PRE-TREATMENT STUDY BY USING AIR STRIPPING PROCESS IN REDUCING CHEMICAL OXYGEN DEMAND (COD), TOTAL SUSPENDED SOLID (TSS) AND AMMONIA NITROGEN (NH3-N) IN PALM OIL MILL EFFLUENT (POME).

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ABSTRAK

Malaysia adalah salah satu pengeluar dan pengeksport produk minyak sawit terkemuka di dunia dalam beberapa dekad ini. Efluen kilang minyak sawit mentah (POME) mengandungi kepekatan sebatian organik dan sisa minyak yang tinggi, mengakibatkan keperluan oksigen biologi (BOD), keperluan oksigen kimia (COD) dan jumlah pepejal terampai (TSS) yang tinggi. Ianya berwarna coklat gelap dan mempunyai nilai asid yang tinggi. Oleh kerana POME mentah adalah efluen yang mengandungi pencemaran yang tinggi, ia tidak dapat dibuang secara bebas ke sumber air tanpa rawatan yang lengkap. Di dalam kajian ini, pra-rawatan pelucutan udara digunakan bagi merawat POME dalam proses anaerobik bagi menghasilkan biogas. Pelucutan udara menggunakan kos dan input tenaga yang sedikit di mana ia melibatkan proses pemindahan amonia dari sisa air ke fasa gas. Kajian ini dilakukan untuk menganalisis masa pelucutan terbaik dan pH awal proses pelucutan udara dalam mengurangkan COD, TSS dan NH3-N POME dan untuk mengenal pasti jumlah pengurangan COD, TSS dan NH3-N setelah proses pra-rawatan pelucutan udara dijalankan. Eksperimen berskala makmal bagi pelucutan udara dijalankan dengan menggunakan 550 mL POME dari Kilang Kelapa Sawit Felda Lepar Hilir 3 dengan menggunakan pelbagai pH awal dan masa pelucutan serta keadaan operasi tetap bagi suhu dan kadar aliran. Sampel POME yang diambil, diuji untuk bacaan COD, TSS dan NH3-N sebelum dan selepas proses pra-rawatan pelucutan udara. Hasil eksperimen menunjukkan pengurangan COD, TSS dan NH3-N yang tinggi sebanyak 22.5%, 50% dan 92.8%, pada pH 12 dan masa pelucutan selama 4 hari. pH yang lebih tinggi dan masa pelucutan yang lebih lama meningkatkan pengurangan COD, TSS dan NH3-N. Oleh itu, pra-rawatan pelucutan udara mampu meminimumkan kesan pencemaran yang disebabkan oleh COD, TSS dan nitrogen ammonia dalam POME di samping menghasilkan kualiti biogas yang lebih baik.

ABSTRACT

Malaysia has emerged as one of the world's leading producers and exporters of palm oil products in recent decades. Raw palm oil mill effluent (POME) includes a high concentration of organic compounds and residual oil, resulting in a high biological oxygen demand (BOD), chemical oxygen demand (COD) and total suspended solids (TSS). It has a dark brownish colour and a high acidic value. Because raw POME is a highly polluting effluent, it cannot be dumped freely into any source of water without previous adequate treatment. In this study, air stripping pre-treatment is used in treating POME for anaerobic digestion process in producing biogas. Air stripping is a cost-effective technique that requires relatively little energy inputs and involves the transfer of free ammonia from wastewater to the gas phase. This research is conducted to analyze the best stripping time and initial pH of air stripping in reducing chemical oxygen demand (COD), total suspended solid (TSS) and ammonia nitrogen (NH3-N) of POME and to identify the amount of COD, TSS and NH3-N after air stripping pre-treatment. Laboratory-scale experiments of air stripping were conducted using 550 mL of POME from Felda Lepar Hilir 3 Palm Oil Mill at various initial pH and stripping time and constant operating condition of temperature and flow rate. The sample of POME collected was tested for its COD, TSS and NH3-N before and after the air stripping pre-treatment. The experimental results showed that the high COD, TSS and NH3-N removal efficiencies of 22.5%, 50% and 92.8%, respectively operating at initial pH of 12 and stripping time of 4 days. Higher pH and longer stripping time resulting higher COD, TSS and NH3-N removal efficiencies. The air stripping pre-treatment able to minimize the polluting effect by COD, TSS and ammonia nitrogen of POME thus produce a better quality of biogas.

