STUDY THE EFFECT OF USING ULTRASONIC MEMBRANE ANAEROBIC SYSTEM IN TREATING SUGARCANE WASTE AND METHANE GAS PRODUCTION

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Abstract

Sugarcane mill produces significant amount of wastes mainly in the form of liquid waste or also knows as sugarcane mill effluent (SCME). SCME can cause water pollution and need proper treatment before it can be discharge into water sources (river or lake). This is due to the high content of Chemical Oxygen Demand (COD), Biological Oxygen Demand (BOD), Total Suspended Solid (TSS) and Volatile Suspended Solid (VSS).In present study, biological treatment (anaerobic system) and membrane filtration assisted with ultrasonic effect was carried out to treat the SCME. In anaerobic system, the decomposition of organic and inorganic substrate occurs without the presence of oxygen to treat high concentration of organic carbon waste such as SCME and methane gas (CH4) is produced as a by product in this process. Ultrasonic assisted membrane system is applied in the system in order to enhance the efficiency of the process in treating the SCME. Study was conducted by comparing the quality of the SCME after undergo the treatment process using membrane anaerobic system (MAS) and ultrasonic membrane anaerobic system (UMAS). From the study, it shows that more than 90% (>90%) percents of removal efficiency (BOD, COD, and TSS), and reduce flux decline is achieved by using UMAS

Keywords: *Sugarcane waste water effluent, Ultrasonic, Anaerobic Digestion*

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1. INTRODUCTION

Environmental problem have increased the global awareness to reduce pollution and protect environment. Sugarcane mill uses generates huge amount of liquid waste (Sugar Cane Mill Effluent) as they uses a lot of water supply in the process. This type of water cannot be discharge directly as the BOD and COD level do not meet the standard of discharge limit set by Department of Environmental (DOE). Solomon, (2005) reported that BOD level for untreated SCME is around 1500 (mg/L) which shows that it has high biodegradability and cause water pollution if it is not treated. Therefore anaerobic treatment process is applicable to treat this typed of waste riches in organic and inorganic matter to degrade by microbes. The process produces CH4 (methane gas) which potentially used as an alternative source of energy instead of fuel oil and reduces world's dependence on oil and chemical fuels (Chandra et al., 2012). In fact, methane is better choice of energy compared to other hydrocarbon as the combustion of methane release less carbon for each unit than other hydrocarbon fuels (Demirbas, 2006). This corresponds to the "waste to wealth" concept which promotes by Malaysian government to reduce waste's discharge into environment.

Anaerobic treatment process are well preferred compared to other process such as trickling filtration and aerobic treatment because it produces useful gas (methane gas) and cheaper compared to the other process but the conventional anaerobic digestion method requires longer retention time, large treatment area and inefficient treatment method (can not meet the standard set by DOE). Stukey, 2012 introduced anaerobic membrane system (AnMR) to improve the process. Ultra or micro filtration was added to the system to treat the waste. However, it faces another problem corresponds to fouling at membrane surface which were blocked by organic matter (Lin *et al*,.2013). Thus, Wen et al (2008) and Abdurrahman *et al*., (2014) designed new treatment system called Ultrasonic membrane anaerobic system (UMAS) which introduced ultrasonic assisted membrane to reduce fouling problem. Table 1.0 shows the optimum condition for UMAS operation in treating palm oil mill effluent (POME) reported by Abdulrahman *et al*., (2014).

Table 1: Optimum Conditions for UMAS (Abdulrahman *et al*., 2014)

Parameter	**Optimum Condition**
pH	6.8-7
Temperature (^oC)	25-37
Pressure (bars)	1.5-2.0
Ultrasound Frequency (kHz)	10

2. MATERIALS AND METHODS

2.1 Characterization of Raw Material

Raw sugarcane waste water was collected from Kilang Gula Felda Perlis Sdn Bhd. The sample was kept in cold room at

4oC to make sure the waste water does not biodegrade due to microbial action. Some of the sugarcane waste water were taken and tested for parameters such as pH, COD, BOD, TSS and VSS to know the initial characteristics of sugarcane waste water.

