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Biomethanation Of Palm Oil Mill Effluent (Pome) By Ultrasonic-Membrane Anaerobic System (UMAS)

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ABSTRACT

Palm Oil Mill Effluent (POME) is the wastewater produced during the production of palm oil. POME is a brownish, colloidal suspension that can cause severe damage to environment because of its high chemical oxygen demand (COD) and biochemical oxygen demand (BOD). POME often released at high temperature (70-80°C) and has pH values between 3.5 and 4.5. In this study, Ultrasonic-Membrane Anaerobic system was used as a cost-effective design to treat POME while methane gas was collected from the biomethanation process. POME was continuously feed into an anaerobic reactor and pH was maintained at 1.75 bar. Temperature was maintained between 30 and 35°C. Samples from reactor and permeate were collected after 5 hours of operation for the analysis of COD, BOD, total suspended solids (TSS) and volatile suspended solids (VSS). At the end of 5 hours operation, biogas was collected from the top of 200 litres of UMAS reactor using a designated syringe. Throughout the experiment, the COD and BOD removal efficiencies were 66.06% and 96.88% respectively. 94.24% of total suspended solids removal was achieved at 10 days of hydraulic retention time. The methane gas production efficiency was 83.61%. The membrane fouling problem reduced and the treatment of POME was improved by UMAS introduction.

INTRODUCTION

POME is a wastewater generated during the production process of palm oil. POME is a non-toxic brownish liquid with an unpleasant odor. It usually will discharge at a temperature between 80-90°C. POME is fairly acidic with pH ranging from 4.0 – 5.0 (N.H.Abdurahman, Priya Dharshini, 2015). POME contains high amounts of COD, BOD and TSS. (Choorit and Wisarnwan, 2007). These can cause severe damage to the environment, especially water pollution. Furthermore, high contents of organic and nutrient contents in POME has large oxygen depleting capability in aquatic system (Zafar, 2013).

Currently, industries use ponding system to treat Palm Oil Mill Effluent before discharge it into rivers and other water sources because it is low cost. But the biogases emitted during biodegradation of POME will be released into atmosphere. These biogases especially methane gas has high potential to cause global warming and greenhouse effect. Moreover, ponding system requires large area and has long hydraulic retention time (HRT) (Poh P.E, 2009). Membrane separation can be used to treat POME but there will be membrane fouling problem caused by high amounts of total solids. The total suspended solids can reduce the membrane permeability and slow down the flow. The membrane can be suffered from fouling and degradation during it is continuous usage (Abdurahman.H.Nour and Nuri ‘AdilahNashrulmillah, January 2014).

High-rate anaerobic bioreactors have shown better treatment efficiency, producing better treated effluent with shorter retention times, as well as greater methane production. (Poh Phaik Eong, 2008). These anaerobic

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bioreactors also require less space. Ultrasound has been widely used as a method for cleaning materials because of the cavitation phenomenon and proved to be able to enhance membrane permeability of solvent and permeate through membrane, facilitate improved separation rate and mitigate membrane fouling effectively in-cross flow filtration of macromolecules (Muthukumaran *et al*., 2007). Combination of filter with ultrasounds increases filter's life as clogging and caking are prevented by continuous cavitation at the surface of filter (Farid Chemat, 2011). The advantages of this process are the low-energy requirement involved in ultrasound and high binding capacity of the polymers (Noble, R. D. & Stern, S. A., 2011.

The first objective of this study is to enhance the treatment of POME using Ultrasonic Membrane Anaerobic System (UMAS). Second objective is to solve the membrane fouling problem using UMAS and increase the purity of methane gas. Third objective is to compare the performance between Ultrasonic Membrane Anaerobic System (UMAS) and Membrane Anaerobic System (MAS).

Experimental:

MATERIALS AND METHODS

Materials:

Raw POME was obtained from Lepar Hilir Oil Palm Mill. Initial characteristic of POME such as COD, BOD, TSS, VSS and pH were measured.