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LIST OF SYMBOLS

MW	Megawatts
%	Percentage
RM	Malaysia Ringgit
US$	United States Dollar
°C	Degree Celsius
g/L	Gram per liter
mL	Milliliter
mg/L	Milligram per Liter
m^3/h	Cubic Meter per Hour
L	Liter
Kg	Kilogram
L/min	Liter per minute
C/N	Carbon to Nitrogen ratio
Cr3+	Chromic Ion
H+	Hydrogen Ion
OH-	Hydroxide
H_2	Hydrogen
H_2S	Hydrogen Sulfide
CH4	Methane
pH	Power of Hydrogen
CO_2	Carbon Dioxide
NH_4+	Ammonium
NH3-N	Ammonia Nitrogen
NaOH	Sodium Hydroxide

LIST OF ABBREVIATIONS

FFB	Fresh Fruit Bunches
POME	Palm Oil Mill Effluent
O&G	Oil and Grease
CPO	Crude Palm Oil
GDP	Growth of Domestic Product
MEGTW	Ministry of Energy, Green Technology and Water
GHG	Greenhouse Gases
GWP	Global Warming Potential
FA	Free Ammonia
SS	Suspended Solids
TDS	Total Dissolved Solids
COD	Chemical Oxygen Demand
TSS	Total Suspended Solids
BOD	Biological Oxygen Demand
AD	Anaerobic Digestion
UASB	Up-flow Anaerobic Sludge Blanket
OLR	Organic Loading Rate
VFA	Volatile Fatty Acids
HRT	Hydraulic Retention Time

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CHAPTER 1

INTRODUCTION

1.1 Background of Study

Malaysia is covered in tropical rainforests and has a year-round humid climate. It is a great opportunity to maximize the biomass generated by agriculture and tropical rain. With the rapid depletion of fossil fuels, renewable energy is seen as a feasible answer to Malaysia's energy needs. In this regard, the 8th Malaysian plan (2001-2005) expanded the government's fuel diversification strategy to include renewable energy, and the government set a goal of acquiring 5% (500MW) of its energy from renewable sources by 2005 (Khairudin et al., 2020). Renewable energy sources include biomass, solar, micro hydropower, industrial wastes, and biogas. Among these sources, biogas is a popular green energy source due to its ability to manage organic waste while also creating electricity, hence resolving many challenges simultaneously (Chien Bong et al., 2017).

Malaysia generates around 103 million tonnes of biomass, primarily from agricultural wastes, which account for 91% of the biomass total, as well as forest residues and urban wastes (Salleh et al., 2020). Malaysia is the second-largest producer and exporter of palm oil in the world, after Indonesia. Oil palm trees are found across Malaysia, and 76 of them are huge enterprises capable of processing more than 250,000 tonnes of fresh fruit bunches (FFB) every year (Chala et al., n.d.). Each year, nearly 80 million tons of FFB are processed in 406 palm oil plants, and approximately 54 million tons of palm oil mill effluent (POME) are produced. It contains 95% of water and the rest 5% of solid. However, untreated POME released methane that is 25 times more dangerous than carbon dioxide (CO_2) (Akhbari et al., 2020).

POME in its natural state is a high-quality waste, depending on the operation of the technique. It is produced primarily during the oil extraction, washing, and cleaning processes in the mill and contains suspended solids (SS), total dissolved solids (TDS), chemical oxygen demand (COD), biological oxygen demand (BOD), fat oil, and grease.

Anaerobic Digestion (AD) is one of the cost-effective and environmentally friendly methods that can treat and recover bioenergy from all kinds of types of organic wastes (Choong et al., 2018). In addition, treated POME generated biogas by anaerobic digestion that included 40% to 70% biogas. The air stripping pre-treatment can be employed to create biogas in the anaerobic digestion of POME (Khairul et al., 2019).

Air stripping pre-treatment method known to reduce the chemical oxygen demand (COD), total suspended solid (TSS) and ammonia nitrogen (NH3-N) that can increase the biogas production in anaerobic digestion. A total NH3-N concentration more than 3 g/L may result in a reduction in methane generation (Bi et al., 2020). To overcome the ammonia inhibitory effect of AD, a variety of ammonia reduction techniques have been developed, including substrate dilution, co-digestion with high carbon substrates, pH and temperature control, the use of adsorptive additives such as activated carbon, bentonite, and zeolite, microflora acclimation and bioaugmentation, stripping, membrane processes, struvite precipitation, ultrasonication, and microwave irradiation (Fuchs et al., 2018).

