METHANE PRODUCTION FROM SEWAGE SLUDGE TREATMENT BY ULTRASONICATED MEMBRANE ANAEROBIC SYSTEM (UMAS)

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ABSTRACT

Sewage Sludge wastewater causes serious environmental pollution due to its high chemical oxygen demand (COD) and biological oxygen demand (BOD). Traditional methods of treating sewage sludge wastewater are disadvantages from both economic and environmental perspectives. In this study, the potentials of Ultrasonicated Membrane Anaerobic System (UMAS) in treating wastewater as an alternative and cost effective method was investigated. Waste sludge samples used in the study were collected from sewage treatment plant of INDAH WATER in Kuantan, Malaysia. The temperature during collection of the raw sewage sludge was 32 ^{o}C. The wastewater was stored in a cold room at 4 ^{o}C prior to use The study began with some characterization studies to provide understanding of fundamental issues such as conventional separation, ultrasonic and membrane separation. The aim was to obtain optimum operation conditions, maximum methane production as well as overall performance of UMAS in treating sewage sludge, upon which further development on wastewater processes could be developed. Four steady states were attained as a part of this study that considered concentration ranges from 6500 to 2.300 mg/l for mixed liquor suspended solid (MLSS). UMAS was used to treat the sewage sludge at organic loading rates ranging from 0.06 to 0.12 kg COD /M_3/day, and throughout the experiment, the removal efficiency of COD was from 79% to 93% and the methane gas percentage was between 93 and 85. The ammonia and nitrogen removal efficiency were 56 - 77 and 56 - 72 percentage respectively. The reactor pH is slightly changing during the experimental period with values around 6.8, 7.1, 7.2 and 7.00 in steady state 1, 2, 3 and 4, respectively. The slight changes in the alkalinity levels of pH indicate process stability. The gas volume was measured daily using a 20-litre displacement bottle. Biogas from sewage digester usually contain 55% to 65% of methane, 35% to 45% of carbon dioxide and < 1% nitrogen. Besides the main components, biogases also contain hydrogen sulphide and other sulphide compound, siloxanes, aromatic and halogenated compounds. The results obtained in this study have exposed the capability of ultrasonic assisted membrane anaerobic system (UMAS) in treating wastewater. Thus, using UMAS for the treatment is a challenging and interesting area; in this research work it is limited to study the steady states operation to provide continuous addition of feed solution (Raw sewage sludge) by gravity flow from feeder tank, which is on top of the reactor. In future, this study could be improved using specific type of ultrasonic against specific type of membrane anaerobic to increase the production methane, thus the performance of full process of UMAS will be increased and can produce more methane as well as it will reduce the time and cost. 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.

