BIOMETHANATION OF SUGARCANE WASTEWATER BYULTRASONIC MEMBRANE ANAEROBIC SYSTEM (UMAS)

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ABSTRACT

The five largest countries that produced 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 2013 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 32^{O}C respectively.After 28 days of experiments , 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 shows that 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.

ABSTRAK

Lima Negara terbesar yang menghasilkan gula daripada tebu pada tahun 2011 adalah Brazil,Thailand, India, Kesatuan Eropah,dan China.Permintaan terhadap gula pada masa kini meningkat saban tahun. Dengan pengeluaran gula yang semakin meningkat, air sisa tebu juga meningkat dan secara tidak langsung menyebabkan banyak pencemaran. Oleh itu, air sisa tebu dirawat untuk menghasilkan metana dengan menggunakan kaedah pencernaanan aerobik. Tetapi, masalah yang berlaku semasa proses rawatan adalah pengotoran membran. Membran yang tidak bersih boleh menyebabkan penurunan fluks yang boleh member kesan kepada kualiti air yang dihasilkan, dan kos untukmembersihkan membrane adalah mahal. Oleh itu, system ultrasonic membranan aerobik (UMAS) digunakan sebagai alternative untuk mengatasi masalahini. Air sisa tebu dibiarkan selama 5 hari sebelum menghidupkan reaktor. Nilai mentah COD yang dicatatkan adalah 2013 mg / L; BOD adalah 2480,35 mg / L, TSS 1,976 mg / L, dan VSS 1,331 mg / L. PH, tekanan, dan suhu telah dimalarkan dalam eksperimen ini dengan nilai antara 6.5-7.5, 1.5-2.0 bar, dan 32 °C .Selepas 28 hari bereksperimen, kecekapan penyingkiran COD yang diperolehi ialah 95%, kecekapan penyingkiran BOD adalah 97% dan komposisi gas metana yang diperolehi ialah kira-kira 75% . Kecekapan penyingkiran TSS dan VSS juga mencapai 99%.. Berdasarkan data yang diperoleh selepas 28 hari bereksperimen menunjukkan bahawa UMAS bukan sahaja boleh merawat air sisa kekuatan yang tinggi, tetapi juga boleh merawat air sisa kekuatan rendah, mengelak daripada berlakunya pengotoran membran dan menghasilkan gas metana daripada air sisa tebu. Walaubagaimanapun, penambahbaikan diperlukan untuk member pemahaman yang lebih mendalam terhadap mekanisme yang terlibat bagi memudahkan pembangunan sistem optimum yang sesuai dengan industri.

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LIST OF ABBREVIATIONS

AD	Anaerobic Digestion
BOD	Biochemical Oxygen Demand
CH_4	Methane
CO_2	Carbon Dioxide
COD	Chemical Oxygen Demand
CUF	Cross Flow Ultrafiltration Membrane
DO	Dissolved Oxygen
DOE	Department of Environment
FBR	Fixed Bed Reactor
GAC	Granular Activated Carbon
HR	High Range
HRT	Hydraulic Retention Time
KOH	Potassium Hydroxide
LNG	Liquified Natural Gas
MAS	Membrane Anaerobic System
MBR	Membrane Bioreactor
MF	Microfiltration
MLSS	Mixed Liquor Suspended Solids
NF	Nanofiltration
OLR	Organic Loading Rate
PAO	Polyalphaolefins
PHA	Polyhydroxylalkanoates
POME	Palm Oil Mill Effluent
RO	Reverse Osmosis
SBR	Sequencing Batch Reactor
SS	Suspended Solids
TDS	Total Dissolved Solids
TSS	Total Suspended Solids
UASB	Upflow Anaerobic Sludge Blanket
UF	Ultrafiltration
UMAS	Ultrasonic Membrane Anaerobic System
VFA	Volatile Fatty Acid
VSS	Volatile Suspended Solids

