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

RAGINI A/P MAHENDRAN

Thesis submitted in partial fulfilment of the requirements

for the award of the degree of

Bachelor of Chemical Engineering

Faculty of Chemical & Natural Resources Engineering

UNIVERSITI MALAYSIA PAHANG

JULY 2014

ABSTRACT

Sugarcane industry is one of the most important industries in many developing countries. However, sugarcane industry produces significant amount of wastes mainly in the form of liquid wastes. In present study, biological treatment with membrane technology and ultrasound effect was carried out to treat sugarcane wastewater. The main objective of this study is to make an overall comparison between membrane anaerobic system (MAS) and ultrasonic membrane anaerobic system (UMAS) in treating sugarcane waste. Raw sugarcane wastewater was operated in a membrane anaerobic reactor for 5 hours for 7 continuous days. After 5 hours of operation, the permeate (filtrate) from the reactor was collected and tested for BOD, COD, TSS and VSS. The gas produced was collected using designated syringe. The experiment was repeated with 10 kHz of ultrasound frequency devise attached to the membrane to investigate the effect of ultrasonic wave towards the process. From this study, for COD and BOD, MAS has achieved 86% removal efficiency and UMAS achieved 96% removal. For TSS, MAS obtained 81% removal efficiency but UMAS attained 100% removal which shows UMAS has removed all the detectable suspended solids from the wastewater. The same trend goes for VSS removal efficiency. MAS produced 1400mL of permeate and UMAS produced 2346mL of permeate. This huge difference in volume was due to the fouling which blocks the membrane pores. For biogas production, 68% and 77% of methane gas have been produced during MAS and UMAS treatments respectively. From these results, it proves that UMAS has prevented fouling and it is more proficient than MAS as it produced permeate which meet the discharge limit fixed by Malaysia Department of Environmental (DOE).

Keywords*: Sugarcane wastewater, Anaerobic Digestion, Membrane Anaerobic Reactor, Ultrasound, Methane Gas*

ABSTRAK

Industri tebu adalah salah satu industri yang penting di antara negara-negara yang sedang membangun. Namun, industri tebu menghasilkan sejumlah besar sisa terutamanya dalam bentuk sisa cecair. Dalam kajian ini, rawatan biologi bersama teknologi membran dan ultrasound telah diperlaksanakan untuk merawat sisa cecair tebu. Objektif utama kajian ini adalah untuk membuat perbandingan keseluruhan antara sistem membran anaerobik (MAS) dan sistem anaerobik membran ultrasonik (UMAS) dalam merawat sisa cecair tebu. Sisa cecair tebu mentah dirawat dalam membran anaerobik reaktor selama 5 jam untuk 7 hari berturut-turut. Selepas 5 jam operasi, air turasan dari reaktor tersebut dikumpulkan dan diuji untuk BOD, COD, TSS dan VSS. Gas yang dihasilkan pula diukur dengan menggunakan picagari yang ditetapkan. Dari kajian ini, untuk ujian COD dan BOD, MAS telah mencapai kecekapan sebanyak 86% dan UMAS pula sebanyak 97%. Untuk TSS, MAS memperolehi 81% kecekapan penyingkiran tetapi UMAS mencapai 100% penyingkiran. Ini menunjukkan UMAS telah mengeluarkan semua pepejal terampai yang boleh dikesan daripada air buangan tebu. VSS menujukkan trend yang sama seperti TSS. MAS telah menghasilkan 1400 mL air turasan dan UMAS pula menghasilkan sebanyak 2346 mL. Jumlah air turasan ini amat berbeza antara dua sistem ini berikutan masalah penyumbatan membran yang menghalang laluan meresap ke dalam membran. Untuk pengeluaran biogas, 68% dan 77% gas metana telah dihasilkan masing-masing dalam MAS dan UMAS Daripada keputusan ini, ia mengaku bahawa UMAS telah menghalang penyumbatan membran dan ia lebih mahir daripada MAS kerana ia menghasilkan air turasan yang memenuhi had pelepasan yang ditetapkan oleh Malaysia Jabatan Alam Sekitar (JAS).