ABSTRAK

Air buangan Enapcemar Kumbahan menyebabkan pencemaran alam sekitar yang serius kerana keperluan oksigen kimia (COD) dan keperluan oksigen biologinya (BOD) yang tinggi. Kaedah tradisional merawat air buangan enapcemar kumbahan mendatangkan keburukan dari sudut ekonomi dan persekitaran. Dalam kajian ini, potensi Sistem Anaerobik Membran Berultrasonik (UMAS) dalam merawat air buangan sebagai suatu alternatif dan kaedah yang menjimatkan telah dikaji. Contoh-contoh enapcemar buangan yang digunakan dalam kajian ini diambil dari loji rawatan kumbahan INDAH WATER di Kuantan, Malaysia. Suhu semasa pengambilan enapcemar kumbahan mentah ialah 32 ^oC. Air buangan tersebut telah disimpan dalam bilik sejuk di bawah suhu 4 ^oC sebelum digunakan. Penyelidikan dimulakan dengan kajian pencirian untuk memberi pemahaman mengenai isu asas seperti pemisahan konvensional, ultrasonik dan pemisahan membran. Tujuannya adalah untuk mendapatkan syarat-syarat operasi yang optimum, penghasilan metana yang maksimum serta pencapaian keseluruhan UMAS dalam merawat enapcemar kumbahan di mana pembangunan lanjut ke atas proses-proses air buangan boleh dijalankan. Empat keadaan mantap telah diperolehi sebagai sebahagian daripada kajian ini yang mengambilkira julat kepekatan 6500 hingga 2.300 mg /l untuk pepejal campuran likuor terampai (MLSS). UMAS telah digunakan untuk merawat enapcemar kumbahan pada kadar muatan organik meliputi dari 0.06 hingga 0.12 kg COD/M_3/hari dalam seluruh eksperimen dengan kecekapan penyingkiran COD adalah dari 79% hingga 93% dan peratusan gas metana adalah antara 93 dan 85. Kecekapan penyingkiran nitrogen dan ammonia, masing-masing ialah 56 - 77 dan 56 - 72 peratus. Kadar pH reaktor sedikit berubah semasa tempoh eksperimen dengan nilai sekitar 6.8, 7.1, 7.2 dan 7.00, masing-masing dalam keadaan mantap 1, 2, 3 dan 4. Tahap-tahap kealkalian pH yang sedikit berubah menunjukkan kestabilan proses. Jumlah gas telah disukat setiap hari menggunakan botol sesaran berkapasiti 20 liter. Biogas dari penghadam kumbahan biasanya mengandungi 55% hingga 65% metana, 35% hingga 45% karbon dioksida dan < 1% nitrogen. Selain komponen utama, biogas juga mengandungi hidrogen sulfida dan sebatian sulfida lain, siloxanes, sebatian aromatik dan menghalogenkan. Keputusan yang diperolehi dari kajian ini mendedahkan keupayaan sistem anaerob membrane ultrasonik (UMAS) dalam merawat air buangan. Oleh sebab itu, penggunaan UMAS untuk rawatan ialah suatu bidang yang menarik dan mencabar; dalam kerja penyelidikan ini, ia dihadkan untuk mengkaji operasi dalam keadaan stabil bagi menyediakan tambahan penyelesaian suapan yang berterusan (Enapcemar kumbahan mentah) melalui aliran graviti dari tangki suapan yang terletak di atas reaktor. Pada masa akan datang, kajian ini boleh diperbaik menggunakan jenis ultrasonik tertentu terhadap membran anaerob tertentu untuk meningkatkan penghasilan metana supaya prestasi proses penuh UMAS akan ditingkatkan dan boleh menghasilkan lebih banyak metana serta mengurangkan masa dan kos. Walaubagaimanapun, kajian lanjut diperlukan bagi memberi pemahaman mendalam berkenaan mekanisme-mekanisme yang terlibat untuk memudahkan pembangunan satu sistem yang optimum kepada industri.

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LIST OF ABBREVIATIONS

AD	Anaerobic digestion/Digester
BLR	Biological loading rate
BOD	Biochemical oxygen demand
C: N:P	Carbon to Nitrogen to Phosphor ratio
CH_4	Methane
CO_2	Carbon dioxide
COD	Chemical oxygen demand (mg/L)
CSTR	Continuously stirred tank reactor
CUF	Cross flow ultra-filtration membrane
d	Day
EC	European community
g	Gram
GHG	Greenhouse gas
hr	Hour
HRT	Hydraulic retention time (day)
L	litre
m	Meter
m^3	Cubic meter (gas volumes assume 0°C and 1.101 bar
MAS	Membrane anaerobic system
MLSS	Mixed liquid suspended solid (mg/L)
MLVSS	Mixed liquid volatile suspended solid (mg/L)
MSW	Municipal solid waste

MWCO	Molecular weight cut-off
OLR	Organic loading rate (kg/m^3/d)
SRT	Solids retention time (day)
SS	Steady state
T	Time (d)
TS	Total solids
TSS	Total suspended solid (mg/L)
UASB	Up flow anaerobic sludge blanket
UMAS	Ultrasonicated membrane anaerobic system
VS	Volatile solids
VSS	Volatile suspended Solids (mg/l)
WAS	Waste activated sludge
y	year

CHAPTER 1

INTRODUCTION

1.1 INTRODUCTION

Sewage sludge is an important source of inland water pollution when it is released into local rivers or lakes without treatment. Sewage Sludge has negative effect to the environment; it contains organic wastes, sewages and fertilizers contain nutrients such as nitrates, sulphates and phosphates (Halim, 1988). Its chemical oxygen demand (COD) and biochemical oxygen demand (BOD) are high. The effluent is non-toxic because no chemicals are added during the sample extraction process (Singh et al., 1999). Most commonly, sewage sludge treatment use anaerobic digestion for the primary treatment.

