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Membrane Fouling Control by Ultrasonic Membrane Anaerobic System (UMAS) to Produce Methane Gas

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Abstract

In Malaysia, more than 30 tonnes of waste sugarcane was burned and damped to an open field. The direct discharge of sugarcane wastewater causes serious environmental pollution due to its high chemical oxygen demand (COD) and biochemical oxygen demand (BOD). Traditional methods for sugarcane treatment have both economic and environmental disadvantages. In this study, Ultrasonic membrane anaerobic system (UMAS) was used as an alternative, cost-effective method for treating raw sugarcane wastewater. Raw sugarcane wastewater treated by UMAS in a laboratory digester with an effective 200-litre volume. The ultrasonic frequency is 25 KHz, with 6 units of permanent transducers and bonded to the two (2) sided of the tank chamber and connected to one (1) unit of 250 Watts 25 KHz Crest's Genesis Generator. The sugarcane wastewater had been added inside the reactor, and it acclimatized for 5 days before running the reactor. The initial value of COD recorded was 1984 mg/L; BOD was 556.8 mg/L, TSS, 0.586 mg/L, and VSS, 0.593 mg/L. The pH, pressure, and temperature were kept constant during this experiment with the value of 7.0-7.6, 1.5 bars, and 32OC respectively. The hydraulic retention time was reduced from 5 to 2 days, and then increased to 4 days to determine the organic loading rate. After 28 days of experiment, the COD removal efficiency obtained was 97%, and the methane gas composition nearly reached 79%. The TSS and VSS removal efficiency also reached 99% of removal. This shows that UMAS not only can treat high strength wastewater, but also can treat low strength wastewater in a short HRT and without membrane fouling. The results obtained in this study have exposed the capability of UMAS techniques as another promising method for treating wastewater. Further works are nevertheless required to provide deeper understanding of the mechanisms involved to facilitate the development of an optimum system applicable to the industry.

Keywords: Membrane, UMAS, fouling, wastewater, methane, treatment

Introduction

Wastewater treatment is important to protect our environment from pollution temperature rising. There are many types of wastewater produced everyday in Malaysia, including POME, ice cream wastewater, sugar wastewater, sewage sludge, slaughter wastewater, brewery wastewater and etc. 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).

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 et al., 2006). 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. 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. By adding ultrasonic-device was added into the MAS system (UMAS), this is a new design that was proposed by NH Abdurahman*et.al*, (2012) in treating POME and producing methane.

Anaerobic digestion, activated sludge treatment, and trickling filtration are processes that are well established in the treatment of both sanitary and

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organic industrial wastes. They are essentially biological decomposition processes which require that bacteria feed on the organic matter of the wastes to convert it to gaseous products of assimilation (RM Candelario, FD Santiago, 1974). Over the past 25 years, anaerobic digestion processes have been developed and applied to a wide array of industrial and agricultural wastes (Speece 1996), (Ghosh 1997).Anaerobic treatment converts the wastewater organic pollutants into small amount of sludge and large amount of biogas as source of energy (Ayati, and Ganjidoust, 2006). In anaerobic digestion, these micro-organisms convert organic matter into simple end products and additional biomass following the general equation for anaerobic biological degradation (Romero, 1999):

$$\text{Organic matters + nutrients} \xrightarrow{bacteria} \text{new cells} + CH_4 + CO_2$$

Table 1 shows the comparison that had been made between 3 different reactors which is UASB, anaerobic filter, and membrane anaerobic system (MAS). Based on the three methods, Membrane Anaerobic System (MAS) had been chose to treat wastewater sugarcane, by adding ultrasonic-device in the system. This is the new proposed design by [N.H Abdurahman et al., 2012] to produce methane and to avoid membrane fouling from occur. This system, UMAS avoid and solve the membrane fouling problems.