Katakunci: *Sisa air tebu, rawatan anarobik, sistem anaerobik membran, ultrasound, sistem anaerobik membran ultrasonik, gas metana*

TABLE OF CONTENT

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

SYMBOL	ABBREVIATION
MAS	Membrane Anaerobic System
MBR	Membrane Bioreactor
AnMBR	Anaerobic Membrane Biorector
UMAS	Ultrasonic Membrane Anaerobic System
HRT	Hydraulic Retention Time
BOD	Biological Oxygen Demand
DO	Dissolved Oxygen
COD	Chemical Oxygen Demand
TSS	Total Suspended Solid
VSS	Volatile Suspended Solid
TDS	Total Dissolved Solid
OLR	Organic Loading Rtae
TS	Total Solid
SBR	Sequencing Batch Reactors
UASB	Upflow Anaerobic Sludge Blanket

UF	Ultrafiltration
MF	Microfiltration
CUF	Cross Flow Ultrafiltration
POME	Palm Oil Mill Effluent
PVC	Polyvinyl Chloride
MWCO	Molecular Weight Cut-Off
NAOH	Sodium Hydroxide
L	Liters
mL	Milliliters

LIST OF APPENDICES

CHAPTER 1

INTRODUCTION

1.1 Background of Study

Environmental problems gained increasing prominence in the 20^{th} century. Global population growth and advance of modern technologies raised pressure on worldwide natural resources such as air, water and land. The most promising source of environmental problem is the untreated effluent from industries. To reach the world demand, the number of companies and factories in all sectors increased rapidly. But, these industries emits unwanted by products which affects the quality of air and water if directly discharged into rivers. It also indirectly affects the health and well being of man. Lots of researches have been done on how to solve these environmental issues. But yet, it is still an unsolved problem.

In many developing countries, especially in Asia and South America, sugarcane industry is one of the most important industries. However, sugarcane industry produces significant amount of wastes. Wastes from sugarcane industries can be sorted as bagasses, solid residues from sugarcane juice extraction, stilage (vinasse or dunder) and liquid waste effluents. The liquid wastes are usually from cane wash water, floor washing and boiler blow-down, excess condenser waters and also soda and acid wastes. Due to lack of knowledge and financial status, many sugarcane industries in developing countries just release their wastewater without any treatment. Sugarcane wastewaters are released in huge amount from a factory as they use a lot of water supply for the process. A survey on 103 cane sugar factories in North India indicated an average production of 1320 L of wastewater per ton of cane with BOD_5 of 570 mg/L (Baskaran *et al.*, 1966). In other literature, it is stated that sugar mill effluent has a BOD amount of around 1500 mg/L (Solomon, 2005). These shows that sugarcane waste water really has high biodegradability and it should be treated before discharging.

The increased attention on the environmental issues and the rise of oil price, government all over the world, including Malaysia are forced to look for alternative energy. Under the 8th and 9th Malaysian Plans, renewable energy is considered as the country's fifth fuel. Nowadays, the government adopts Renewable Energy and Green Technology. On 26th Jan 2010, government launched Green Technology Financing Scheme to encourage the search for alternative energy. Sustainable and renewable energy with the green technology will be the core of economic growth for all countries. This shows Malaysia is in high demand of expertise in renewable and sustainable energy.

Methane is the main component of natural gas. It is used for generating electric by burning it in a turbine or boiler. Methane is a good source of energy compared to other hydrocarbon fuels. This is because; burning of methane produces less carbon dioxide for each unit compared to other hydrocarbons. Therefore, methane can be used as an alternative energy source. Methane is usually produced from burning of fossil fuels or partial oxidation of hydrocarbon fuels. But, these methods lead to emission of greenhouse gasses and global warming. So, production of methane from renewable sources as industrial and agricultural wastes by anaerobic digestion is not only an environmental friendly way of producing methane, but also a good way of handling those wastes.

There are few methods available to treat sugarcane wastewaters such as trickling filtration, aerobic treatments and anaerobic treatments. Among all these treatments, anaerobic treatments are well preferred because it produces useful methane gas and cheaper compared to other process. But, since there is huge amount of biomass and harmful organics matters in anaerobic systems, the chances to still have those matters in the effluent is high. To solve this conflict, membrane anaerobic system (MAS) was introduced where a membrane module of microfiltration or ultrafiltration added to the system to purify the effluent. A lot of studies have been conducted regarding MAS but it still contains some unsolved problems mainly membrane fouling. Few methods has been proposed to control membrane fouling which includes optimum operating conditions, modification of mixed liquor characteristics and membrane materials, high shear across membrane and cleaning methods (Xu *et al*., 2011). Although all these methods have been implemented, membrane fouling still has not been solved. Therefore, Wen *et al*. (2008) has come out with a new design which is using ultrasound on the membrane to reduce membrane fouling (Wen *et al*., 2008, Abdulrahman *et al*., 2014).

Thus, this present research is attempted to study the effect of using ultrasonic membrane anaerobic system (UMAS) in treating sugarcane waste. By this study, it is attempted to propose another way of treating sugarcane wastewater, producing renewable methane gas and also controlling membrane fouling.