Over the last century, anaerobic digestion (AD) has emerged as a reliable treatment solution for the stabilization and disintegration of sludge. The process was initially used for the treatment of domestic wastewater and sewage sludge in the municipal treatment plants. But over the past 20 years, the true potential of anaerobic digestion has been explored and major advances in reactor design, configuration and operation and in our understanding of the nature of the microbial biochemistry; physiology and ecology have been reported (Craik et al., 1995). The growing interest of the researchers in this process is a testimony to the viability and applicability of the process .High ultrasonicated membrane anaerobic system treatment (UMAS) would reduce treatment costs by increasing the digestion rate and eliminating the need for cooling facilities prior to biological treatment (Chiemchaisri et al., 1995).

The feed system was designed to provide continuous addition of feed solution (Raw sewage sludge) by gravity flow, from feeder tank which is on top of the reactor. The laboratory digester is completely mixed-semi continuous followed steady state operation, so that the experimental results could be used to investigate the performance of ultrasonicated membrane anaerobic system (UMAS) under steady state conditions .And the volume of biogas produced is measured by using a 20 litres water displacement bottle.

1.2 RESEARCH BACKGROUND

Anaerobic digestion is biological process that occurs in environment. It occurs naturally in swamp, water -logged soil and paddy fields, deep bodies of water, and the digestive systems of terminates and large animal. It utilizes microorganisms to break down biodegradable organic material with little or in the absence of oxygen. Almost any organic material can be processed with anaerobic digestion including waste papers, agriculture wastes, industrial effluents, leftover food, animal and human excreta. It is widely used for the treatment of wastewater sludge in many industries (Residua, 2003).

Anaerobic digestion is a renewable energy source because the process produces bio methane which consists of methane (50 - 80%). Methane is a gas that contains molecules of methane with one atom of carbon and four atom of hydrogen (CH_4). It is the major component of the "natural" gas used in many home for cooking power generation. As methane is about twenty times more potent as carbon dioxide this has significant negative environmental effects. Besides, anaerobic digestion also releases carbon dioxide (20 - 50%) and traces levels of other gases such as hydrogen, carbon monoxide, nitrogen, oxygen, and hydrogen sulphide. (Noor et al., 2010).

The relative percentage of these gases depends on the feed material and management of the process. Anaerobic digestion is one of the fundamental processes in sewage sludge treatment for reducing and stabilizing the organic solids due to its high organic fraction. There are more innovative waste treatment facilities attributed to improve anaerobic digestion technology. With the advancement of membrane technology, application of membrane filtration in the treatment of sewage sludge can contribute to developing an efficient sewage sludge treatment process that is capable of retaining biomass concentration within the reactor and producing high quality effluent .Membrane separation techniques have proven to be an effective method in separating biomass solid from digester (Noor et al., 2010).

Anaerobic digesters produce conditions that encourage the natural breakdown of organic matter by bacteria in the absence of air. Utilizing anaerobic digestion technologies can help to reduce the emission of greenhouse gasses in a number of key ways: such as

Replacement of fossil fuels, reducing methane emission from landfills, displacing industrially-produced chemical fertilizers, reducing vehicle movements and reducing electrical grid transportation losses. Methane and power produced in anaerobic digestion facilities can be utilized to replace energy derived from fossil fuels, and hence reduce emissions of greenhouse gasses increasingly, however, anaerobic digestion is seen not as a process for stabilizing sludge, but as an opportunity to recover the energy embedded in the substrate, traditionally in the form of methane (Horan and Nigel, 2009). The major contaminants found in wastewater are biodegradable organic compounds, volatile organic compounds, recalcitrant xeno biotic, toxic metal, suspended solid, nutrients (nitrogen and phosphorus), microbial pathogens and parasites as displayed in Figure 1.1.