Table 3.1: Initial characteristics of raw POME

Parameters	Initial Measurement
pH	4.00
Temperature (°C)	60
COD (mg/L)	3463
BOD (mg/L)	264
TSS (mg/L)	28
VSS (mg/L)	26
Methane Production (%)	0.0

Methods:

Sample Preparation:

POME was preserved at a temperature less than 4°C and higher than freezing point to prevent biodegradation and stored in PVC container. Before the experiment, POME was filtered to remove suspended materials.

Operating Procedure:

50 litres Ultrasonic-Membrane Anaerobic system was used for this study. The filtered POME was left in feeder tank for 5 days for acclimation process. Some of the POME was collected and analyzed for the parameters such as pH, COD, BOD, TSS, VSS, color and temperature to obtain initial characteristic of POME. PH was controlled in the range of 6.8 to 7.4, pressure was set to be 1.5 to 2 bars and temperature was maintained within 25°C to 37°C. The reactor was left to operate for 5 hours. After 5 hours, the permeate was collected and tested for various parameters. The gas produced was collected using designated syringe. The experiment was conducted for every of the subsequent days.

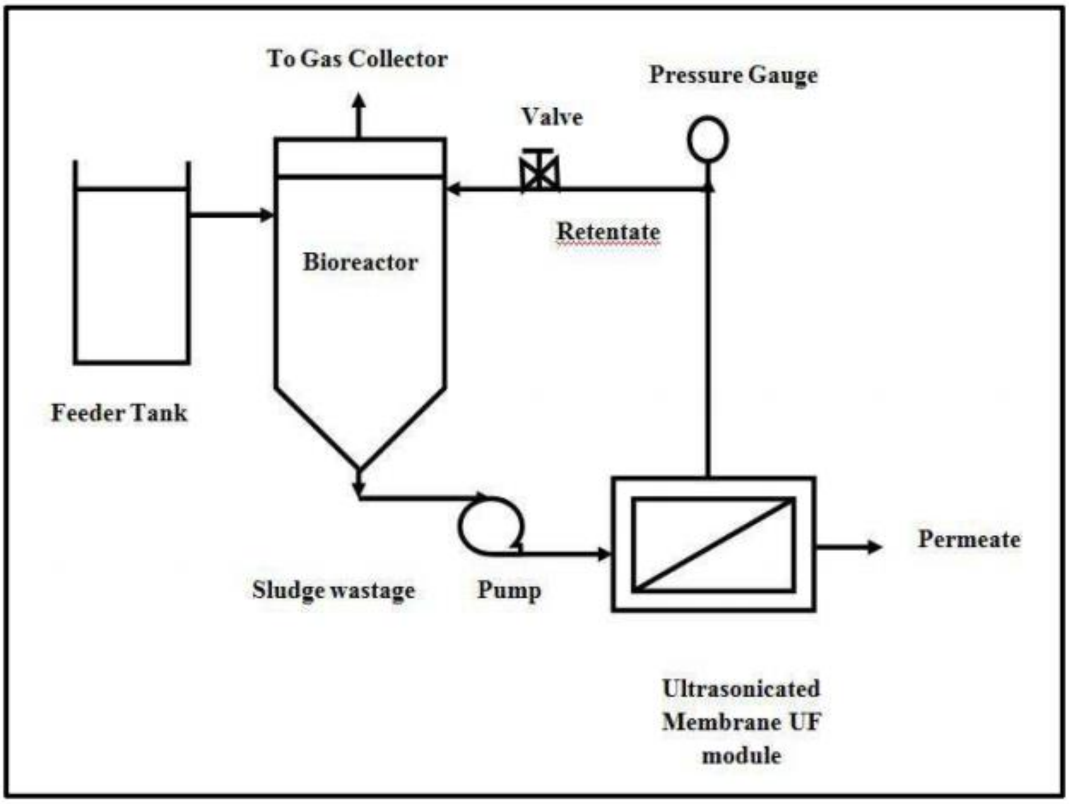

Fig. 3.1: Experimental Set-Up

Determination Of Parameters:

Methane gas measurement:

J-tube gas analyzer was used for the measurement of methane gas component. 0.5M of potassium hydroxide (KOH) was drawn into the syringe to absorb carbon dioxide. The end of the glass tube was immersed into the water to prevent gas escape. The biogas column was measured.