Air stripping is a cost-effective technology that needs very few energy inputs and involves the transfer of free ammonia from wastewater to the gas phase (K. Li et al., 2018). Experiments on ammonia stripping have been conducted using a range of approaches and under a variety of operating conditions, including pH, temperature, and stripping agent (air, nitrogen, steam, or biogas) (Georgiou et al., 2019). Air stripping has been successfully used as a pre-AD process to a variety of feedstocks, including household and industrial wastewaters, piggery and poultry wastes and as a post-AD process to the effluent of anaerobic digestion (Georgiou et al., 2019). Thus, this study intended to evaluate the air stripping as pre-treatment in reducing COD, TSS and NH3-N of palm oil mill effluent.

1.2 Problem Statement

Crude palm oil (CPO), derived from oil palm, has grown in all around the world, with Indonesia and Malaysia dominating the production and exportation. Malaysia has emerged as one of the world's leading producers and exporters of palm oil products in recent decades. Every year, the number of palm oil plants is increasing, leading to an increase in fresh fruit bunch waste or effluent discharge. Malaysia contributes approximately 30% of global output and 37% of global exports, which contribute to the growth of domestic product (GDP) (Kushairi et al., 2018). Although the palm oil industry has been recognized for its contributions to economic growth and rapid development, it also contributed to environmental contamination by generate large quantities of by-products during the oil extraction process. Raw palm oil mill effluent (POME) contains a high concentration of organic materials and residual oil, resulting in a high biological oxygen demand (BOD) and chemical oxygen demand (COD). It has dark brownish in colour, high acidic value and high total suspended solids (TSS) which can highly polluting wastewater and cannot simply being release to the water stream (Zainal et al., 2017).

Methane release from POME has been one of the most critical sources of global warming. Shahidul et al. (2018) stated that there is about 600 million m^3 potential of global methane production from POME that potentially causes global warming and contributes to climate change. However, various findings showed that methane potential of POME could be a reliable source of renewable energy rather than carbon emissions (Loh et al., 2017). Natural gas, which is mainly made up of methane, is the most environmentally friendly fossil fuel. However, methane emitted into the atmosphere before being burned is detrimental to the environment because it traps heat in the atmosphere and hence leads to climate change.

Malaysia currently generates approximately 2% of its energy from renewable sources compared to the total generation mix, with a goal of reaching 20% renewable energy in the energy mix by the year 2025 (Abdullah et al., 2019). Anaerobic Digestion (AD) is a widely accepted technology used around the world to convert the massive amounts of waste produced every day into methane gas, which can then be used to generate heat and electricity in combined heat and power systems. The generation of renewable energy from AD - based biogas to offset fossil fuel-based electricity and prevent the release of harmful greenhouse gases, such as methane, will aid in increasing energy independence and meeting the CO_2 emission reduction targets to which most countries have committed (Labatut & Pronto, 2018).

For significant methane yields, the substrates for AD, which are typically activated sludge, energy crops, agro-industry residues, and animal breeding farms, should have a balanced C/N (carbon/nitrogen) ratio, a pH between 6.5 and 8.0, and a noticeable content of organic compounds (Folino et al., 2020). The high ammonia concentration in the wastewater, on the other hand, will inhibit the activity of methanogenic bacteria in AD plants, resulting in a significant reduction in methane yield. The removal of nitrogen compounds prior to AD may increase methane production by lowering the toxicity of the compounds to the microbial consortium (Folino et al., 2020). Some physico-chemical treatments, such air stripping, can remove nitrogen compounds from wastewater and this increase the production of methane.

Among numerous pre-treatment process, air stripping pre-treatment has received considerable attention due to the high denitrification rate, versatile operations, and small footprints (Jia et al., 2017). Air stripping pilot plants have been used to treat a wide variety of wastewater containing high concentrations of ammonia and toxic compounds, such as the one derived from municipal wastewater treatment plant secondary effluent, animal manure, and landfill leachate (Kinidi et al., 2018). It is a simple desorption process that is used to reduce the ammonia content of a wastewater stream. Ammonia stripping has recently been applied to anaerobic-digested effluent because it offers both economic and environmental benefits. The anaerobic digestion biogas was used to remove ammonia, which prevented methanogenesis in the anaerobic reactor from being inhibited (Kinidi et al., 2018).