Table 1: Comparison based on reactors of Anaerobic Digestion

Type of Reactor	Advantages	Disadvantages
UASB	• the granular sludge can be stored for many months without losing its activity (Lettinga et al., 1980 in Polprasert et al. 2001)	• lower methanogenic activity • problems related to mass transfer resistance and/or the existence of concentration gradients inside the systems
Anaerobic filter	• Capable of treating wastewaters to obtain good effluent quality with at least 70% of COD removal efficiency with methane gas composition of more than 50% (NH Abdurahman et al., 2012)	• Clogging usually occurs during the treatment process.
Membrane separation anaerobic treatment process	• High COD removal in membrane anaerobic system (MAS)	• Membrane fouling • low turbidity

Materials and methodology

Raw sugarcane wastewater will be treated by UMAS in a laboratory digester with an effective 200-litre volume. Figure 1&2 presents a schematic representation of the Ultrasonic-Membrane Anaerobic System (UMAS) which consists of a cross flow ultra-filtration membrane (CUF) apparatus, a centrifugal pump, and an anaerobic reactor. 25 KHz multi frequency ultrasonic transducers (to create high mechanical energy around the membrane to suspends the particles) connected into the MAS system. The ultrasonic frequency is 25 KHz, with 6 units of permanent transducers and bonded to the two (2) sided of the tank chamber and connected to one (1) unit of 250 Watts 25 KHz Crest's Genesis Generator. The UF membrane module had a molecular weight cut-off (MWCO) of 200,000, a tube diameter of 1.25 cm and an average pore size of 0.1 µm. The length of each tube was 30 cm. The total effective area of the four membranes was 0.048 m². The maximum operating pressure on the membrane was 55 bars at 70 ºC, and the pH ranged from 2 to 12. The reactor was composed of a heavy duty reactor with an inner diameter of 25 cm and a total height of 250 cm. The operating pressure in this study was maintained between 2 and 4

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bars by manipulating the gate valve at the retentate line after the CUF unit.

The raw waste water of sugarcane is stored inside the reactor, and then the sample was leave for 5 days for acclimation process. After 5 days, the process had been started continuously for 5 hours. The controlled parameters in this experiment are pH, pressure and volume. The volume will be maintained for 50L for every process that runs. After 5 hours, the amount of COD, BOD, TSS, VSS, and VFA were determined from permeate and treated. The process will be run for 12 times to compare the value of all the parameters stated.