2.2 Experimental Setup

This study was conducted in laboratory scale using a specially designed reactor equipped with ultrasonic device and cross flow ultrafiltration membrane, Ultrasonic Membrane Anaerobic System (UMAS) as shown in Figure 1.0. Sugarcane wastewater was treated in a 50 L reactor equipped with cross flow ultrafiltration (CUF) membrane and a centrifugal pump. The reactor is made up of PVC with inner diameter of 25cm and a total height of 100cm. The ultrasonic frequency was set at 10 kHz. The pressure will be manipulated in the range of 1 to 2 bars using the gate valve at the retentate line after CUF unit

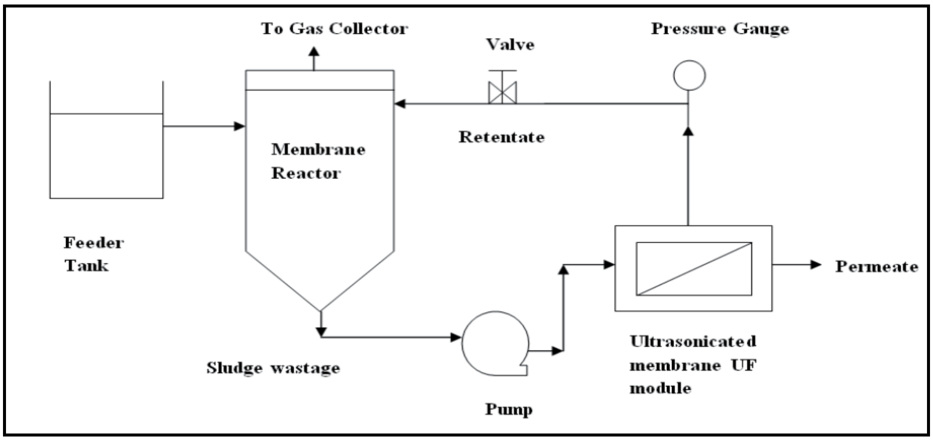

Fig 1: Experimental Set up (Abdulrahman *et al.*, 2014)

2.3 Reactor Operation

The sieved sugarcane waste water was fed into the membrane anaerobic reactor and was left in the reactor for 5 days to make sure the microorganisms was fully acclimatized with the reactor's environment. The reactor was covered with aluminium 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. 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. The experiment was conducted for 7 days to find the effect of using membrane anaerobic system (MAS) in treating sugarcane wastewater and methane gas produced. After the 7 days, the whole procedures were repeated again with an ultrasonic device with frequency of 10 kHz attached to the ultrafiltration membrane. This was done to determine the effect of ultrasound in treating sugarcane wastewater and methane gas produced.

3. RESULTS AND DISCUSSION

3.1 pH Testing

On the first 3 days, pH of the sugarcane wastewater was maintained at pH 3.87 because acidogens typed of bacteria prefer to be in acidic condition or also known as transition zone. (Siddiqui *et al.*, 2012). Starting from day 4, pH was increased to the optimum condition by adding base solution (sodium hydroxide). Generally, pH has to be maintained at 6.8 to 7.2 during the biomethanation process to ensure the growth of the microbes is not inhibited (Chandra *et al.*, 2012).

3.2 Chemical Oxygen Demand (COD) and Biological Oxygen Demand (BOD) Testing

Figures 2 & 3 show the COD and BOD removal efficiencies profile for MAS and UMAS respectively. For MAS, the highest removal efficiency for both COD and BOD was achieved on the 4th and 3rd day respectively at 87% removal efficiency. However the removal efficiency for UMAS is even 10 % greater compared to MAS. 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 (Buvaneswari *et al.*, 2013).

From the last 3 days, removal efficiency of BOD and COD started to drop gradually for MAS, but for UMAS the removal efficiency does not change much and nearly become constant at this duration. The difference in trends shows by UMAS and MAS performance at this time might due to the fouling of the membrane which blocked the membrane surface in MAS system. However in UMAS, the fouling effect is overwhelmed by the presence of ultrasonic wave avoid the accumulation of particle at the membrane surface. Similar pattern of results was reported by Abdulrahman *et al*. (2012) for UMAS using slaughterhouse wastewater as substrate.