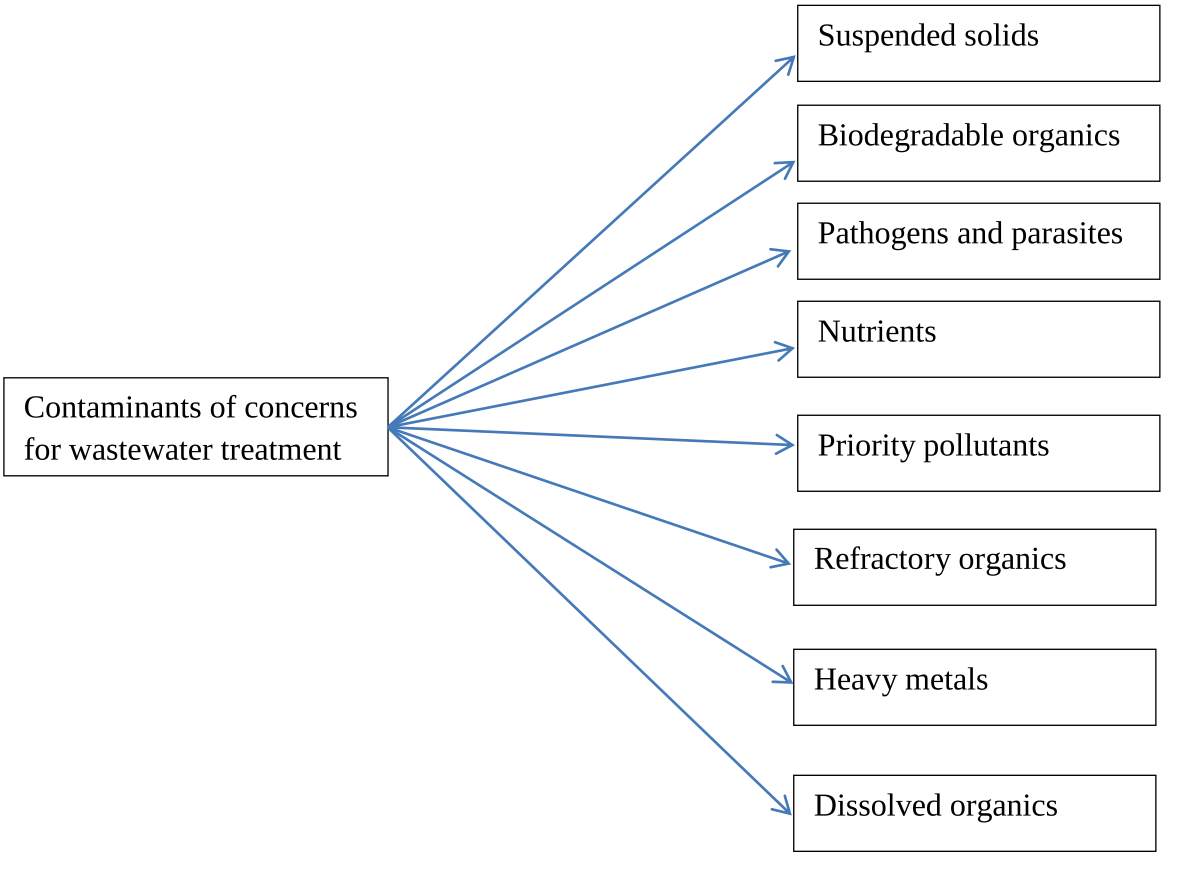

Figure 1.1: Major contaminants in waste water

Source: Gabriel and Bitton (2005).

Domestic wastewater is a combination of human and animal excreta (feces and urine) and grey water resulting from washing, bathing and cooking. People excrete 100 - 500 g wet weight of feces and between 1 and 1.3 litres of urine per capita per day. Each person contributes 15 - 20 g BOD_5/day (Feachem et al., 1987; Gabril and Braune, 2005 and Sterritt and Lester, 1988). Other characteristic of human feces and urine were displayed in Table 1.1. Whereas, the chemical characteristics of untreated wastewater are displayed in Table 1.2

Table 1.1: Composition of human feces and urine

Component	**Feces**	**Urine**
Quantity (wet) per person per day	100-400g	1.0-1.31kg
Quantity (dry solids) per person per day	30-60g	50-70g
Moisture content	70-85%	93-96%
Approximate composition (percent dry weight) organic matter	88-97	65-85
Nitrogen(N)%	5.0-7.0	15-19
phosphorus(as P_2O_5)%	3.0-5.4	2.5-5.0
Potassium(as K_2O)%	1.0-2.5	3.0-4.5
Carbon (C)%	44-55	11-17
Calcium (as CaO)%	4.5	4.5-6.0
C/N ratio	6-10	1
BDO_5 content per person per day	15-20	10g

Source: Polprasert (1989)

