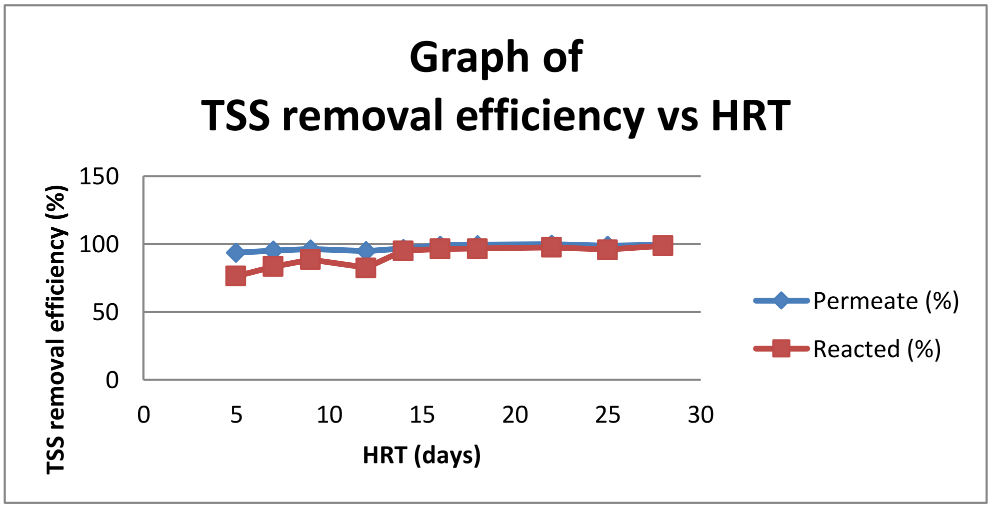

Figure 4 : Graph of TSS removal efficiency vs HRT

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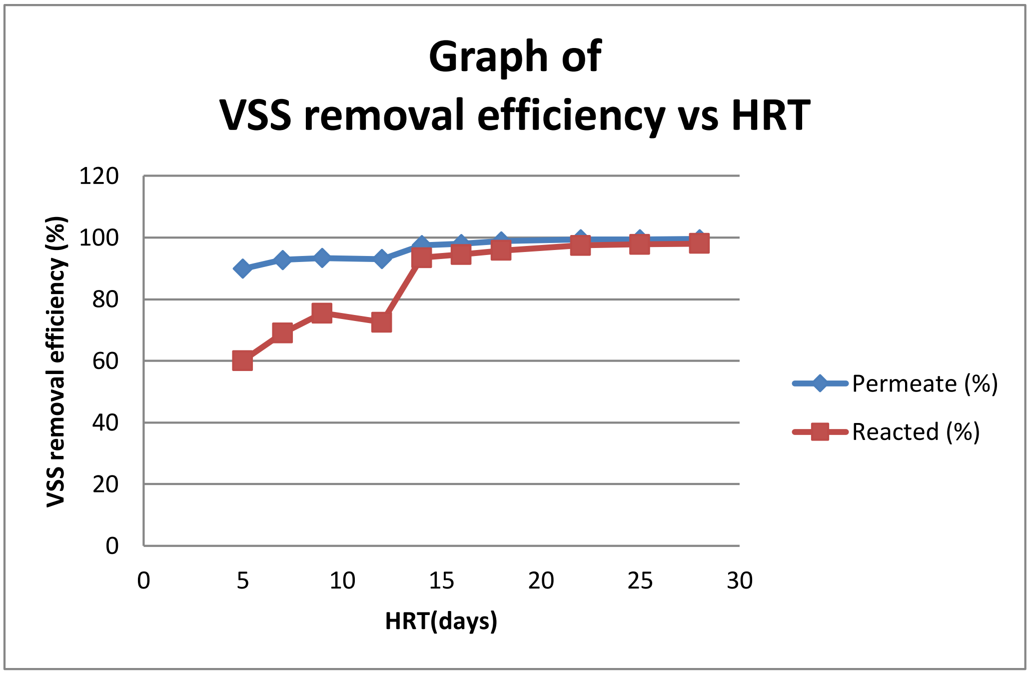