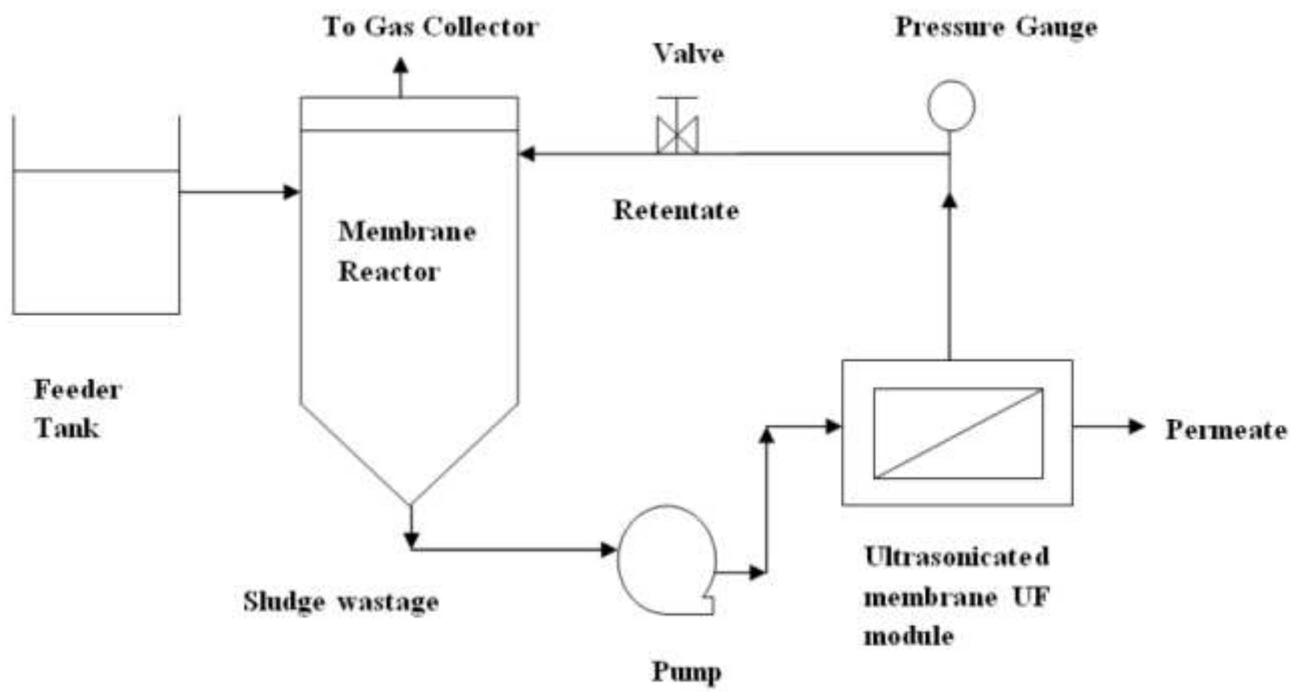

Figure 1: Experimental Set-up

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Figure 2: Schematic for Ultrasonic Membrane Anaerobic System (UMAS)

Sugarcane wastewater

The waste water of sugarcane has been collected at Chuping Perlis for about 75 Litres. The samples were collected from the pond before the effluents enters the treatment process. During collecting the samples, the temperature recorded is 36ºC. The samples were filtered using sieve, and stored in a cold room at 4^0C prior to use. Samples analysed for chemical oxygen demand (COD), total suspended solids (TSS), pH, volatile suspended solids (VSS), and Volatile Fatty Acid (VFA).

Results and discussion

As soon as the reactor had been loaded with 50L of sugarcane wastewater, the reactor was fully covered with aluminium foil to avoid sunlight from entering the reactor, with the hydraulic retention time (HRT) of 5 days, and organic loading rate (OLR) of 0.5 g COD/l.d. After 4 weeks of experiment, with approximately the same loading rate, steady-state removal efficiency was obtained. During the experiment, the pressure, pH, and temperature were kept constant with 1.5 bar, 7.0-7.6, and 32ºC respectively. Although during the 4th week the pH was slightly decreased, still there were no negative effects on the production of methane gas.

COD and BOD Removal Activity

The initial value of COD for the sugarcane wastewater was measured, with the value of 1984mg/L. After 5 days of acclimation process, the reactor was run for 5 hours continuously, and the reactor had a COD removal efficiency of approximately 30% for the first experiment. The COD removal efficiency reached approximately 80% after the reactor had been run for the 4th time, which was at day 13th. The result can be seen clearly in Figure 3, where the value of COD decreased linearly with the number of experiments run. At the end of the experiment on day 28, the COD removal efficiency reached 97% for both reacted and permeate samples (refer Figure 4). This result was higher than the 86% COD removal obtained by the sugarcane wastewater treatment by using UASB reactor that was reported by (SE Nayono, 2012). Figures 3 and 4 show that the

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reactor eventually achieved a consistent lowering of effluent COD and increase in COD reduction. U.S Hampannavar, C.B Shivayogimath (2010) stated that although the COD removal efficiency varied marginally as the organic loading increased, the COD removal rate continued to increase. There was a large increase in the COD removal efficiency from day 9 to day 15 where the percentage increased for about 30%. Based on (C.Carol, 1991), this is due to unacclimatized of the effluent that consist mostly aerobic bacteria, and therefore it needed time to adapt with anaerobic conditions on the reactor environment before it contained a large enough anaerobic bacteria population to break down the influent COD.