Table 1.2: Typical characteristic of domestic waste water

Parameter	**Concentration**		
	Strong (mg/L)	Medium (mg/L)	Weak (mg/L)
BDO_5 mg/L	400	220	110
COD mg/L	1000	500	250
Organic N mg/L	35	15	8
NH3-N mg/L	50	25	12
Total N mg/L	85	40	20
Total P mg/L	15	8	4
Total solids mg/L	1200	720	350
Suspended solids mg/L	350	220	100

Source: Gabril and Braune (2005); Metcalf and Eddy (1991)

1.3 PROBLEM STATEMENT

Environmental pollution became one of the tedious problem facing today's world and it continuously increasing with every passing year and causing grave and irreparable damage to the earth. Water pollution is one of the main reasons that lead to pollution of the environment (Natural Resources Management and Environment Department, 2009).Water pollution happens when toxic substances enter water bodies such as lakes, rivers, oceans and so on, getting dissolved in them, lying suspended in the water or depositing on the bed. This degrades the quality of water. Not only does this spell disaster for aquatic ecosystems, the pollutants also seep through and reach the groundwater, which might end up in our households as contaminated water we use in our daily activities, including drinking.

Water pollution can be caused in a number of ways, one of the most polluting being city sewage and industrial waste discharge. Indirect sources of water pollution include contaminants that enter the water supply from soils or groundwater systems and from the atmosphere via rain. In Malaysia rivers play a major role for communities especially in fisheries and as a source of water for people residing within the vicinity. Water quality is of utmost importance and it covers a wide range of approaches and conflicts. The continues increase in socio-economic activities in this area has been accompanied by an even faster growth in pollution stress on river quality.

One of the challenges in evaluating and improving water quality are the many different factors affecting water quality. Water quality is affected by air quality, pesticides and toxics **(**Cunningham et al., 2007). In today's urbanized society, as an example many commercial and industries releasing organic wastes, sewages and fertilizers contain nutrients such as nitrates, sulphates and phosphates to stream, rivers lakes and oceans. This can lead to severe water pollution when an overwhelming amount of waste accumulates in natural ecosystem. Consequently, when the wastes are not destroyed as fast as produce they make it unfavourable to humans and many other organisms. Sewage sludge produced in large quantities in Poland; about 359, 819 tons of dry matters in 2000, from those almost 156, 128 tons of dry matter was land filled is considered to be another example. Thus a twofold increase of sewage sludge mass in 2014 relation to 2000 is expected (Sonsnowskia and Klepacz, 2007) .Sewage sludge is one of the factors that contribute to the issue if discharge into environmental without pre-treatment. Besides the dramatic increases in sewage sludge production, the increases cost of land and public awareness of environmental and health issues encourage sewage sludge treatment. The treated sewage sludge is less contaminated with trace elements which include heavy metals and organic compound.

Sewage sludge contains pathogenic bacteria, viruses and protozoa along with the other parasitic helminthes which can give rise to potential hazards to the health of humans, animals and plants. Hence it is very important to prevent the pollution of vital and limited resources of water by providing adequate treatment of liquid waste emanating from domestic and industrial sources. The numbers of pathogenic and parasite organisms in sewage sludge can be significantly reduced by anaerobic digestion. According to WHO Report (1981) on the risk to health of microbes in sewage sludge applied to land identified salmonellae and Taenia as giving rise to greatest concern (Natural Resources Management and Environment Department, 2009). Sewage sludge is renamed compost due to its toxic nature of sewage sludge. Federal Clean Water Act (CWA) classifies sewage sludge as hazardous pollutant (Abby, 2002). The facilities to treat and dispose the sewage sludge are limited. However, the producing of sewage sludge is increasing in every year due to the population is increasing. The sewage sludge treatment is complicated, taking longer time and occupied big area of land. Sewage sludge is hazard to environmental and public health if the excess sewage sludge is untreated due to limited treatment plant. Therefore, alternative sewage sludge treatment is needed to manage the large capacity of sewage sludge production.