1.3 Objective of Study

The main purpose of this study is to reduce chemical oxygen demand (COD), total suspended solid (TSS) and ammonia nitrogen (NH3-N) of Palm Oil Mill Effluent (POME) by using air stripping as pre-treatment process for anaerobic digestion. With this, the following sub-objectives are as following:

i. To study the performance of air stripping in reducing chemical oxygen demand (COD), total suspended solid (TSS) and ammonia nitrogen (NH3-N) of palm oil mill effluent (POME).

ii. To analyze the best stripping time and initial pH in air stripping pre-treatment process for anaerobic digestion.

1.4 Scope of Study

This research is conducted to produce biogas in anaerobic digestion of POME by using air stripping pre-treatment to reduce COD, TSS and NH3-N content in POME. In this study, POME sample obtained from Felda Lepar Hilir 3 Palm Oil Mill was used as a feedstock in the preparation of air stripping pre-treatment process to produce biogas in anaerobic digestion.

The experiment will be started with the collection of POME from the anaerobic pond. Then, POME will be tested for its, Chemical Oxygen Demand (COD), and Total suspended solids (TSS) and ammonia nitrogen (NH3-N). The 550 mL of raw POME sample was then changed to pH 8 and was filled in the glass bottle to undergo air stripping pre-treatment process. The glass bottle was connected with nalophan bag and aerator to supply 4 L/min of air flow rate for air stripping pre-treatment process. The nalophan bag is used to trap ammonia gas arise from the pre-treatment process from released to the environment. Air stripping pre-treatment process was conducted for 1 to 4 days stripping time with maintaining the temperature of 35°C by putting the glass bottle containing POME in a water bath.

After the air stripping pre-treatment was conducted, the treated POME will be tested for its COD, TSS and NH3-N. The results of parameter test before and after air stripping pre-treatment process were compared to identify the amounts of COD, TSS and NH3-N reduction and to analyze the best stripping time and initial pH in air stripping pre-treatment process for anaerobic digestion. The air stripping pre-treatment process was repeated with different value of initial pH which are 10 and 12 and the pre-treatment process was conducted for 1 to 4 days. All the laboratory work for COD, TSS and NH3-N this study was conducted at Environment Laboratory in Universiti Malaysia Pahang.

1.5 Significance of Study

The finding of this research will give benefits to the new era of renewable energy since Malaysia generate 91% of agricultural waste represents of the biomass amount, of which most is derived from palm oil mill residues. Air stripping has been proven to remove up to 98 % of volatile organic compounds (VOCs) and up to 80% of certain semi-volatile molecules. Contaminated water with volatile organic compounds (VOCs) and semi-volatile compounds has been successfully treated using air stripping. It is very effective in purifying wastewater containing ammonia nitrogen and hazardous chemicals. Aside from being cost-effective for ammonia removal, air stripping paired with anaerobic digestion seems to improve the effectiveness of the anaerobic digestion process.

Besides, air stripping reduces the amount of ammonia during anaerobic digestion process to produce more methane gas. High amount of ammonia will greatly affect the methane production during anerobic digestion process hence, with the of air stripping pre-treatment, around 98% ammonia nitrogen can be removed while improve the quality of the biogas production. Apart from that, high removal of COD, BOD, total dissolved solids, and suspended solid using air stripping will reduce the environmental pollutant. Air stripping has been used to anaerobic-digested wastewater because it provides both economic and environmental benefits.

1.6 Hypothesis

Based on the research that has been carried out, the COD, TSS and NH3-N removal of POME were influenced by operating condition in air stripping pre-treatment such as initial pH, stripping time, air flow rate and temperature. In this study the temperature and flow rate are the control parameter at 35°C and 4 L/min of air flow rate while the initial pH and stripping time are manipulated. Hence, the higher pH and longer stripping time provide a higher COD, TSS and NH3-N removal efficiencies in air stripping pre-treatment of POME.

CHAPTER 2

LITERATURE REVIEW

2.1 Renewable Energy

Renewable energy has the potential to be a huge success in the economic growth of a nation and it may completely insulate energy sources while simultaneously preventing and mitigating climate change by lowering fossil fuel usage, which is beneficial to the economy and long-term sustainability. In 2019, renewable technologies provided around 11% of global primary energy(Statistical Review of World Energy, 2021). Malaysia has been devoted to green energy production since 2001 in order to diversify energy sources for power generation, in accordance with the market force philosophy. Unfortunately, the government determined that the business-as-usual method is unsuited and ineffective for long-term development (Mohd Chachuli et al., 2021).