Figure 5 : Graph of VSS removal efficiency vs HRT

Methane Gas Measurement

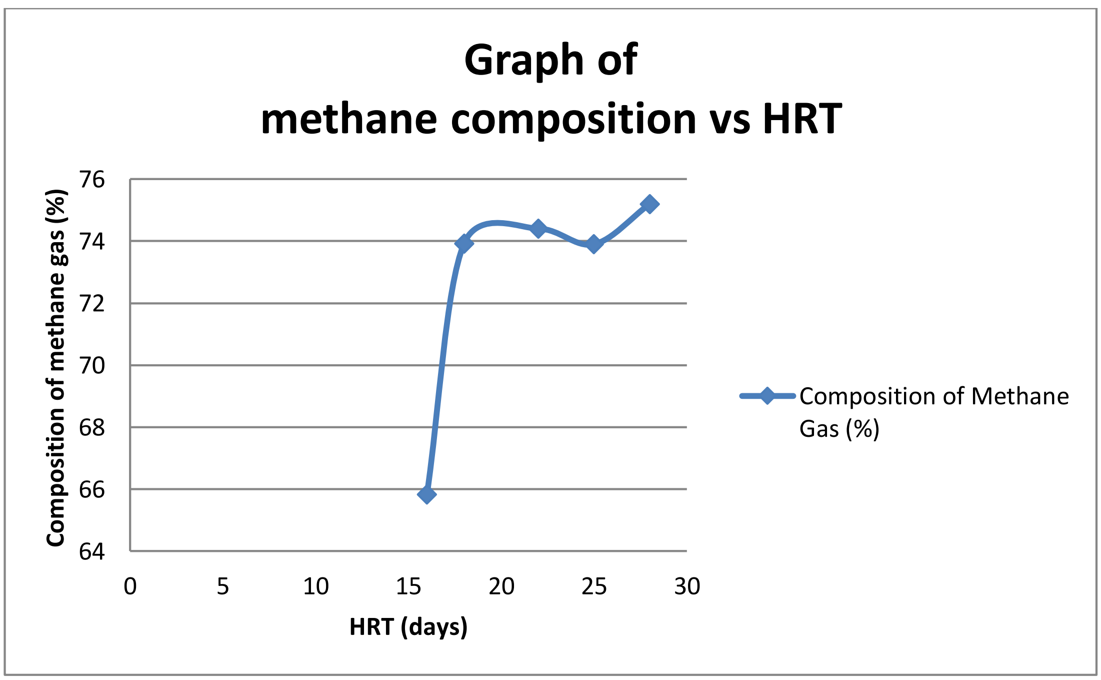

Figure 6 : Graph of methane composition vs HRT

Figure 6 shows that the composition of methane gas increases within the 14 days of experiment, as the COD removal increases .The highest percentage of methane gas obtained was 78 % which obtained from day 28th of the experiment. The collection of gas is high compare to the experiment reported by P.Y.C

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Alice that treated low strength wastewater with only 6.5 % of methane was obtained. UMAS system can obtain high composition of methane gas because it has ultrasonic waves which remove the cake layer on the membrane surface and retain the organic particles back into the reactor (Youngsukkasem, 2013)The reading of methane gas obtained only changed slightly might due to the fatty acid form due to small deviation of pH while conducting the experiment . Methanogenesis is strongly affected by pH ; methanogenic activity will decrease when the pH in the digester deviates from the optimum value (N.H. Abdurahman, 2012) . The increase of fatty acid will cause more production of carbon dioxide (CO2), which will decrease the production of methane gas. Therefore, it is important to maintain the pH value it its optimum range to maximize the production of methane gas in the reactor.

CONCLUSION

Based on the results obtained, it shows that membrane fouling does not occurs while using ultrasonic device as a support for membrane anaerobic system (MAS) .UMAS is not only adequate for the biological treatment of high strength wastewater such as POME, but it is also suitable to treat low strength wastewater sample such as sugarcane wastewater. The production of methane gas also gave a satisfactory as the composition obtained was 78% on the 28th day of the experiment.

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