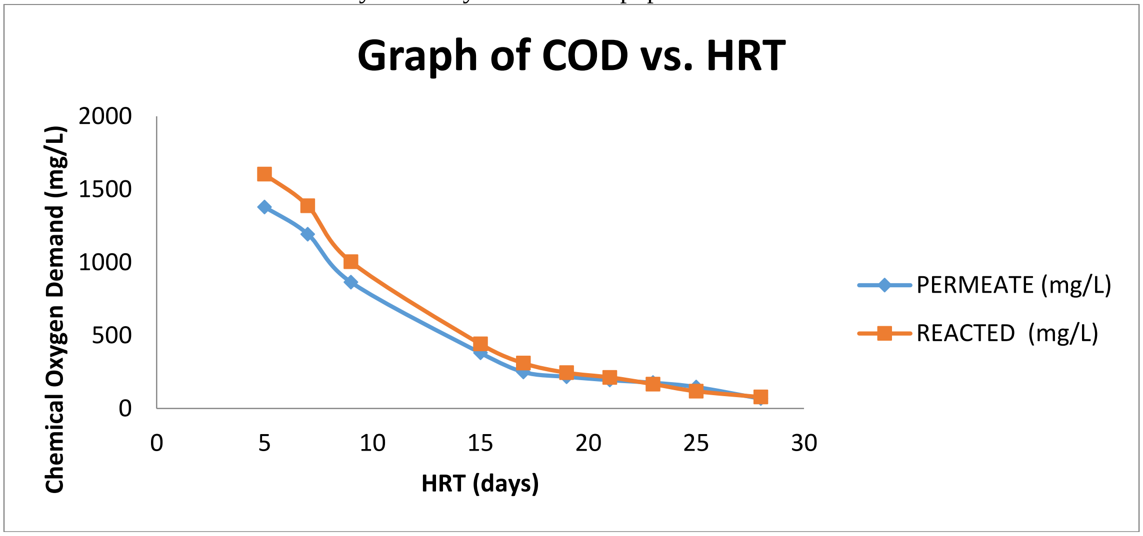

Figure 3: Graph of COD versus HRT

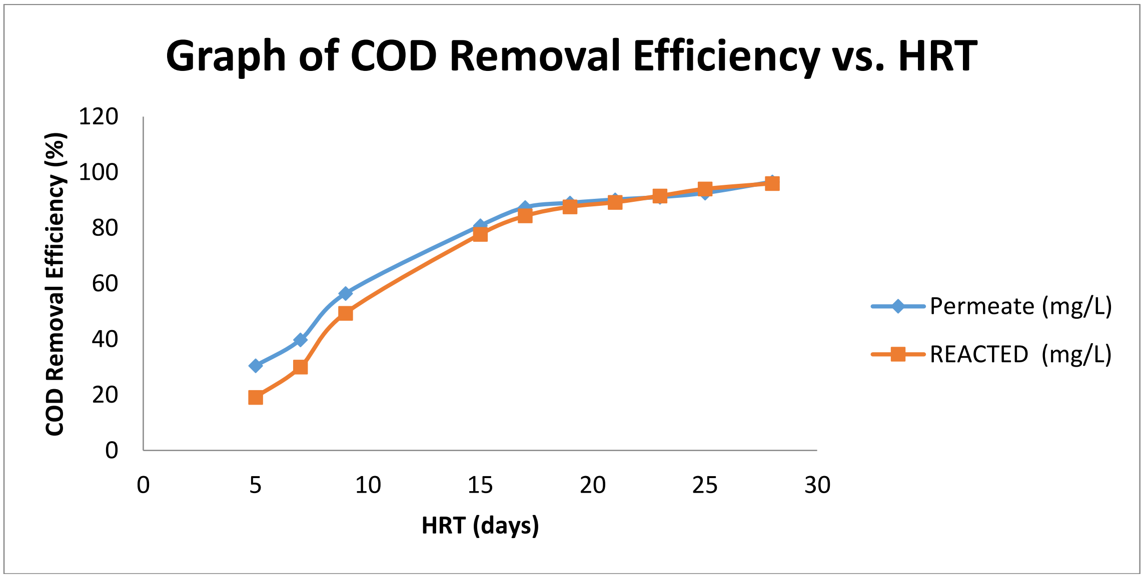

Figure 4: Graph of the COD Removal Efficiency vs. HRT

From Figure 5, it shows that the amount of BOD decreased as the increase of the reactor runs for the treatment of wastewater sugarcane. The initial BOD calculated for the wastewater sugarcane is 556.8 mg/L, and for the first experiment the BOD removal efficiency reached approximately 40%, for both permeate and reactor sample. At the end of the experiment, a total of approximately 97% of BOD removal efficiency was obtained.