The Malaysian government developed an ambitious plan known as the National Renewable Energy Policy and Action Plan in 2008 in order to provide a balanced strategy for Malaysia's renewable energy industry, taking into account critical lessons learnt from the previous approach (Mohd Chachuli et al., 2021). The plan is to increase the use of renewable energy in the national energy mix while simultaneously encouraging long-term socioeconomic development. The strategy also emphasizes the necessity of a comprehensive research and development (R&D) plan, as well as human capital development, in assisting the renewable energy industry to grow more quickly, resulting in economic advantages via the creation of innovative products and services.

Malaysia said in 2018 that it will use 20 % sustainable energy in its power mix by 2025. The Southeast Asian nation, which is mostly fueled by thermal power plants, has a 2% renewable energy contribution to its generating mix at the end of 2018. To meet 2025 target, Malaysia's renewable energy industry is anticipated to invest RM33 billion (US$8 billion) in Malaysia's Ministry of Energy, Green Technology, and Water (MEGTW) as an effort to encourage renewable energy and energy conservation to ensure the sustainability of environment and natural resources (Statistical Review of World Energy, 2021). In line with the Five Fuel Policy, the Ministry emphasizes the use of renewable energy in the generation of electricity and the manufacture of biogas. This idea was made in the Eighth Malaysian Plan (2001-2005) and was given consideration in the Ninth Malaysian Plan (2006 - 2010) (Zakaria et al., n.d.)

Renewable energies play an important role in the global energy mix in the long run, due to increased energy demand, a strong commitment to reducing carbon emissions, technology breakthroughs, and legislative assistance. Countries such as Denmark and Belgium, for example, aspire to achieve 100 % renewable power in total energy output by 2050. The investments are intended to reduce greenhouse gas emissions by at least 40% by 2030 while simultaneously enhancing economic development and job creation in Europe (Anton & Afloarei Nucu, 2020). A stable and well-developed financial framework enables greater finance for the renewables industry at cheaper rates, leading to more investment and, in turn, increased energy consumption. Firms will employ sophisticated capital markets to lower their liquidity risk and raise financing for long-term energy-efficient technological development. Furthermore, financial growth will contribute to the allocation of capital away from inefficient conventional energy and toward renewable energy development (Anton & Afloarei Nucu, 2020).

2.2 Type Of Biofuels

Biomass is a promising feedstock not only for valuable fuels but also for value-added chemicals. The conversion can be accomplished through thermochemical or biochemical means. Land-based biomass and aquatic biomass are the two broad categories of biomass. Land-based and aquatic biomass have very different main constituents. The majority of land-based biomass is lignocellulosic, which means it contains cellulose, hemicellulose, and lignin. Lipids, carbohydrates, and protein comprise the majority of aquatic biomass (Aliyu et al., 2021). This means it could be used as a feedstock for a variety of products other than biofuels. Some species have high lipid or carbohydrate content, which can be used to produce biofuels through chemical for example, transesterification of oils to biodiesel or biological routes (fermentation, for bioethanol).

Waste biomass feedstocks, such as municipal, agricultural, forestry, and industrial waste, can be used to produce biofuels (Aliyu et al., 2021). Biofuels are a type of environmentally friendly fuel derived from abundant biological sources. Biofuel is considered a renewable energy source because the feedstock content can be easily replenished, unlike fossil fuels like petroleum, coal, and natural gas. Biofuel is frequently promoted as a cost-effective and environmentally friendly alternative to petroleum and other fossil fuels, particularly in light of rising petroleum prices and increased concern about the role of fossil fuels in global warming. It includes a diverse range of fuels such as biogas, biodiesel, bioethanol, biohydrogen, etc. Biofuels are classified according to their components and existing forms, such as solid biofuels, liquid biofuels, and gaseous biofuels. Solid biofuels are typically defined as raw biomass fuels, treated biomass, and biomass residue after conversion (Zhang & Zhang, 2019). Both liquid and gaseous biofuels are byproducts of biomass conversion and are referred to as bio-oil and syngas, respectively. A more well-known classification is based on feedstock types, which divides biofuels into generations, as shown in Table 2.1.