Calculations for gas measurement:

$$\textbf{Percentage of methane gas (\%)} = \frac{Final\ gas\ column\ length(cm)}{Initial\ gas\ column\ length(cm)}\ x\ 100 \quad (3.1)$$

Determination of Chemical Oxygen Demand (COD):

COD digestion reactor was reheated to 150°C. 2.00 mL of the POME was added to the COD Digestion Reagent Vials. The prepared sample and blank vial was heated for two hours in the COD reactor. After two hours, the vials were let to cool to 120°C. The reading was taken by placing the vials in the spectrometer, HACH DR/2400.

Determination of Biochemical Oxygen Demand (BOD):

Phosphate buffer solution, Magnesium sulfate solution, Calcium chloride solution and Ferric chloride solution were prepared at the beginning of the experiment. 1mL of each of the solutions were added to 1L volumetric flask and distilled water was added to 1L. 10mL of POME will be added into 500mL beaker and dilution water will be added up to 300mL. The prepared sample was put in 300mL incubation bottle. The DO concentration was measured using Dissolved Oxygen Meter. After water is added to the flared mouth of the bottle it was covered with aluminium foil. The bottle was put in BOD incubator for five days and temperature was set to 20°C. The final DO value was measured after five days.

Calculations:

$$\mathbf{BOD_5,\ mg/L = (D_1 - D_2)\ x\ Dilution\ factor} \quad (3.2)$$

Dilution factor = Bottle volume (300mL) / Sample volume

D_1 = Dissolved Oxygen value in initial sample

D_2 = Dissolved Oxygen value in final sample

Determination of Total Suspended Solids (TSS):

A filter paper was dried at 103°C and weighed. In a Buchner flask, 50mL of POME pipetted onto centre of filter paper. The filter was washed with three successive 10mL volumes of distilled water. The filter paper was dried at least one hour at 103°C and weighed. The cycle of drying, cooling and weighing was repeated until a constant weight is obtained.

Calculations:

$$\text{mg TSS/L} = \frac{(A - B) \times 1000}{\text{Sample volume, mL}} \quad (3.3)$$

where;
A = weight of filter + dried residue, mg
B = weight of filter, mg

Determination of Volatile Suspended Solids (VSS):

The filter used for total suspended solids testing was ignited at 550°C for 30 minutes. The weight lost on the ignition of the solids will represent the volatile solids in the sample.

Determination of PH, Temperature and Color:

The color changes before and after the experiment was observed. Temperature and pH were measured using thermometer and pH meter respectively.

RESULTS AND DISCUSSION

Results:

The designated syringe used to collect biogas produced from decomposition of POME. Since the biogas contained only carbon dioxide and methane gas, a portion of sodium hydroxide used to absorb carbon dioxide gas and left the methane gas to be measured. Other than methane gas, other parameters such as COD, BOD, TSS, VSS and pH also were studied. The anaerobic system with ultrasonic treated the POME and gave highest removal of BOD that is about 96.88% in short time.

Table 4.1: Initial characteristics of POME

Parameters	Initial Measurement
pH	4.00
Temperature (°C)	60
COD (mg/L)	3463
BOD (mg/L)	264
TSS (mg/L)	28
VSS (mg/L)	26
Methane Production (%)	0.0