1.2 Motivation

Environmental problems are the most serious problem our surrounding faces nowadays. Direct discharge of sugarcane wastewater into rivers creates severe water pollution. This is because sugarcane wastewater is highly polluted with high COD, BOD and TSS values which can affect the quality of water drastically (Candelario *et al*., 1974). Lots of researches have been done on how to solve these environmental issues. Besides that, the rise of oil and fuel price forces human to look for alternative fuels which are cheaper and environmental friendly. Methane is a good source of hydrocarbon fuel. But its production through hydrogenation of carbon dioxide leads to emission of greenhouse gasses and global warming (Wang *et al*., 2011). Therefore, production of methane from renewable sources as industrial and agricultural wastes by anaerobic digestion will be more favorable than other routes.

However, anaerobic digestion face both economical and environmental disadvantages such as requirement of large footprints and long hydraulic retention time (HRT) and at the same time not capable to produce effluent which meet the discharge standard fixed by Malaysian Department of Environment (DOE). Therefore, anaerobic digestion with membrane technology has been used to filter out the effluent to be clearer and free from suspended solids. However, membrane system faces fouling problem which can lead to decrease the filtering efficiency. Thus, ultrasonic membrane anaerobic system (UMAS) is a perfect system which can reduce fouling, increase filtering efficiency and also the biomethanation process.

1.3 Problem Statement

Sugarcane wastewater is one of the wastewater that is discharged in huge amount. This is because, during the process of sugarcane milling, large amount water is used. Normally, sugarcane wastewaters have high BOD and COD values. Direct discharge of this liquid into river water may deplete dissolved oxygen, destroy aquatic life, and makes the water unfit for community water supply. Methane is an important natural gas which should be produced in an environmental friendly way. Since the costs of fossil fuels are increasing, transforming waste materials into useable energy is a good alternative way of producing energy. Besides that, waste management through this method can be considered as economical and environmental friendly. Due to fouling problem in anaerobic membrane system, ultrasonic membrane anaerobic system is evolved to control fouling.

1.4 Objective of Study

The research aims to solve the problem statements by accomplishing the following objectives:

a) To make an overall comparison between membrane anaerobic system (MAS) and ultrasonic membrane anaerobic system (UMAS) in treating sugarcane waste.
b) To compare the quantity of methane gas generated from the process of using membrane anaerobic system and ultrasonic membrane anaerobic system.

1.5 Scope of Research

Raw material used in this study is sugarcane waste water from sugarcane mill. The raw material was taken from Kilang Gula Felda Perlis Sdn Bhd. To fulfill the objective of my study, a 50L anaerobic membrane bioreactor system was used. The experiment was first conducted using membrane anaerobic system (MAS) for 7 days. The reactor was then attached with an ultrasonic device on to the membrane to modify it to ultrasonic membrane anaerobic system (UMAS). The wastewater was treated in UMAS for 7 days also. Parameters such as pH, temperature and pressure are maintained in optimum operating conditions. Hydraulic retention time (HRT) was set to 7 days. Other parameters that should be considered in evaluating the system performance was Chemical Oxygen Demand, Biological Oxygen Demand, Total Suspended Solid and Volatile Suspended Solid for the raw material, reacted wastewater and permeate to find the efficiency of the system.

1.6 Rationale and Significant

This study mainly will contribute an effective way of handling and managing the sugarcane wastewaters rather than just discharging into rivers. This can reduce the environmental problem caused by industrial wastewaters. Besides that, this research also produces alternative renewable energy that can be applied in many industries as substitute for fossil fuels which cost a lot.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

In the 20th century, major research emphasis have been the centre of development of fossil crude oil, coal and natural gas based refinery to exploit the cheaply available fossil feedstock for development of industry (Demirbas, 2006). The combustion of fossil fuels is the main contributor to the increase in the level of carbon dioxide into the atmosphere which will directly increase global warming. Biomass resources are the most suitable and renewable primary energy resources that can provide alternative transportation fuels (Hamelinck *et al*., 2005). Biofuels produced from biomass help to reduce both the world's dependence on oil and carbon dioxide production. Methane production from many type of biological wastes through anaerobic digestion technology is advancing worldwide and it is very economical and benefits environmentally.