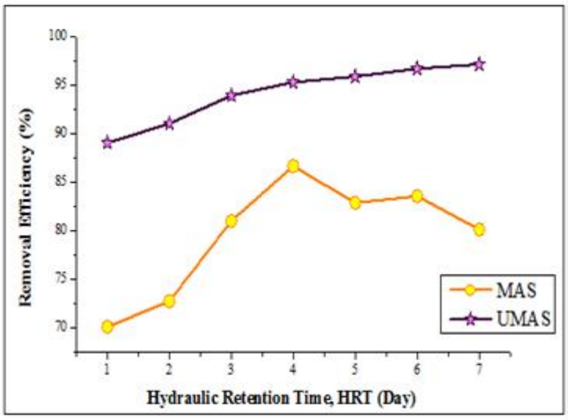

Figure 2: COD Removal Efficiency for MAS and UMAS

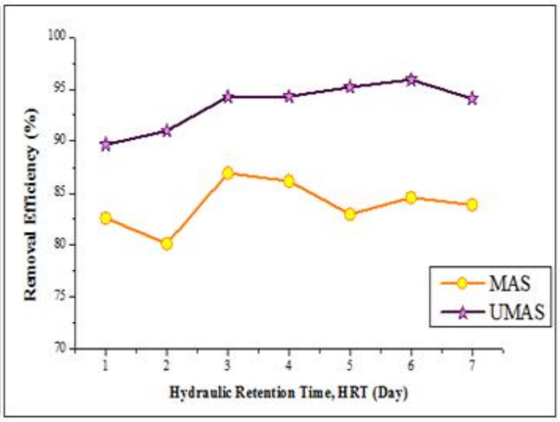

Figure 3: BOD Removal Efficiency for MAS and UMAS

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

Figures 4&5 depict the TSS and VSS removal efficiency for MAS and UMAS. 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* (2010) which claimed that high concentration of suspended solid leads to the high removal rate of COD and BOD. Again similar to the COD and BOD removal trends, UMAS depicts higher percent of TSS and VSS removal compared to MAS as shown in Figures 4&5. In fact, 100% removal was achieved for both TSS and VSS during UMAS treatment, and 79% removal efficiency for MAS. The possible reason will be the clogging of inorganic particles on the membrane surface that inhibit smooth filtration process. In the research done by Abdulrahman *et al*. (2014), 99% of TSS removal using POME as substrate was achieved during the same UMAS treatment. Removal in this study was higher because sugarcane wastewater has lower TSS value compared to POME. Therefore it is much easier to remove all the suspended solids from sugarcane mill effluent.

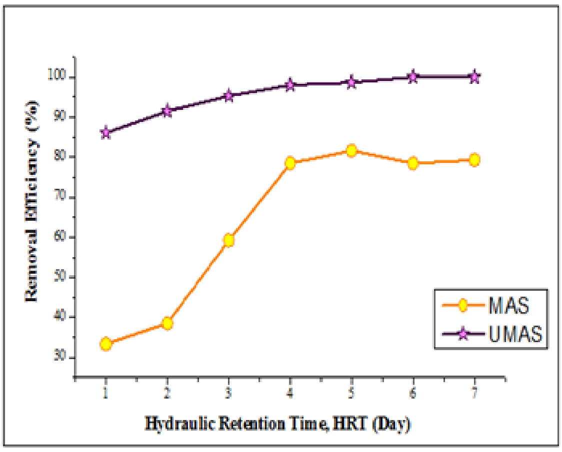

Figure 4: TSS Removal Efficiency for MAS and UMAS

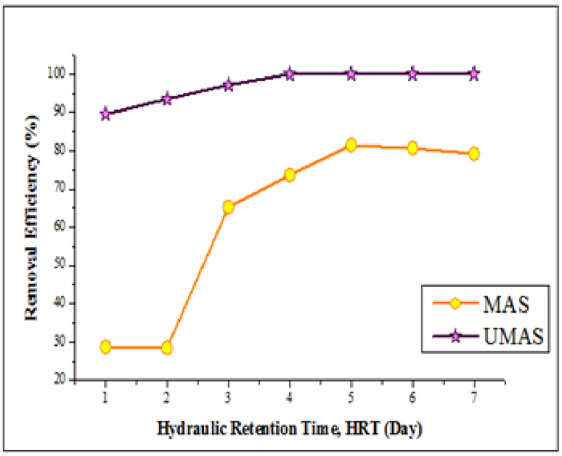

Figure 5: VSS Removal Efficiency for MAS and UMAS

3.4 Permeate Flux

Comparison of permeate flux between MAS and UMAS is shown in Figure 6. It is clearly shows that the decrease in flux is significant for MAS compared to UMAS, perhaps the trends becomes constant after day 3. Again, this is due to the presence of ultrasound effect in UMAS which eliminates particles from blocking the pores of the membrane. Chang et al (2002). Both systems (MAS and UMAS) showed high flux on the first day which was 25.6 $L/m^2.h$ and 35.7 $L/m^2.h$ for MAS and UMAS respectively. This indicates that on the 1'st day, there was less fouling or no fouling occur on the membrane surface, but as the time increases, the pores have started to block with the particle and lead to the reduction in membrane flux. However for the UMAS, flux reduction is less significant compared to MAS as the value of flux obtained on the last day is only 1.8 % less compared to the original one.