Table 4.2: Summary results of UMAS performance

Hydraulic Retention Time	COD Permeate	% Methane	COD Removal (%)	TSS Removal (%)	BOD Removal (%)	VSS Removal (%)	pH of Permeate
1	2239	-	12.64	75.72	96.88	80	5.86
2	2019	-	7.8	94.24	66.67	94.44	6.23
3	1945	-	17.58	78.78	46.67	75.42	8.16
4	1970	83.61	49.10	83.45	35.53	82.22	8.16
5	1963	62.5	54.82	84.64	26.20	80.33	8.08
6	1870	64.3	52.05	92.34	25.68	88.35	6.59
7	1849	70.85	55.68	90.27	24.97	86.04	7.91
8	1838	53	64.21	92.34	23.67	89.77	6.78
9	1868	67.11	66.06	91.68	22.99	87.27	6.6
10	1950	68.15	62.82	92.09	15.59	90.79	7.7

Table 4.2 summarizes UMAS performance for 10 hydraulic retention times. The COD of permeate was 2239 mg/l on the first day and 1950 mg/l on the tenth day. This shows that long retention time of UMAS leads to decomposition of suspended solids in the POME into biogas. The color of permeate on the tenth day is clearer than the raw POME. Table 4.2 also clearly shows that the highest percentage of methane gas obtained was 83.61%. This value is better than the value reported in other study on anaerobic slaughterhouse wastewater digestion (N.H.Abdurahman, Y.M.Rosli and N.H.Azhari, 2015). The values that differ clearly explain that the percentage of methane gas produced depends on the amount of organic matters in the wastewater.

Discussions:

Chemical Oxygen Demand Removal with Hydraulic Retention Time:

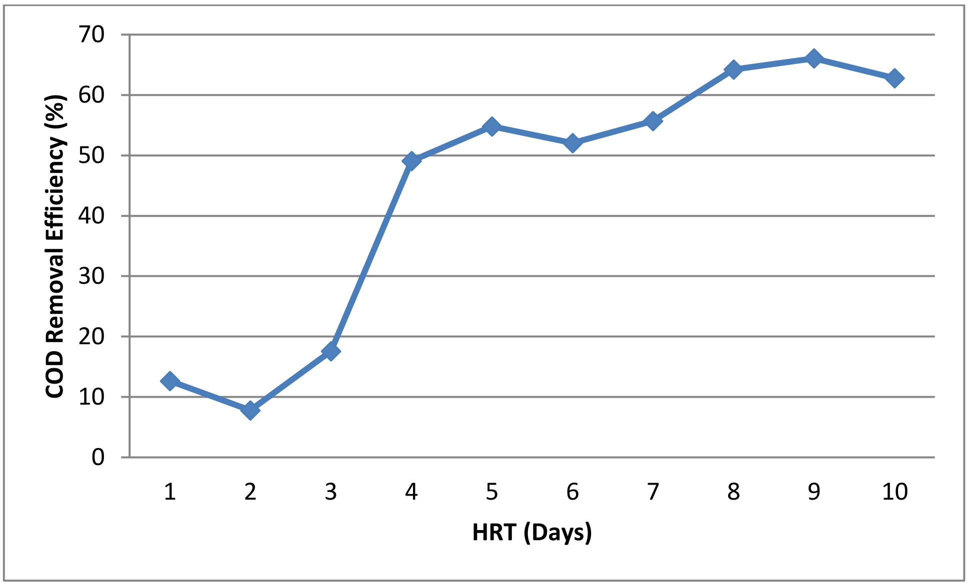

Fig. 4.1: COD Removal at different retention times

Figure 4.1 shows that the chemical oxygen demand (COD) removal efficiency increases and become constant after fifth day. The COD removal efficiency is very low on 2nd and 3rd days. Since hydraulic retention time is experimented in this project, the microorganisms have no sufficient time to acclimatize and produce new cells. The sudden increase in graph after 3rd day shows that microorganisms already acclimatize and new bacteria were produced. The constant COD removal efficiency after fifth day explains that most of the biodegradable matters in POME already reduced.