2.2 Sugarcane Waste

Sugarcane is world's largest crop which can grow 10-20 feet high and 1-3 inch in diameter. Sugarcane consists of about 15% of fiber, 85% of water and soluble solids, including sucrose of about 15% (Lamb.J.C). 80% of sugar in world is produced from cane and the rest is from sugar beets. Some of the major sugar producing countries is India, Mexico, Brazil and many more. The world production of cane sugar in 1962 was nearly 30 million per year (Guzman, 1962). However, the process involved to produce sugar causes major problem due to waste produced from sugar mills. The most significant by products from a cane sugar mill are bagasses, solid residue from sugarcane juice extraction, stillage (vinasse or dunder) and liquid waste effluent (Gunkel *et al*., 2006). The liquid wastes are normally from cane wash water, floor washing and boiler blow down, excess condenser waters and also soda and acid wastes. These liquid needs to be treated to meet the effluent discharge standard for sugarcane waste water. Figure 2.1 below shows the sources of waste water from a sugar mill.

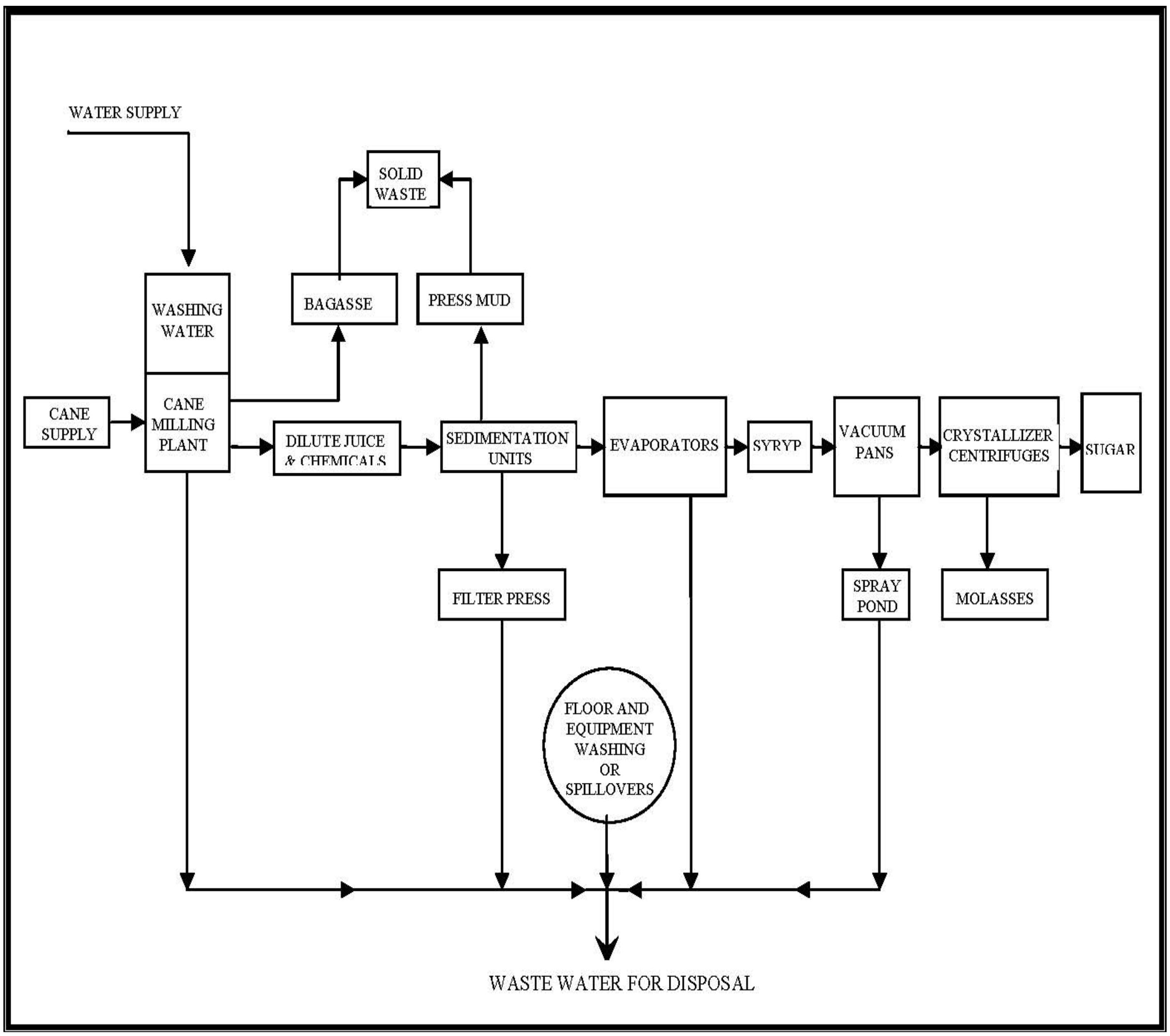

Figure 2.1: Sources of Waste Water in Cane Sugar Manufacturing Factory. (Akbar *et al*., 2006)

Table 2.1 shows the characteristics of a sample of sugarcane mill effluent and Table 2.2 shows the Malaysia sewage and industrial effluent discharge standards.