Table 2.1 Biofuels and their corresponding feedstocks

Class	**Biomass**	**Biofuels**	**Generation**
Edible feedstock	Starch (wheat, barley, corn, potato); sugars (sugarcane, sugar beet); oil crops (rapeseed, soybeans, sunflower, palm, coconut, used cooking oil, animal fats)	Bioethanol, biodiesel	First
Nonfood-based	Forest and forest residue; agricultural biomass (straw, grass); energy crops (jatropha, cassava, miscanthus); municipal solid waste (MSW); animal manure	Hydrocarbon fuels, hydrogen, methanol, alcohols, F-T (Fischer-Tropsch) fuel, aviation fuel,	Second

		olefins	
Aquatic biomass	Microalgae; seaweed; microbes	Naphtha, diesel, hydrogen, methanol, ethanol	Third
Feedstock based on nonarable land	Engineered photosynthetic microorganisms; synthetic living factories	Various tailored biofuels (in conceptual stage)	Fourth

Source: Zhang & Zhang (2019)

Biogas is a mixture of methane and carbon dioxide with traces of hydrogen sulphide, mercaptans, and ethane, among other contaminants. The amount of methane in a substrate range from 55 to 90% by volume, depending on the substrate's nature and material, digestion process, and other factors. Gas that contains less than 50% methane is not combustible. Biogas is widely used in countries with developed agriculture (such as India, China, and Brazil), as a cost-effective and environmentally sustainable alternative to waste management and energy demand (Beschkov, 2017).

Besides, transesterification of natural lipids produces methyl or ethyl esters of fatty acids, which are used to make biodiesel. Rapeseed, soybean, refined residual sunflower oil, animal fats, and certain forms of algae are among the natural fats used as raw materials. Moreover, ethanol is a renewable energy source that is made from sugar fermentation. Ethanol is commonly used as a partial fuel substitute around the world. Since the 1980s, corn-based fuel ethanol has been used in gasohol or oxygenated fuels. The ethanol content of these gasoline fuels can vary from 5% to 10% by volume. Using ethanol-blended fuel in automobiles can significantly decrease petroleum consumption and greenhouse gas emissions (Beschkov, 2017).

Biohydrogen has the potential to be a valuable and viable alternative energy carrier to fossil fuels. Fermenting biohydrogen is the most environmentally friendly and sustainable method of producing biohydrogen, but its efficiency and production costs must be significantly reduced. The primary cost of fermentative biohydrogen production is raw material, which can be reduced by using second- and third-generation biomasses, which produce cost-competitive biohydrogen when compared to existing physicochemical methods (Zhang & Zhang, 2019).

2.2.1 Biogas

Biogas is a naturally occurring gas that is produced by anaerobic bacteria from the breakdown of organic matter and is used in energy production. Biogas differs from natural gas and it is a renewable energy source derived from anaerobic digestion rather than a fossil fuel derived from geological processes. Biogas is a gas mixture that primarily consists of methane and carbon dioxide, with minimal amounts of hydrogen sulphide and ammonia, and is saturated with water vapour. It can be burned to generate heat and electricity. It has been stated that 1.0 m^3 of POME would produce approximately 28 m^3 of biogas which has the methane potentials of about 15m^3 (Shahidul et al., 2018). Compared to natural gas, biogas produced from biomass resources has the potential to reduce greenhouse gas (GHG) emissions by 42–82% (Aparicio et al., 2020). Agricultural crops, animal wastes, sewage sludge, and other raw materials are commonly used in biogas processing.

Biogas is produced naturally in compost piles, as swamp gas, and as a by-product of enteric fermentation in cattle and other ruminants. Biogas can also be produced from plant or animal waste in anaerobic digesters or collected from landfills. It is either burned to produce heat or used in combustion engines to generate electricity. Biogas development by anaerobic digestion is divided into four stages: hydrolysis, acidogenesis, acetogenesis, and methanogenesis. Anaerobic digestion with biogas production is a complex process that involves the subsequent hydrolysis of organic macromolecules (carbohydrates and proteins) to oligosaccharides and peptides, acidogenesis to volatile fatty acids (primarily formic, acetic, and propionic), acetogenesis, and methanogenesis. The digestion process bacteria's activity and biogas production are most rapid between two temperature ranges:

29°C and 41°C (mesophilic fermentation) and 49°C and 60°C (thermophilic fermentation). The mesophilic range between 32°C and 35°C is more reliable for stable and continuous methane production. Biogas produced outside of this range of temperatures contains a lot of carbon dioxide, is not combustible and thus has no calorific value. The thermophilic regime produces more biogas but has a lower net energy efficiency due to energy losses during high temperature maintenance (Beschkov, 2017).