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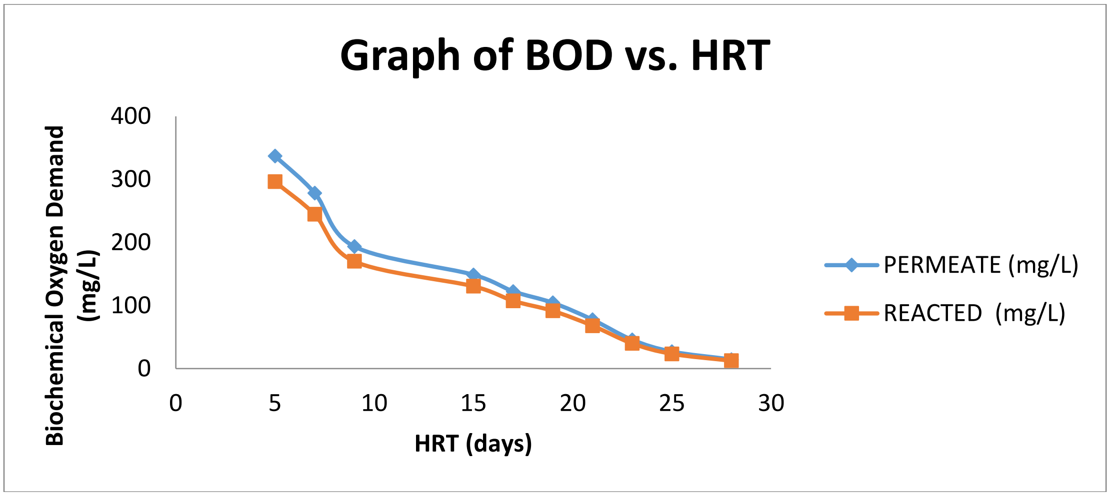

Figure 5: Graph of BOD versus HRT

TSS and VSS Removal Activity

The data for TSS for the reacted is decrease rapidly during the 3rd experiment. Figure 6 and 7 shows the value of TSS and VSS obtained for both samples respectively. This shows that the concentrations of TSS were decrease, as stated by (S.Murphy, 2007) high concentrations of suspended solids can decrease the dissolve oxygen and increase the surface temperature. Lower TSS and VSS value shows that the wastewater sugarcane had been suitable treated by UMAS. Information about the solid levels in the effluent is useful in that it gives an indication about the amount of sludge being washed out of the reactors, since volatile suspended solids levels are usually taken to mean the amount of biomass in the sample (C.Carol, 1991). From both graphs of TSS and VSS, overall, the values tend to decrease for both permeate and reacted, with periodic increases. The reacted one had larger reductions in effluents for both TSS and VSS. As reported by (C.Carol, 1991), this happens due to the reacted is denser than permeate. The reacted TSS and VSS level at the beginning of the experiment is extremely high compared to permeate. This shows that the reacted one had experienced considerable sludge loss compared to permeate.

Several factors are recognized to determine the amount of solids leaving the filter. A gradual accumulation of solids is usually observed in the anaerobic filter during which the effluent suspended solids remained low (P.Y.C Alice, 1982). It is only after the filter has reached its maximum storage capacity would the effluent solids show an increase (Chain, 1976).