1 INTRODUCTION

1.1 Research Background

Wastewater treatment is important to protect our environment from pollution and temperature rising. There are many types of wastewater produced everyday in Malaysia, including POME, sugar wastewater, sewage sludge, slaughter wastewater, brewery wastewater and etc. Before treatment processes, the value of chemical oxygen demand (COD) and biochemical oxygen demand (BOD) of each wastewater will be examined and compare it with Standard A and Standard B in Department Of the Environment (DOE). If the value of COD and BOD exceed the value from Standard A and Standard B, then treatment is compulsory. Usually, wastewater treatment plants require large area and sophisticated treatment processes, and the operational cost for treatment plant will be extremely high.

The production of sugar is increasing every year in Malaysia. Sugarcane is important for the production of sugarcane and also used as a seed for subsequent plantation. In Malaysia, sugarcane are produced widely at Chuping, Perlis for the production of sugar. But, the sugarcane plantation has been stopped in 2011 and replaced with palm oil tree plantation. Still, the production of sugar runs in Malaysia, but the sugarcane are imported from other countries such as Thailand and Brazil. Rapid deterioration begins when the cane is cut; Sugarcane cannot be stored for later processing without excessive deterioration of the sucrose content (Panda, Tapobrata, 2011)Then, the juice was extracted from the cane, by crushing methods. The crushed sugarcane will be transported through conveyor to the next mill. Next ,the evaporation process take 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,was the major environmental problem which sugar industry faced. This will cause pollution to the environment and temperature level of surroundings will increased. The solution to this problem is by converting the waste by 'waste-to-wealth' method. The waste of sugarcane can produce methane and fuel which can be a source of energy.This eventually will increase the production of methane from the waste sugarcane as methane is the largest source for natural gas and Liquefied Natural Gas (LNG). It is alsoan important aspect for electrical generation by burning it as a fuel in a gas turbine or steam boiler. Renewable Fuel Association stated that at the turn of the 20^{th} Century, energy supply crunches and price spikes focused attention on the need for industrial process improvement and development of alternative energy sources such as ethanol fuel. Besides, the waste sugarcane is a renewable resource. Some of the sugar cane mill effluent can be used for irrigation. 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)Generally, the waste sugarcane will be stored prior for further processing. It is stored under moist condition for electricity production, and for paper and pulp production, it is normally stored wet in order to assist in removal of the short pith fibres, which impede the papermaking process, as well as to remove any remaining sugar.

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. Table 1 shows the comparison of three treatment type between anaerobic and alternative treatment methods.

Table 1 : Advantages and disadvantages between three treatment methods.

Treatment types	Advantages	Disadvantages	Reference
Membrane	Require less energy, only need small space for treatment plants, do not involve phase change.	Membrane fouling, short membrane life, expensive and difficult to handle.	(Mulder, 1996)
Anaerobic	Consume low energy, no aeration, reduces the emission of landfill gas into the atmosphere. Producing methane gas. Lower capital cost.	Large area required for conventional digesters, has significant capital and operational costs.	(AFBI Northern Ireland Audit Office, 2013) (Borja, R, & Banks, C. J., 1995b)
Aerobic	Easy to control, easy start up, few odours are experienced if properly designed and operated.	Does not produce methane gas, high energy requirement.	(Hill, 2012)

Based on the above comparison, 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.(Cote, 2006)

1.2 Problem Statement

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. 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. To overcome this problem, membrane replacement or chemical cleaning method can be used, but these will increase the operating costs of a treatment plant. Therefore, another economic solution to overcome this problem is by adding ultrasonicated-device into the MAS system. This is a new design that was proposed by NH Abdurahman*et.al*,(Abdulrahman, 2014)in treating POME and producing methane. Still there are few things that have to be upgrade to improve the Ultrasonic Membrane Anaerobic System to produce methane gas.

1.3 Research Objective

The objective of this research are to study the performance of Ultrasonic membrane anaerobic system (UMAS) in treating sugarcane wastewater and 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.