The anaerobic digestion of sewage sludge can be considered as an excellent alternative to dumping, composting, and incinerating of organic waste or to simple fermentation processes (Sosonwskia and klepacz, 2008) .Anaerobic sewage treatment is one of the major waste treatment processes in use today. It is not a new technology and indeed it is the innovative approach used by water companies to stabilize sludge as the first stage in the process of generating bio solid intended for recycling to agricultural land. More recently there has been considerable interest in applying this process to the treatment of strong and medium strength industrial wastes (Noor et al., 2008). The anaerobic process is time tested and does not require the purchase of special bacteria or nutrients because the bacteria are anaerobic they do not require oxygen like the organisms in an aerobic process by using anaerobic digestion in the treatment of wastewater sludge, the overall cost of sewage treatment is reduced and it also furnishes a considerable power supply. Although many sludge stabilization methods exist, anaerobic digestion is unique for it has the ability to produce a net energy gain in the form of methane gas; it optimizes cost effectiveness and minimizes the amount of final sludge disposal, thus decreasing the hazards of wastewater and sewage treatment by-products. Thus the municipal wastewater treatment plants it is most cost effective and environmentally sound to use anaerobic digestion in the stabilization of sewage sludge. Besides, this process is helping clients to convert liabilities into assets and green energy; that is form "Form Waste to Energy".

In recent years, there has been an increasing interest worldwide in the production of alternative energy from the waste. To circumvent the problem, UMAS is used to treat the sewage sludge before discharge to the earth. Sewage sludge treatment ensures the hygienic safety and sensory acceptability of the sludge. It is also a contribution to save the environment by reducing the waste in the world. The more sewage sludge is used as fuel in generating renewable energy, the more reduction in greenhouse gas emissions. By this way, sewage sludge can be utilized as a valuable resource rather than to be considered merely as a waste to be got rid of. Thus using the UMAS to treat the waste and produce methane gas which is benefit to human by producing the methane gas. The methane gas produced at the end of the experiment is used to heat the digester and, in some cases, also to fuel gas engines to generate electricity. The sludge resulting from anaerobic digestion is much less offensive in order than the untreated raw sludge and is generally suitable for use in agriculture in liquid or solid form (Noor et al., 2010).

1.4 OBJECTIVES OF THE RESEARCH

There are four objectives of this research, which are:

1. To examine experimentally the treatability of sewage sludge by controlling operation process parameters in UMAS.
2. To investigate the performance of ultrasonic membrane anaerobic system (UMAS) under steady state conditions.
3. To determine the chemical oxygen demand (COD) removal efficiencies and biogas production
4. To evaluate the formation of methane gas production from sewage sludge by ultrasonic membrane anaerobic system (UMAS).

1.5 SCOPES OF RESEARCH

- Firstly, this research uses 50 litres volume of laboratory scaled ultrasonicated membrane anaerobic system (UMAS) combining ultra-filtration (UF) membrane and centrifugal pump with anaerobic reactor was designed and used to treat raw sewage sludge which was taken from sewage treatment plant.
- Secondly, enrichment cultures of methanogenic bacteria were developed in the digester which is semi-continuously mixed under steady state operation.

- Thirdly, the process comprises only three general degradation phases: hydrolysis, acidogenesis, and methanogenesis.
- Fourthly, study the parameters that affect the performance of UMAS such as pH, Chemical Oxygen Demand (COD), Biological Oxygen Demand (BOD), and Total Suspended Solid (TSS). However this study is focused to determine the result of COD.
- Finally, measure the percentage of methane gas production by using J-Tube gas Analyzer.

1.6 LAYOUT OF THE THESIS

This thesis has been prepared to give details about the facts, calculations, parameters and procedures in order to meet its objectives. Chapter 1, generally describes the brief background of anaerobic digestion, methane production, and major contaminant in wastewater, the problem statement, objectives, and scope of the research. Chapter 2, reviews the anaerobic process wastewater treatment, application of anaerobic digestion , types of anaerobic process, scale of anaerobic process, reasons of anaerobic process, benefit of anaerobic digestion, comparison with aerobic digestion, chemical oxygen demand, VFAs, factors controlling anaerobic digestion, mechanism of biological, types of reactors used in anaerobic process, microbiology of anaerobic process, methane gas usage, membrane separation technology, ultrafiltration membrane, ultrasound and ultrasonic machining. Chapter 3, presents the treatment of sewage sludge by using ultrasonicated membrane anaerobic system, Materials, Methods, bioreactor operation, membrane cleaning, experimental procedures, analytical techniques and gas measurement. Chapter 4, elaborates the data and experimental results and analysis for the steady states, semi-continuous ultrasonic membrane anaerobic system (UMAS) performance, effect of organic loading rate and solid retention time and gas production and composition. The conclusions of the present research are summarized and presented in Chapter 5.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