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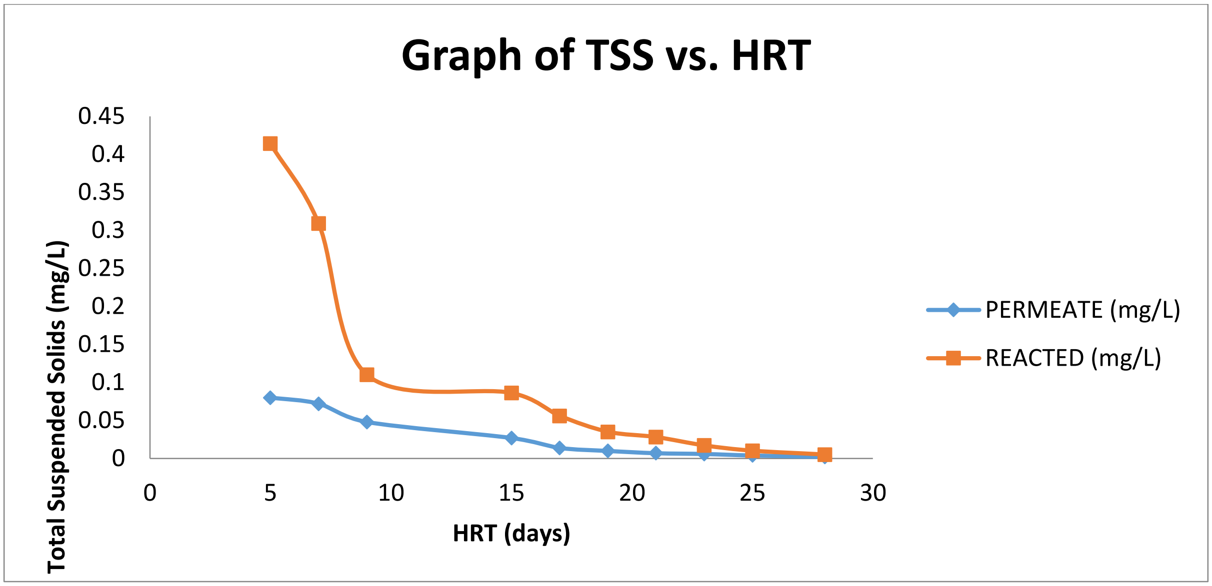

Figure 6: Graph of TSS versus HRT

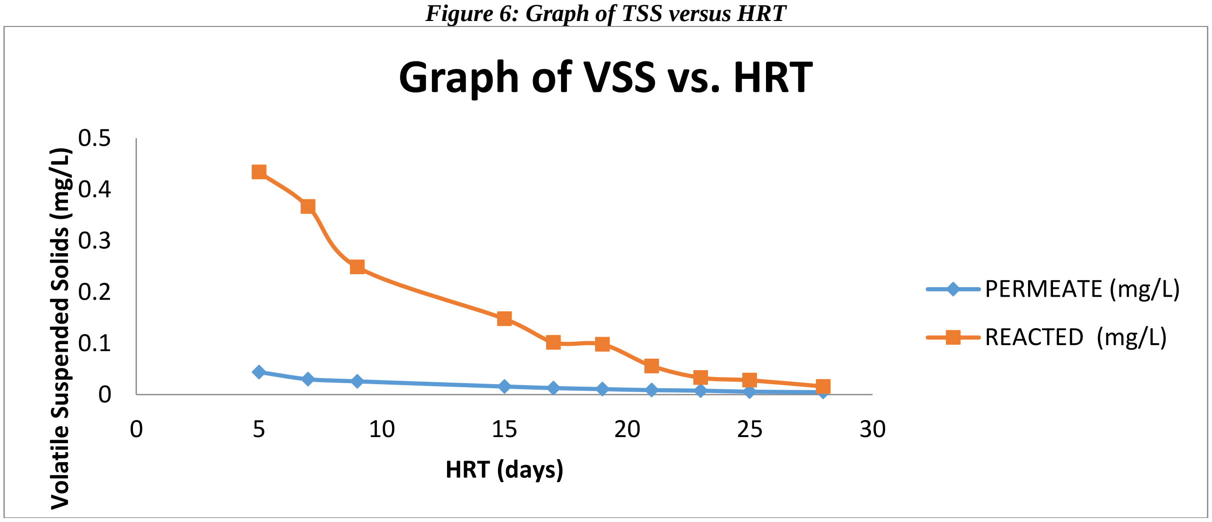

Figure 7: Graph of TSS versus the number of experiment

L.Korsak (2008) stated that the TSS is the portion of total solid retained by the filter and VSS is the volatile fraction of TSS after ignition, and VSS is commonly used as an indicator of the amount of biomass present in the sample. From Figure 8, on day 5, the percentage of TSS removal for permeates reached almost 87%, while for the reactor sample reached only for about 30% removal. R.M Candelario, F.D Santiago, and A.P Andrade (1974) stated that the larger increase in acidity during digestion of wastewater corresponds to a larger increase in the amount of suspended solids which disappears through biochemical decomposition processes. The total percentage of TSS removal reached almost 100% at the end of the experiment on