1.4 Scope Of Study

There are four scopes of this research which are;

1.4.1 To design a laboratory scaled ultrasonic membrane anaerobic system (UMAS) with an effective 100 litre volume to treat raw sugar cane wastewater

1.4.2 To monitor parameters such as Biochemical Oxygen Demand, Chemical Oxygen Demand, Total Suspended Solid, Volatile Suspended Solid, and pH

1.4.3 To study the effect of organic loading rate (OLR) in the performance of UMAS

1.4.4 To determine the amount of methane gas produced by the volume of permeates.

1.5 Significance Of Study

Rationally, this research can produce another environmentally friendly method which is the ultrasonicated membrane anaerobic system to treat the sugar cane wastewater before releasing it to the environment. It's also considered an alternative and cost effective method to the conventional methods for wastewater treatment. In addition, this UMAS system can capture the methane gas (CH_4) as a final product which can be consider as a green technology.

2 LITERATURE REVIEW

2.1 Aerobic Activated Sludge

Aerobic activated sludge and tertiary nutrient removal processes are the current mainstream technologies for wastewater treatment. But, both of these processes seems to be based on high capital cost, which consume more energy, more skilled labour requirement, produce more sludge, and do not allow recovery of valuable energy and nutrients (Nayono, 2005). Both of the methods are not economically and technologically affordable for developing countries like Malaysia, as the permanent energy supply and thê availability of high skilled personal are not guaranteed.

The combination of anaerobic high intensity reactors of new generation with granular sludge with aerobic reactors of various modifications by SK Nicholay, produced a high intensity of high-loaded wastewater processing,compactness of treatment facilities and economy of resources & energy at the anaerobic treatment stage. As the bioavailability of organic pollution increases, the amount of excess activated sludge dereases for the aerobic stage , but it could not reach the standards of wastewater treatments even after combining with both aerobic and anaerobic methods.N Abdullah et al. stated that the effluent quality by using sequencing batch reactor (SBR) was unsatisfactory , but the COD removal efficiency reached 91.1% for the treatment of POME , and stable aerobic granular sludge was achieved in the experiment. (Abdullah, 2011)

Sheikh AR, Muller EE and Wilmes P,2014 stated that PAOs assimilate organic carbon substrate e.g , volatile fatty acid is stored as polyhydroxyalkanoates (PHA) during anaerobic treatment (Kong KY, 2014) , while when exposed to aerobic conditions,PAOs oxidized PHAs , which provides energy for polyphosphate accumulation , leading to PHA removal from the wastewater by biomass retrieval. (Abdul R Sheik, 2014)

2.2 Anaerobic Digestion

Anaerobic digestion, activated sludge treatment, and trickling filtration are processes that are well established in the treatment of both sanitary and organic industrial wastes. They are essentially biological decomposition processes which requires bacteria feed on the organic matter of the wastes to convert it to gaseous products of assimilation (R.M. Candelario, F.D. Santiago and A.P. Andrade, 1974).Over the past 25 years, anaerobic digestion processes have been developed and applied to a wide array of industrial and agricultural wastes (RE, Speece, 1988),.Anaerobic treatment converts the wastewater organic pollutants into small amount of sludge and large amount of biogas as source ôf energy(Ayati, 2006). In trickling filtration, there is no filtering action involved. The thickness of the slime layer increases and prevents the oxygen from penetrating the full depth of slime layer in trickling filtration. Therefore, with the absence of oxygen, anaerobic decomposition will be active near the surface of the media. This cycle is continuously repeated throughout the operation of a trickling filter. Clogging could happens while the distribution processes runs, therefore to prevent it from happening and with economy control, trickling filters should be preceded by primary sedimentation tanks equipped with scum collecting devices.