Anaerobic fermentation is one of the oldest processes used in stabilization of solids and bio-solids. It involves the decomposition of organic matter and inorganic matter such as ammonia and nitrate to digested particles in the absence of oxygen. The major application of anaerobic digestion is applied in the stabilization of sewage sludge. Later on, it was successfully used for the treatment of industrial and domestic wastewaters. Mass reduction, methane production, and improved dewatering properties of the fermented sludge are important features of anaerobic digestion (Metcalf and Eddy, 2004). Furthermore, anaerobic digestion of municipal sewage sludge can produce sufficient amount of digester gas to meet most of the energy needs for the plants. Anaerobic conversion of organic materials and pollutants is an established technology for environmental protection through the treatment of wastes and wastewater. The end product is biogas a mixture of methane and carbon dioxide, which is a useful, renewable energy source (Fruteau-de-Laclos et al., 1997).

Anaerobic digestion is a technologically simple process, with a low energy requirement, used to convert organic material from a wide range of wastewater types, solid wastes and biomass into methane. A much wider application of the technology is desirable in the current endeavours towards sustainable development and renewable energy production. In the 1980's several projects were initiated in the Netherlands to produce biogas from wastes. Many projects were terminated due to insufficient economic viability. Currently, the production of methane from wastes is receiving renewed attention as it can potentially reduce CO_2 emissions via the production of renewable energy and limit the emission of the greenhouse gas methane from especially animal manure. This trend is supported by the growing market demand for 'green' energy and by the substantial optimization of anaerobic digestion technologies in the past decades, especially the development of modern 'high rate' and co-digestion systems. (Ad-nett, 1997).

Biogas or landfill gas is primarily composed of methane (55 - 75 vol%), and carbon dioxide (25 - 45 vol%) with smaller amounts of H_2S (0 - 1.5 vol%) and NH_3 (0 - 0.05 vol%). The gas mixture is saturated with water vapour and may contain dust particles and trace amounts of H_2, N_2, CO and halogenated compounds depending on the feed-stock and process conditions (Wellinger and Lindberg, 1999). The fuel value of biogas containing 55 - 75 vol % methane ranges between 22 - 30 J/Nm (Higher Heating Value) and 19 - 26 MJ/Nm_3 (Lower Heating Value), respectively. Biogas can be utilised for the production of heat, co-generation of electricity and heat (CHP) or for upgrading to natural gas or fuel gas quality. A part of the biogas energy is utilised on site to provide for the internal energy requirement of the plant (digester heating, pumps, mixers etc.). Membrane processes cover a group of separation processes in which the characteristics of a membrane (porosity, selectivity, electric charge) are used to separate the components of a solution or a suspension. In these processes the feed stream is separated into two: the fraction that permeates through the membrane, called the permeate, and the fraction containing the components that have not been transported through the membrane, usually called the retentate The size of the components to be separated and the nature and magnitude of the driving force provide criteria for a classification of the membrane separation processes.

Membrane processes do not require heating, which makes the process suitable for the treatment of thermolabile products. In addition the relatively low capital and operating costs involved make membrane processes an appealing alternative to more conventional separation processes, particularly when dealing with dilute solutions, (Bowen, 1991). According to Biwater UK (2002) Microfiltration, 7,500m^3/day (2 MGD) the Biwater is supplied and installed the microfiltration water treatment plant near Lydden, Kent, after carrying out the complete Mechanical, Electrical and Civil design for the plant. The plant is a cryptosporidia barrier for raw water sources from three boreholes. The work was carried out for Folk stone and Dover Water Services Limited and was undertaken on a site that is environmentally sensitive as it is classified as an area of outstanding natural beauty, surrounded by areas of ancient woodland with an adjacent site of special scientific interest (SSSI).