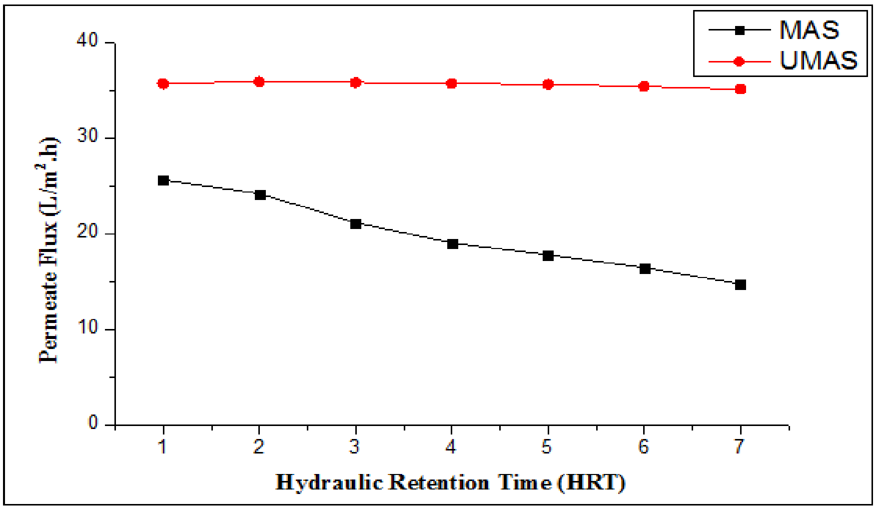

Fig 6: Permeate Flux of MAS and UMAS

3.5 Methane Gas Measurement

Figure7 depicts the methane gas production rate obtained from UMAS and MAS treatment. Overall, both treatment shows the increased in methane gas composition as the time increase. On the first 3 days, the production of methane gas was low. This might due to the oxygen contamination during the manual recycle of permeate at the beginning of day 3 into the reactor that inhibit the methanogens growth (Basri et al., 2010). However this value has increased gradually and become constant on the last two days with UMAS achieved 77% of methane gas production while MAS achieved 68% of methane gas production. Abdurrahman et al reported that the constant trend of methane gas production in the last two days is caused by the decline in COD, BOD and TSS values (Abdurrahman et al 2014). Higher percentage in methane gas production obtained in UMAS compared to MAS is caused by the presence of ultrasonic wave in UMAS system which remove the cake layer on the membrane surface and retain the organic particles back into the reactor (Youngsukkasem et al., 2013). This will speed up the degradation process and provide more substrate at the same time.In the research done by Abdulrahman et al. (2014), methane yield of 94.14% has been achieved using POME as substrate for the same UMAS treatment. Comparing these two studies, methane yield in this study during UMAS was very low. This was due to the high amount of totals suspended solids present in POME than sugarcane wastewater which serves more foods for microbes to produce methane gas. This steady increase in the biogas production was also due to the increase of COD and BOD removal explained earlier.

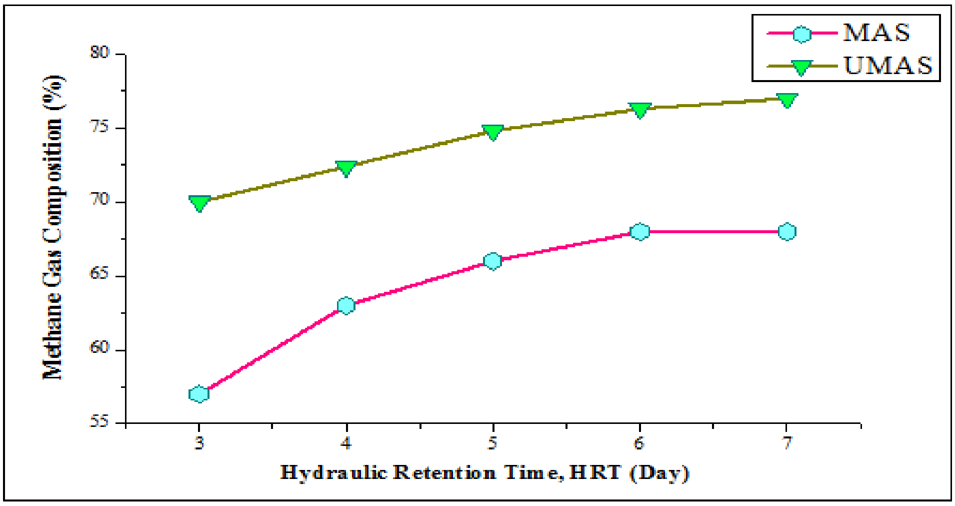

Fig 7: Methane Gas Composition of MAS and UMAS

4. CONCLUSIONS

In overall UMAS depicts better performance in treating the sugarcane mill effluent (SCME). It has achieved higher removal efficiency for COD, BOD and TSS compared to MAS which was about 97%, 96% and 100% of removal efficiency respectively. Hence UMAS system achieved 13% greater in methane gas production compared to MAS system, which will be benefited as an energy resource in sugar cane mill process.

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