2.3 Palm Oil Mill Effluent (POME)

POME is a liquid waste stream from palm oil mills that is extracted during the palm oil extraction/decanting process, and it is also seen as a major environmental concern. Apart from that, it is also an excellent source of biogas. As a result, a number of palm oil-producing countries are enacting stronger legislation regarding POME discharge. (Claribelle et al., 2020). Palm oil manufacturing generates highly toxic wastewater, which is frequently deposited in disposal ponds, leading in pollutant leaching into groundwater and soil, as well as leakage of methane gas into the environment. Palm oil processing mills produce POME, which is an oily effluent containing numerous suspended components. (Kamyab et al., 2018).

Apart from producing palm oil, the oil palm sector also generates a significant amount of viable and sustainable oil palm biomass (OPB). The oil makes up just around 10% of the palms' total dry matter, with the remaining 90% being of oil palm biomass. In 2010, about 80 million tonnes of OPB were produced, but by 2020, that number is predicted to rise up to 100 million tonnes. (Zainal et al., 2017). POME is a non-toxic waste since no chemicals are employed in the oil manufacturing process. Due to its organic and nutritional content, it has a high oxygen depletion potential in aquatic systems. The majority of the suspended particles in the POME are oil-bearing cellulosic compounds from the fruits. The POME is a rich source of nutrients for microorganisms because no chemicals are utilised in the oil extraction process (Kamyab et al., 2018). As the production of oil palm plantations and palm oil mills continues throughout the year, Malaysia is now one of the world's top producers and exporters of palm oil. Oil palm biomass waste accounted for nearly 47% of global palm oil supply (Abdullah et al., 2019).

However, due to the rapid development of oil palm plantations, a large amount of oil palm waste is generated, which is a huge environmental concern. Furthermore, oil palm biomass offers a wide range of applications for converting waste into value-added products. According to the Malaysia Palm Oil Board, oil palm was cultivated on 5.74 million hectares in Malaysia in 2016 (Derman et al., 2018). Palm oil biomass has recently grown, making it an ideal alternative for energy production. Palm oil mills extracted and refined roughly 11.09 tonnes of fresh fruit bunches (FFBs) per hectare in 2017, generating approximately 2.18 tonnes of crude palm oil per hectare. Palm oil output is rapidly increasing, which means more biomass or by-product residues are produced during the extraction process (Derman et al., 2018).

POME has been found to have a high concentration of nutrients such as starch, protein, and mineral salts, all of which have been proved to promote microorganism growth. A variety of strategies have been used to collect microorganisms. The processes used were mechanical, electronic, biological, and chemical. Mechanical procedures such as centrifugation, filtration, sedimentation, dissolved air flotation, and ultrafiltration membranes are used to extract microorganisms (Louhasakul et al., 2019). Electrical methods are used to concentrate cells having a negative surface charge by transporting them in an electric field. Inorganic or organic flocculants, as well as some electrolytes and synthetic polymers, cause chemical flocculation. Centrifugation and filtration have been the most extensively utilised procedures for extracting cells due to their high efficiency. These technologies, on the other hand, consume a lot of energy and necessitate a lot of upkeep (Louhasakul et al., 2019).

The advancement of new biotechnological developments and innovations has turned the role of POME from waste to non-waste or resource. Biogas capture technology and an integrated POME treatment system are currently popular in the palm oil mill, with the ultimate goal of zero discharge. This can be done by integrating several bioprocesses with the goal of transforming POME into high-value materials (Claribelle et al., 2020). POME is an excellent resource for biomass development since it contains a lot of organic acids, carbohydrates, minerals, and proteins. In fact, POME refers to a hazardous waste substance that cannot be released into the atmosphere due to the treatment process. Both aerobic and anaerobic techniques can be used to cure POME. Anaerobic digestion processes have received much interest because of their high output rate, low energy consumption, and versatility in employing a variety of organic wastes such as dairy effluent, sewage sludge, and POME (Akhbari et al., 2020)

2.4 Anaerobic Digestion

Anaerobic digestion is one of the most efficient methods for food waste processing and dealing with agricultural waste and sewage sludge. Anaerobic digestion for biogas processing takes place in a sealed vessel called a reactor, which comes in a range of shapes and sizes depending on the site and feedstock requirements. Diverse microbial communities break down (or digest) waste in these reactors to produce biogas and digestate (the solid and liquid substance end-products of the AD process), which are then discharged from the digester (US EPA, n.d.).