Biochemical Oxygen Demand Removal at Hydraulic Retention Time:

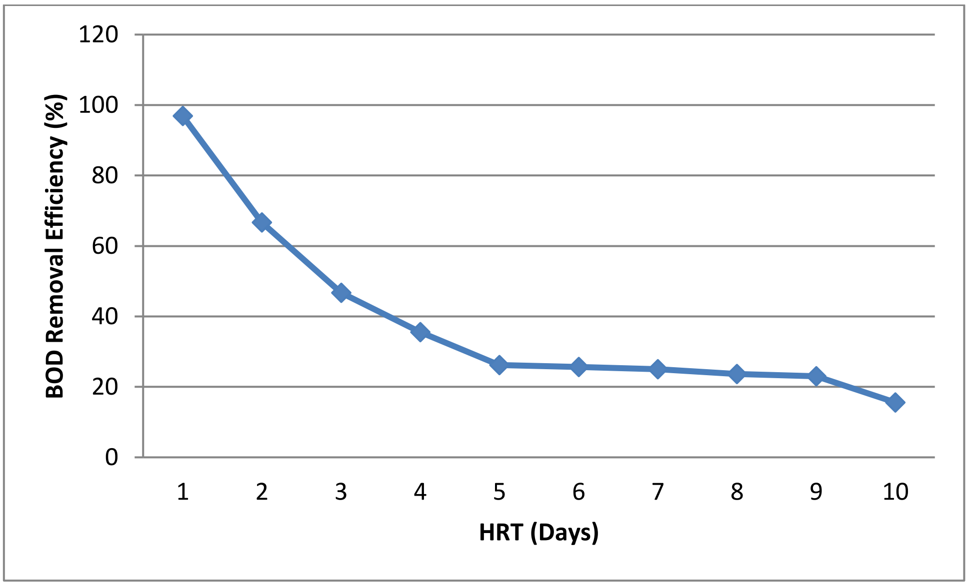

Fig. 4.2: BOD Removal at different retention times

Figure 4.2 shows the decrease in BOD removal efficiency as days pass. Biochemical oxygen demand only focuses on biodegradable matters. As days pass, the amount of biodegradable matters change to biogas also increase. Hence, the amount of biodegradable matters in the POME inside reactor also reduced. These can explain the reason of the decrease in BOD removal efficiency as time passes. From above graph, the highest removal rate of BOD is 96.88%. This value is better when compared with other study on anaerobic treatment of POME (Abdurahman.H.Nour and Nuri ‘AdilahNashrulmillah, 2014)

Total Suspended Solids Removal at Hydraulic Retention Time:

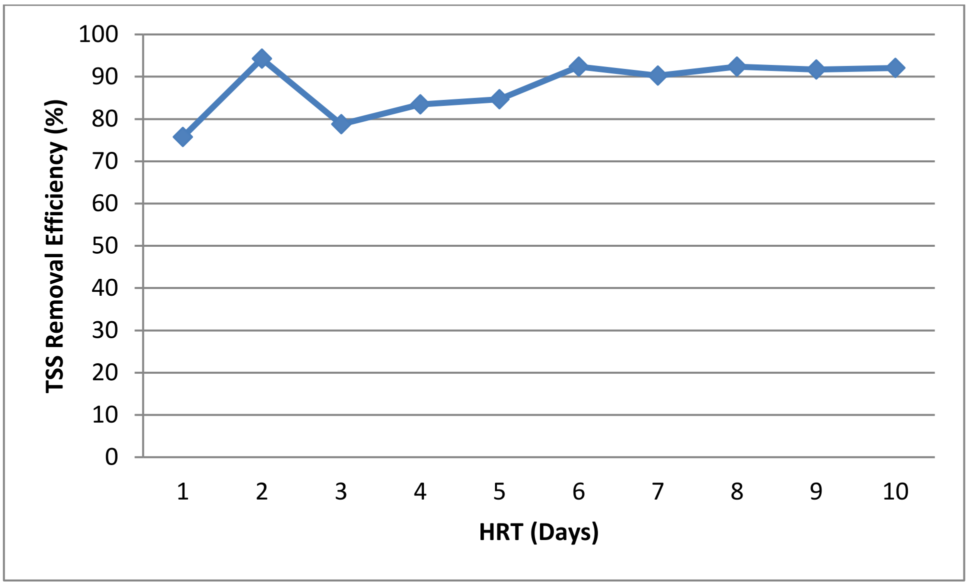

Fig. 4.3: TSS Removal at different retention times

Figure 4.3 shows the relationship between total suspended solids (TSS) removal efficiency and hydraulic retention time. The trend of the graph is increasing. This shows that the amount of solids hydrolyze, dissolve and turn into biogas also increasing as days pass. Apart from that, it also indicates that the microorganisms inside the reactor are increasing.