In Anaerobic digestion, the methane and acid forming microorganisms differ widely in terms of physiology , growth kinetics , nutritional needs, amd sensitivity to environmental conditions (Fox, 1994)). If it fails to maintain the balance between these two groups of microorganisms , it will make the primary cause of reactor instability (Yenigün, 2002). Inhibitory substances are always found to be the main cause of anaerobic reactor failure since it present in substantial concentrations in wastewater and sludges , and there is a wide variety of substances that been reported to be inhibitory to the anaerobic digestion processes (Chen Y., 2008). Anaerobic reactors for wastewater treatment have been used since more than 2000 years ago in the form of Indian and Chinese animal manure digesters (S, Veenstra, 2000)The application of anaerobic process for industrial and municipal wastewater treatment has been considered as a practical and an economical alternative to aerobic wastewater treatment (Hickey RF, 1991)In anaerobic digestion, these micro-organisms convert organic matter into simple end products and additional biomass following the general equation for anaerobic biological degradation (JA, Romero, 1999)

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

The first group of organisms of anaerobic digestion is hydrolytic fermentative (acidogenic) bacteria. These bacteria hydrolyse the complex polymers to organic acids, alcohols, sugar, hydrogen, and carbon dioxide. The second group converts the fermentation products of the previous step into acetate and carbon dioxide; the microbial community involved in this process are hydrogen producing and acetogenic organisms. The third group is the methanogens, they convert simple compounds (acetic acid, methanol, and carbon dioxide plus hydrogen) into methane (Hutnan M., 1999)

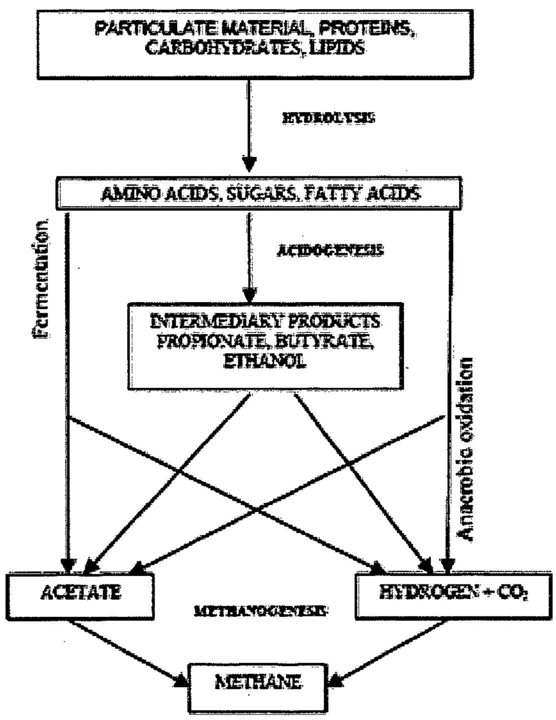

Figure 2-1 : Schematic Diagram of carbon flow conversion in anaerobic digesters (Hutnan M., 1999)