day 28. From Figure 9, it shows that permeates samples reached 99% of removal efficiencies, while 97% removal efficiencies for the reactor samples. C.Carol (1991) stated that usually the volatile suspended solids level in influent and effluent were quite low, often below 100 mg/L. This statement varies with the results obtained in this experiment, where the value of VSS is only 0.044 mg/L for permeate and 0.434 mg/L for reactor sample.

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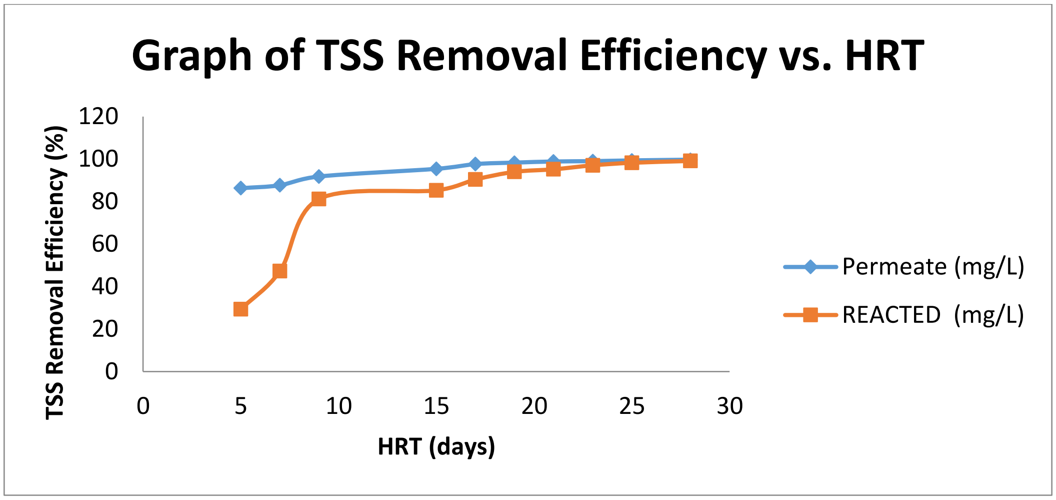