Volatile Suspended Solids Removal at Hydraulic Retention Time:

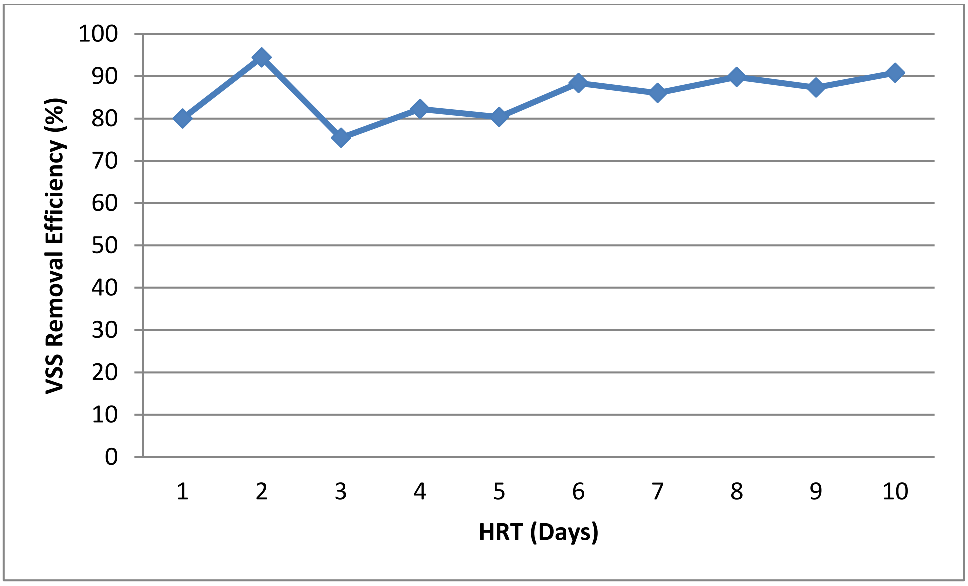

Fig. 4.4: VSS Removal at different retention times

Figure 4.4 shows that the volatile suspended solids (VSS) removal efficiency almost constant as time passes. The graph shows that not all the solid mass participates in the conversion of the organic fraction. There is also some inorganic compound that does not play active role in biological treatment. When total suspended solids removal increases, the volatile suspended solids removal also increases. This indicates that the UMAS system facilitates decomposition of suspended solids well. It can be concluded that microorganisms acclimatize well with UMAS system environment.

PH of Permeate at different retention times:

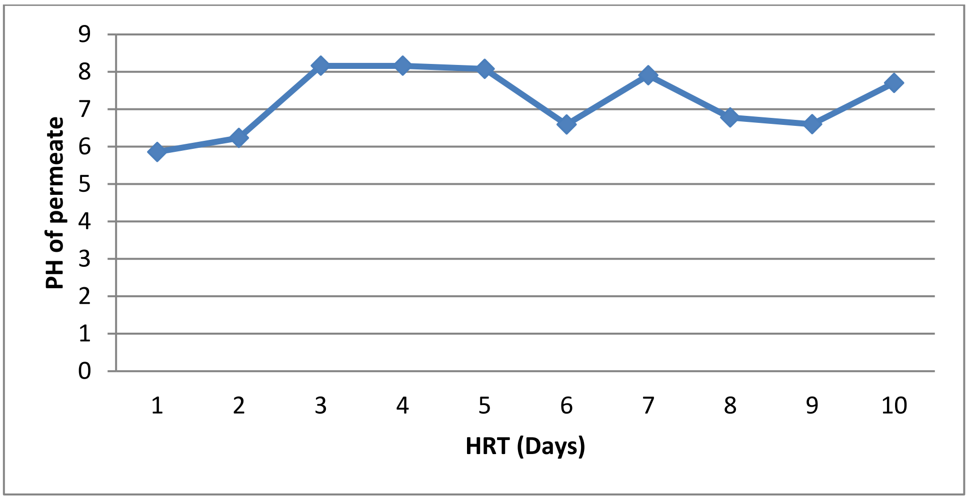

Fig. 4.5: pH of permeate at different retention times

Figure 4.5 shows the relationship between pH of permeate and hydraulic retention time. PH inside the reactor need to maintain between 6.5 to 8 for the UMAS system operates effectively. From the figure, it can be seen clearly that there is sudden pH drop on the 6th day. It can be concluded that the amount of carbon dioxide gas inside the reactor is increasing. So, a specific amount of sodium hydroxide was added to increase the pH.

Table 4.3: Comparison between performance of MAS and UMAS

Parameters	Removal Efficiency (%)	
	MAS	UMAS
COD (%)	50.29	66.06
BOD (%)	64.32	96.88
TSS (%)	75.72	94.24
VSS (%)	94.44	94.44

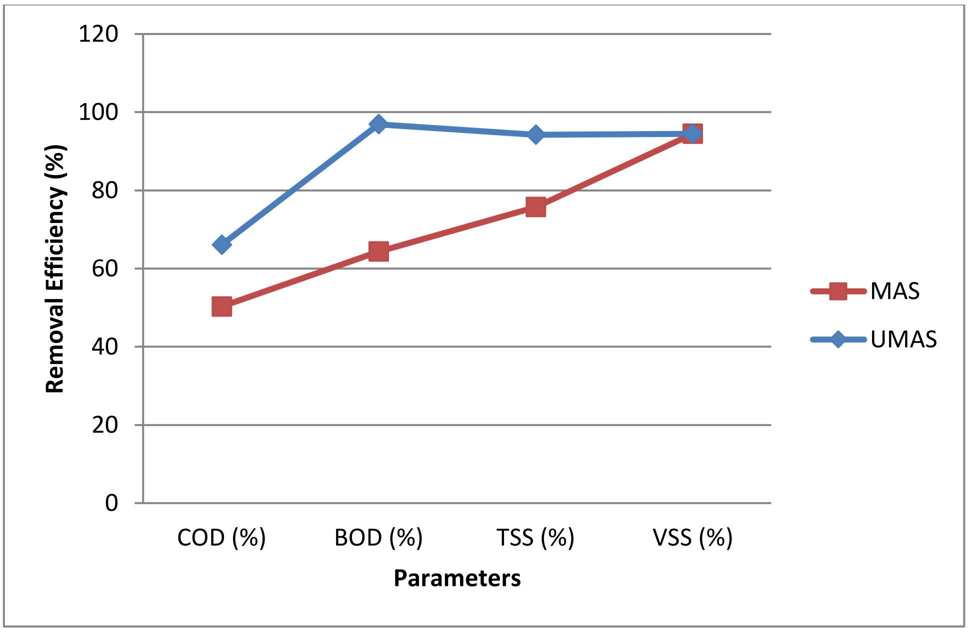

Fig. 4.6: Comparison between UMAS and MAS

From the graph above, it can be clearly seen that the performance of Ultrasonic Membrane Anaerobic System (UMAS) better than Membrane Anaerobic System (MAS). The removal efficiency of COD, BOD, TSS and VSS of UMAS are higher than MAS. This shows that UMAS successfully overcome membrane fouling problem.

Conclusions:

The Ultrasonic Membrane Anaerobic system is an effective method to treat POME as it can overcome membrane fouling. From the results obtained, the performance of UMAS is better than MAS. The highest BOD removal efficiency is about 96.88%. UMAS also successfully capture methane and the highest amount of methane gas captured is 83.61%.

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