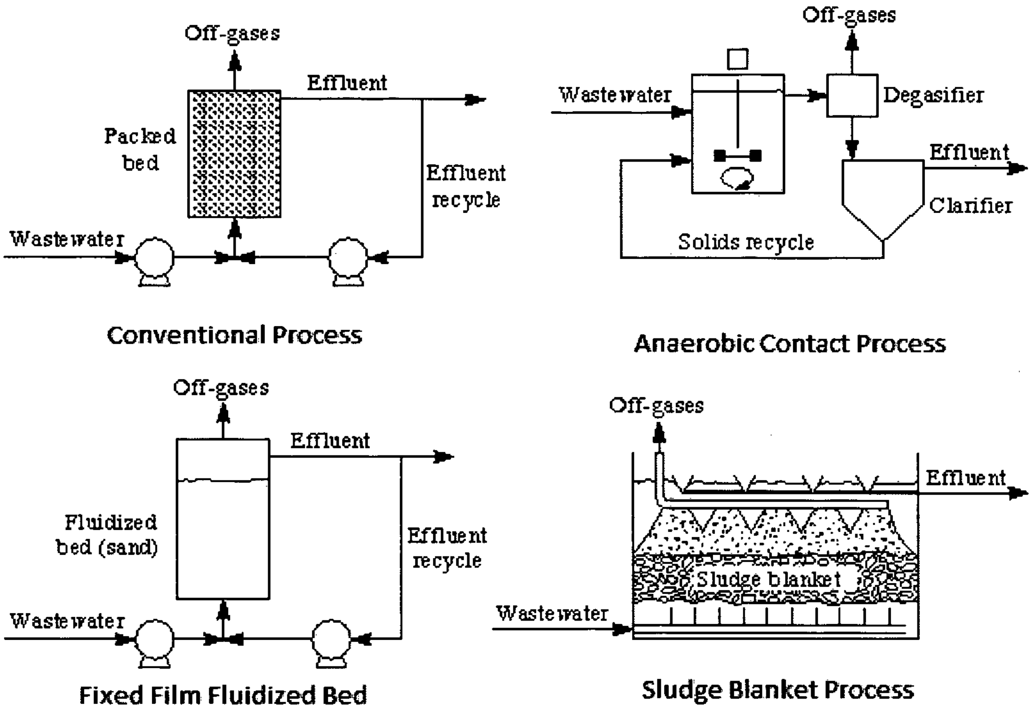

Figure 2-2 : Various Anaerobic Treatment Processes

Considering the kinetics, microbiology and modelling aspects, (J., Iza, 1991) suggested that the concept of high-rate anaerobic reactors is based on three fundamental aspects, based on (Nayono, 2005) :

(i). Accumulation of biomass within the reactor. Since the growth of microorganisms is very slow, the efficient operation of high rate anaerobic treatment is determined by the ability to retain biomass concentration within the reactor by effective separation of the biomass from the liquid. This aspect can be reached by means of settling or attachment to support media or by re-circulation.

(ii). Improving contact between wastewater and biomass. This aspect overcomes the problems of substrates and products from the bulk liquid to the biomass (bio films or granules). It can be reached by proper mixing within the reactor (e.g.: contact process reactor), eventually distribute the effluent and avoid short-circuit (e.g.: anaerobic filter reactor, UASB, and fixed bed reactor) or provide sufficient reactor height in order to achieve proper distribution of effluent (e.g.: down flow stationary fixed film reactor).

(iii). Enhancing the activity of the biomass, due to adaptation and growth. Since anaerobic process is performed by a number of bacterial tropics groups, it is necessary to characterize the population dynamics and activity of these different groups.

Based on (R.M. Candelario, F.D. Santiago and A.P. Andrade, 1974),from a kinetic viewpoint, anaerobic treatment may be described as three-step process involving:

a) The hydrolysis of complex organic substances. Complex organics are converted to less complex organic materials by enzymatic hydrolysis.
b) The production of acids. The hydrolysis products are fermented to simple organic compounds, predominantly volatile fatty acids, by the so called 'acid forming bacteria'.
c) The fermentation of organic acids into gaseous products, mainly methane and carbon dioxide. The simple organic compounds are fermented to methane and carbon dioxide by a group of strictly anaerobic bacteria called the 'methane formers'.

Y.Chen et al. stated that problems such as low methane yield and process instability are always encountere in anaerobic digestion , preventing this technique from being widely applied (Chen Y., 2008). A large variety of inhibitory substances are the primary cause of anaerobic digester failure since it present in substantial concentrations in wastes . To remove or counteract toxicants before anaerobic digestion can significantly improve the waste treatment efficiencies. , co-digestion with other wastes , adaptation of microorganisms to inhibitory substances , and incorporation of methods can be applied . Compared to mesophilicdigestion , the thermophilic anaerobic digestion has additional benefits which includes high degree of wastes stabilization, more thorough destruction of viral and bacterial pathogens , and improve post-treatment sludge dewatering (Lo, 2010) . However ,Dupla et al. stated that poor operational stability still prevents anaerobic digestion from being widely commercialized (Dupla, 2004) .