Table 2.1: Characteristics of Sugar Mill Effluent (Kumar *et al*., 2012)

Parameters	**Concentration**
pH	6.85
TSS, mg/l	340
TDS. mg/l	2055
TS, mg/l	2395
BOD5, mg/l	1620
COD, mg/l	2210
Total Nitrogen. Mg/l	13.35
Total Phosphorus, mg/l	5.50

Table 2.2: Parameter Limits of Effluent of Standards A and B

Parameter	**Unit**	**Standard A**	**Standard B**
(i) Temperature	°C	40	40
(ii) pH Value		6.0 - 9.0	5.5 - 9.0
(iii) BOD5 at 20°C	mg/l	20	50
(iv) COD	mg/l	50	100
(v) Suspended Solids	mg/l	50	100
(vi) Mercury	mg/l	0.005	0.05
(vii) Cadmium	mg/l	0.01	0.02
(viii) Chromium, Hexavalent	mg/l	0.05	0.05
(ix) Arsenic	mg/l	0.05	0.10

(x) Cyanide	mg/l	0.05	0.10
(xi) Lead	mg/l	0.10	0.5
(xii) Chormium, Trivalent	mg/l	0.20	1.0
(xiii) Copper	mg/l	0.20	1.0
(xiv) Manganese	mg/l	0.20	1.0
(xv) Nickel	mg/l	0.20	1.0
(xvi) Tin	mg/l	0.20	1.0
(xvii) Zinc	mg/l	1.0	1.0
(xviii) Boron	mg/l	1.0	4.0
(xix) Iron (Fe)	mg/l	1.0	5.0
(xx) Phenol	mg/l	0.001	1.0
(xxi) Free Chlorine	mg/l	1.0	2.0
(xxii) Sulphide	mg/l	0.50	0.50
(xxiii) Oil and Grease	mg/l	Not detectable	10

Source: *Malaysia's Environmental Law, ENVIRONMENTAL QUALITY ACT, 1974 the Malaysia Environmental Quality (Sewage and Industrial Effluent) Regulations, 1979, 1999, 2000.*

The table shows that, cane sugar mill effluent have high amount of BOD and COD values which does not meet the standard limit. Organic pollutants present in the effluent are sugar and other carbohydrates. There is immediate oxygen demand by these effluents which causes rapid depletion of dissolved oxygen of receiving streams. This may lead to severe anaerobic conditions. This condition results in the release of foul odour and in the production of hydrogen sulphide. Hydrogen sulphide precipitates iron as black sulfide and lead to unsightly appearance (Hendrickson, 1971). All these effects make the water totally unfit for fish and other aquatic life. Also the dissolved and suspended solids deteriorate slowly resulting in obnoxious odor. Besides that, suspended impurities also block the drainage and detach (Kolhe *et al*., 2001).

Direct use of sugarcane mill effluent for agricultural practices such as for irrigation purpose, will affect the soil fertility as well as the plant growth and seed germination. In a study conducted by Ramkrishan *et al*. (2001), it is reported that sugar mill effluent reduced the rate of germination of seed on the paddy crop. Furthermore, sugar mill effluents also affect the soil fauna. The bacteria and fungi which maintain the soil fertility will be affected by the highly toxic chemicals releases from sugar mill effluent. Besides that, sugar mill effluent has high toxic chemicals and heavy metals which can affect aquatic flora and fauna (Senthil *et al*., 2001). Economically, important fishes having nutritive values which are under threat due to discharge of sugar industry effluent into fresh water ecosystem. This is due to depletion of dissolved oxygen (Avasan, 2001). This proves that effluent is also not environmental friendly to be discharged into river or land directly. So, proper treatments should be applied to convert the effluent into useful products and at the same time avoiding environmental problems.

2.3 Methane Gas

Methane is a colourless, odourless gas which is widely spread in the nature. It is a natural gas which contains 75% CH_4, 15% ethane (C_2H_6) and 5% of other hydrocarbons as propane (C_3H_8) and butane (C_4H_{10}). Methane gas can be produced from decomposition of plant and animal matter in the presence of anaerobic bacteria (Scifun.Chem.Wisc,). Methane gas is less dense than air in the room temperature. The melting and boiling points are -183°C and -164°C respectively. There will be energy released during the combustion of methane. Methane has potency as an alternative source to heat homes and commercial buildings and also used in the generation of electric power. Methane commonly produced by hydrogenating carbon dioxide and it is also a side product of carbon monoxide hydrogenation (Wang *et al*., 2011). However, these methods are not very effective because