2.2 ANAEROBIC WASTE WATER TREATMENT

Anaerobic treatment is a process in which microorganisms convert organic matter into biogas in the absence of oxygen. Anaerobic treatment is an energy-efficient process that is typically utilized to treat high-strength industrial wastewaters that are warm and contain high concentrations of biodegradable organic matter (measured as BOD, COD and/or TSS), (Lettinga and Antonie, 1987). An anaerobic system can be used for pre-treatment prior to discharging to a municipal wastewater treatment plant or before polishing in an aerobic process. Anaerobic processes offer substantially lower energy use, lower chemical usage, and reduced sludge handling costs compared to aerobic treatment options. In addition, the biogas produced in the anaerobic process is a form of renewable energy that can be used to displace fossil fuels such as oil or natural gas, or to generate electricity. Anaerobic digestion is the most common (mesophilic) treatment of domestic sewage in septic tanks, which normally retain the sewage from one day to two days, reducing the biochemical oxygen demand (BOD_5) by about 35 to 40 percent. This reduction can be increased with a combination of anaerobic and aerobic treatment by installing Aerobic Treatment Units (ATUs) in the septic tank.

According to Biomass using anaerobic digestion, the mesophilic anaerobic digestion (MAD) is also a common method for treating sludge produced at sewage treatment plants. The sludge is fed into large tanks and held for a minimum of 12 days to allow the digestion process to perform the four stages necessary to digest the sludge. These are hydrolysis, acidogenesis, acetogenesis and methanogenesis. In this process the complex proteins and sugars are broken down to form more simple compounds such as water, carbon dioxide and methane. One major feature of anaerobic digestion is the production of biogas (with the most useful component being methane), which can be used in generators for electricity production and/or in boilers for heating purposes. Many larger sites utilize the biogas for combined heat and power, using the cooling water from the generators to maintain the temperature of the digestion plant at the required 35 ± 3 °C.

Anaerobic treatment systems such as the conventional activated sludge (CAS) process are widely adopted for treating low strength wastewater (< 1000 mg COD/L) like municipal wastewater. CAS process is energy intensive due to the high aeration requirement and it also produces large quantity of sludge (about 0.4 g dry weight/g COD removed) that has to be treated and disposed off. As a result, the operation and maintenance cost of a CAS system is considerably high. Anaerobic process for domestic wastewater treatment is an alternative that is potentially more cost-effective, particularly in the subtropical and tropical regions where the climate is warm consistently throughout the year. Anaerobic wastewater purification processes have been increasingly used in the last few decades. These processes are important because they have positive effects: removal of higher organic loading, low sludge production and high pathogen removal, methane gas production and low energy consumption (Nykova et al., 2002).

Anaerobic digestion consists of several interdependent, complex sequential and parallel biological reactions, during which the products from one group of microorganisms serve as the substrates for the next, resulting in transformation of organic matter mainly into a mixture of methane and carbon dioxide. Anaerobic digestion takes place in four phases: hydrolysis/liquefaction, acidogenesis, acetogenesis and methanogenesis. To ensure a balanced digestion process it is important that the various biological conversion processes remain sufficiently coupled during the process so as to avoid the accumulation of any intermediates in the system. Microorganisms from two biological kingdoms, the bacteria and the archaea, carry out the biochemical process under strict anaerobic conditions (Parawira, 2004). Anaerobic reactors have been used mainly for industrial wastewater treatment. Researchers have shown than anaerobic systems such as the Up flow Anaerobic Sludge Blanket (UASB), the Anaerobic Sequencing Batch Reactor (ANSBR) and the anaerobic filter (AN) can successfully treat high-strength industrial wastewater as well as low-strength synthetic wastewater.

The predominant reason given for is, that municipal sewage are to weak (to low BOD or COD) to maintain high biomass (in the form of granules-suspended solids or fixed film) content in reactor. There are however, some successful examples in pilot and full scale (Orozo, 1997) investigated a full scale anaerobic baffled reactor (ANBR) to treat municipal sewage of an average BOD of 314 mgO_{2}/L for a hydraulic retention time of 10.3 hours, (organic loading rate 0.85 kg/m3·d) and achieved a 70% removal efficiency. It has to be stressed that the process was run at very low temperature between 13 and 15 ^{o}C. Treatment of domestic wastewater in a UASB and two anaerobic hybrid (ANH) reactors was conducted by Elmitwalli et al. (1999) at a temperature of 13 ^{o}C. For pre-settled wastewater treatment, the ANH reactors removed 64% of total COD, which was higher than the removal in the UASB reactors. The main objective is to decrease the cost of sewage treatment and minimize the amount of excess sludge produced. There is however, another important aspect, which