2.3 Previous Work On Anaerobic Treatment Methods

2.3.1 Fluidized Bed Reactor

Fluidize bed reactor can be used to carry out a variety of multiphase chemical reactions, and it exhibits several advantages that make it useful for treatment of high-strength wastewaters (N.H. Abdurahman, 2012).Hickey and Switzenbaum (1991) reported on the development of the anaerobic expanded bed process, which was found to convert dilute organic wastes to methane at low temperatures and at high organic and hydraulic loading rates. (Hickey RF, 1991)

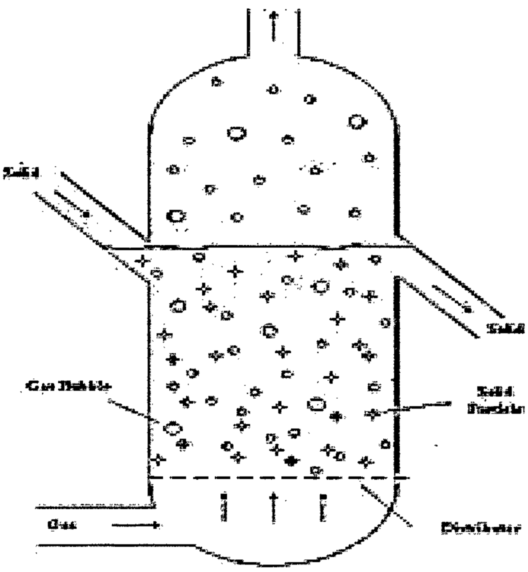

Figure 2-3 : General Design for Fluidized Bed Reactor

Sen S and Demirer GN had done research on anaerobic treatment of real textile wastewater with a fluidized bed reactor (FBR). During the operation period, real cotton textile wastewater was fed to the anaerobic FBR. To achieve the maximum colour removal efficiency in the reactor, the effect of operational conditions was investigated. Based on the results obtained, it shows that anaerobic treatment for textile wastewater was possible as the amount of corresponding maximum COD, BOD, and colour removals were found to be around 82%, 94% and 59%, respectively. But, by increasing the external carbon source to be added into the real textile wastewater, the colour removal efficiency of the anaerobic FBR reactor will not increase. (Sen S , Demirer GN, 2003)

John S. Jeris reported that wastes containing COD from 5,000 to 54,000 mg/ℓ, were treated with 65 to 95 percent COD removal in 0.3 to 4.9 days hydraulic detention time. An energy comparison showed anaerobic treatment to produce a positive energy balance compared to an energy need for comparable activated sludge treatment. (Jeris, 1983)

By using fluidized bed reactor, there are different COD removal efficiencies with every different types of waste. Based on POME waste water treatment, (Borja, R, & Banks, C. J., 1995b)reported that the COD removal efficiency is 78% to 94%. (Hawkes, 1995)found that fluidized bed using granular activated carbon (GAC) gave about 60% COD removal. This shows that only suitable support material can be used using fluidized bed reactor to obtain high COD removal efficiency in the system.

2.3.2 Up-Flow Anaerobic Sludge Blanket (UASB) Reactor

SE Nayono had been conducted on anaerobic treatment of waste water sugar cane recently by using Up-flow Anaerobic Sludge Blanket (UASB) reactor. The reactor was water jacketed and operated at constant temperature of 37°C. Figure 1 shows the schematic diagram of UASB reactor.

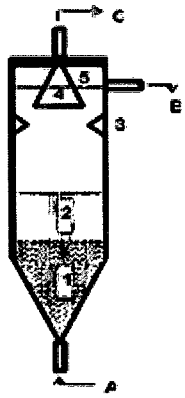

Figure 2-4 : Typical cross section of a UASB reactor

Source: (Nayono, 2005)