Figure 8: Graph of the TSS Removal Efficiency vs. HRT

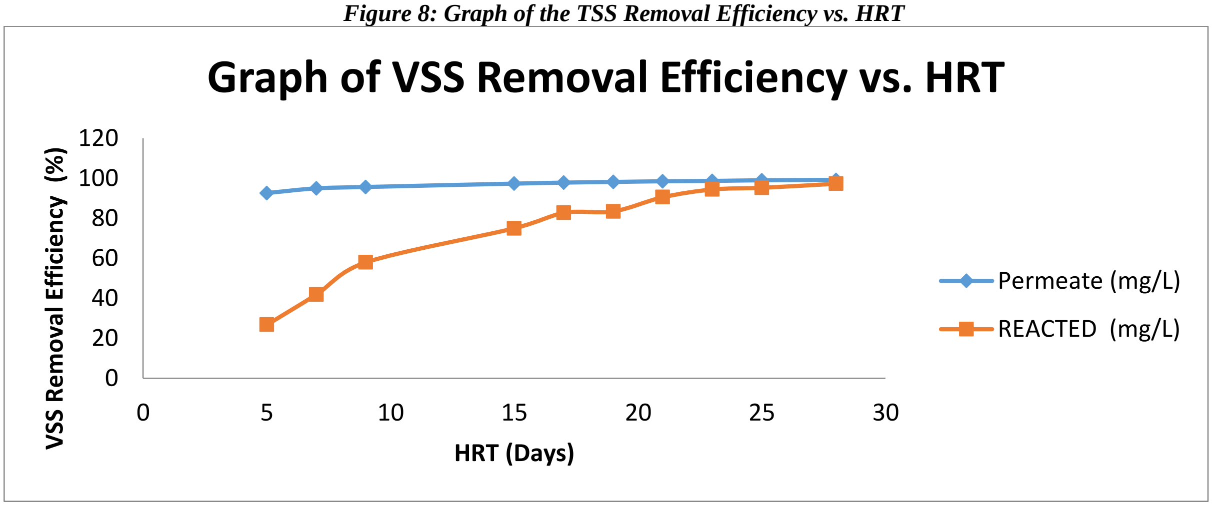

Figure 9: Graph of VSS Removal Efficiency vs. HRT

Gas Methane Collection Data

For the stability of the anaerobic reactor, it is important to determine the composition of methane gas inside the reactor. Figure 10 shows that the increase in the percentage of methane composition within 14 days of experiment, as the COD reductions increased. The first gas collection reading was collected after 11 days of running the experiment, and the data collected is quite successful as the composition of methane gas reached approximately 71% at the short period of time. Then the data is continuously collected for 5 readings, and for the final reading for the composition of methane gas, which is at day 28, the value nearly reached 80%. The collection is high compared to the experiment reported by (P.Y.C Alice, 1982) that treated low strength wastewater, only little amount of methane gas was collected during the experiment which is 6.5%, with the remainder is nitrogen gas. This happens due to the loss of methane gas during the collection period. This shows that UMAS can treat low strength wastewater very well as it can produce approximately 80% of methane gas after 28 days of experiment, within a short period of time without membrane fouling. But, within the 5 readings of the gas composition, the reading is only slightly increased. This is due to fatty acid as the pH deviates a little 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 *et al.*, 2012). The increase of fatty acid will cause more production of carbon dioxide (CO_2), and will decrease the production of methane gas (CH_4). Thus it is very

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important to maintain the pH value in order to reduce the CO_2 formation inside the reactor.

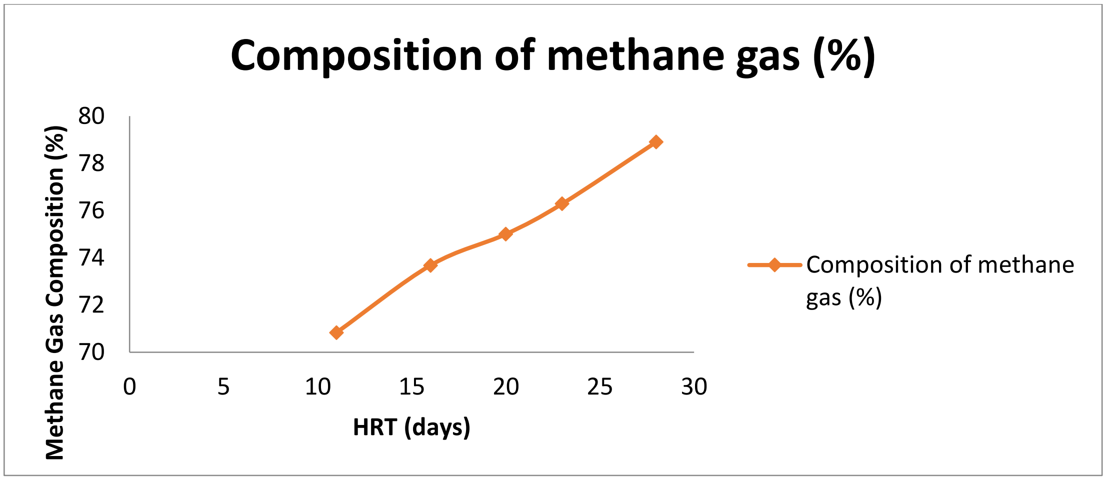

Figure 10: Graph of the composition of methane gas

Conclusions

Ultrasonic membrane anaerobic system, UMAS was found to be a successful biological treatment that achieved high COD (97 %) removal efficiency in a short period of time. UMAS reduced the retention time from 60 days to 28 days. The system avoids fouling of membrane via intermittent ultrasonic application. Hence the plant size can be reduced, eg. from 50X20 m to 10x5 m. The methane gas production reached 78%.

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