On the 18th week of operation, the reactor experienced a failure at the thermostat due to twisting of warm jacket tube. This failure causes a temperature drop from 32°C to about 24°C. This effects the COD efficiency removal. The COD removal efficiency was also hindered when the temperature suddenly dropped. It took 5 weeks to reach 80% of COD removal efficiency. This temperature decrease occurred when the operation of the reactor was considered as not yet stable after increment of its organic loading rate (COD removal efficiency has not yet reached80 % and residual fatty acids concentration in the effluent were more than 10mg/L). The combination of both conditions caused the COD removal efficiency of the reactor dropped from 73 % to 59 % (Nayono, 2005)

Hampannavar and Shivayogimath conducted the experiment of anaerobic treatment on waste water of sugarcane industry, using UASB reactor. It is reported that the maximum COD removal efficiency of 89.4% was achieved. The COD rate linearly increases with the increase of OLR. The ratio of VFA to alkalinity is varied between 0.19-0.33 during the treatment. The methane content in the biogas was found to be between 73% and 82% at steady state conditions. This shows that anaerobic treatment is feasible in treating waste water of sugar industry. (Hampannavar, 2010)

Carol Cronin had conduct a research on anaerobic treatment of brewery waste water using a UASB reactor seeded with activated sludge (Cronin, 1991). Two UASB reactors were set up at the temperature range between 19^0C to 23^0C. The average sludge loading rate was different for both reactors since each was seeded with a different amount of sludge. Reactor B was seeded with 5.93 g VSS/l, while Reactor A was seeded with 1.98 g VSS/l, so that the sludge loading rate of Reactor A was about three times more than Reactor B. The methane composition content from both reactors increased as the hydraulic retention time was reduced. Hickey et al., reported that brewery wastewater treated at an operating temperature of 19 – 23 ^{0}C inoculated with digested sewage sludge and activated sludge took 12 months to achieve the 90% of efficiency COD removal (Hickey RF, 1991). The lower methanogenic activity of this sludge caused the methane biogas content on both reactors low (Cronin, 1991)

T.A. Elmitwalli, M. Shalabi, C. Wendland and R. Otterpohl (2007) have made a research on grey water treatment in UASB reactor at ambient temperature. The batchrecirculation experiments showed that a maximum total-COD removal of 79% can be obtained in grey-watertreatment in the UASB reactor. In the first phase, at the lowest temperature of 18^0C, the reactor has the lowest COD removal. For the second phase, the UASB reactor had the highest total-COD removal of41%, because the reactor was operated in summer period at an average wastewatertemperature of 23^0C. When the hydraulic retention time decreased to 8 hours at 20^0C at the third phase, the total COD removal decreased to 31%. Based on the result obtained, the removal of colloidal COD depended on the wastewater temperature, while the removal ofsuspended and dissolved COD depended on the wastewater temperature and the hydraulic retention time ofthe UASB reactor. (Tarek A.Elmitwalli , Ralf Otterpohl, 2007)

For the stillage treatment from sugarcane , the thermophilic AFBR reactors were inoculated with a granular sludge of a thermophilicupflow anaerobic sludge blanket reactor (UASB) , and used for the treatment for biogas production (CH_4) (Silvia Helena Zacarias Sylvestre, 2014). It shows that the system is less rone to be contaminated with methanogenic bacteria at higher temperature (van Groenestijn, 2002)

The conventional UASB reactor concept showed severe limitations, mainly owing to problems related to mass transfer resistance and/or the existence of concentration gradients inside the systems. If the biogas production rate drops, e.g. for low-strength or cold wastewater, the degree of mixing must be raised hydraulically to ensure the required mass transfer (Van Lier J.B., 2001)

2.3.3 Anaerobic Filtration

The anaerobic filter process was first developed by (Coulter, 1957) but was virtually forgotten until 1964 when (McCarty, 1964)renewed interest by demonstrating the process's ability to treat a medium to high strength carbohydrate/protein wastewater (Stenstrom, 1982)

An experiment was conducted using anaerobic filtration. The anaerobic filtration was seeded by 30 gallons of sludge from apilot scale 50-gallon digester. During the entire experiment, the anaerobic filter was effective in treating the oxygen demanding forms of nitrogen and sulphides produced during anaerobic fermentation. A total of 5971.9 gm of COD was removed, resulting in an apparent yield of 0.0019 gm VSS/gm COD removed. The values reported by (Chain, 1977) were 0.012 gm and 0.015 gm VSS/gm COD for fatty acid waste respectively (Stenstrom, 1982)The value in this experiment calculated is relatively low due to the sludge could only be partially drained. If the accumulation of the biological solids onto the plastic media were also measured, a higher yield would also be obtained. From this experiment, it concludes that the low production of biogas methane is due to two factors; low organic loading rates, and a few amounts of methane are loss through the effluent even though methane gas are considered as insoluble.Figure below shows a few factors influencing filtration in membrane bioreactor.

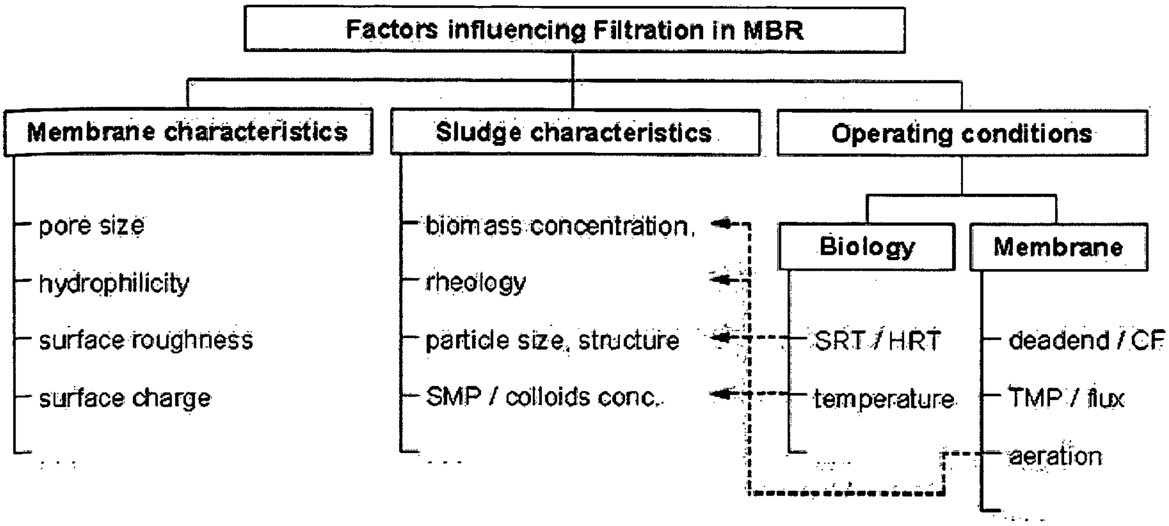

Figure 2-5 : Factors influencing Filtration in MBR

Anaerobic filters are 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% (N.H. Abdurahman, 2012). But, clogging of anaerobic filter is the major disadvantage that occurs in the process (Parawira , W. Murto ,M. Zvauya , and Mattiasson, 2006) . Clogging usually occurs during the treatment process of POME (Borja, R, & Banks, C. J., 1995b)and slaughterhouse wastewater. This is due to the high organic loading rate (OLR) which had higher suspended solid content compared to the lower one. By using up flow anaerobic filter to treat POME, the overall removal efficiencies reached 90% and the filters effluents contained almost no suspended solids , and the methane production reached 60% (Borja, R, & Banks, C. J., 1995b) . Alkalinity is the most important factor controlling reliability of the anaerobic treatment of industrial effluent (Oscar Monroy, 2000)

Based on Naessens et al , to understand and optimize a complex system such as a membrane reactor (MBR) is a difficult and time consuming process (Naessens T, 2012). This is due to the large number of sub-processes took place simultaneously , which are generally highly dependent upon each other. By using membrane filtration, the biomass retention required for high rate anaerobic wastewater treatment can be reached; however , low flux seems to be common factor when operating anaerobic membrane bioreactors (H. Díaz, 2014).