There are more than 1,300 anaerobic digestion systems based on sewage sludge are in use or under construction around the world. In Europe, biogas production from anaerobic digestion has increased by 4.5–5.0 % per year, with Germany becoming the main producer (Jason Travis Papenfuss et al., 2019). While in Malaysia, more than 85% of palm oil mills have chosen the ponding method for POME handling, with the remaining mills opting for open digesting tanks. In order to resolve the low removal efficiencies in terms of chemical and biological oxygen demand (COD and BOD), total suspended solids (TSS), and oil and grease (O&G) content in treated POME, as well as many environmental concerns associated with the current POME treatment process, an alternate approach was suggested to improve the treatment process of palm oil mill effluent (POME) (Khadaroo et al., 2020).

Digestion systems are technologically simple since it required little energy and area. The two types of anaerobic treatment systems are high-rate systems with biomass retention and low-rate systems without biomass retention. The growing need for "green" energy, as well as substantial advancements in anaerobic digestion technology in recent decades, particularly the development of current "high rate" and "co-digestion" systems, have all contributed to this pattern (Khadaroo et al., 2020)

2.4.1 Hydrolysis

The anaerobic digestion of POME involves a series of processes, including hydrolysis, acidogenesis, acetogenesis, and methanogenesis. Extracellular enzymes from hydrolytic microbes break down particulate inorganic materials or complex molecules, such as sugars, proteins, and lipids, into simpler molecules, such as sugar and amino acid, in the hydrolysis step (Khadaroo et al., 2019).

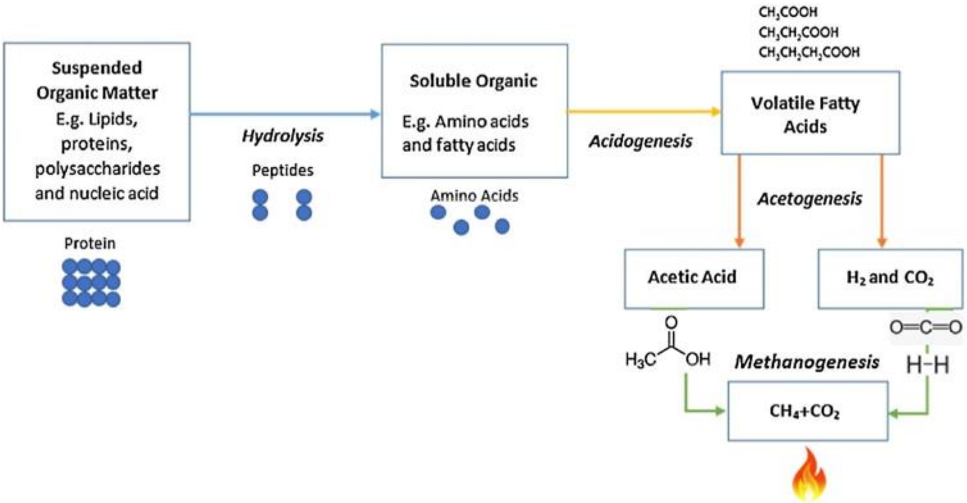

Figure 2.1 Anaerobic digestion process

Source: Khadaroo et al. (2019)

Hydrolysis occurs when water is broken down into H+ cations and OH- anions. Larger polymers are frequently hydrolyzed, usually with the aid of an acidic catalyst. Hydrolysis is a crucial first stage in anaerobic digestion because biomass is often made up of very big organic polymers that are otherwise useless. Hydrolysis breaks down large polymers like proteins, lipids, and carbohydrates into smaller molecules like amino acids, fatty acids, and simple sugars (Speight, 2018).

2.4.2 Acedogenesis

Acedogenic bacteria further degrade hydrolyzed molecules into organic acids and intermediates, resulting in acetic acid, carbon dioxide, and hydrogen, as well as inorganic chemicals including ammonia and hydrogen sulphide (Khadaroo et al., 2019). These fermentative bacteria create an acidic environment in the digestion tank by creating ammonia, CO_2, H_2S, shorter volatile fatty acids, carbonic acids, alcohols, and trace amounts of other by-products. Although acedogenic bacteria continue to break down the organic matter, it is still too large and unsuitable for the ultimate goal of producing methane, thus the biomass must be converted to acetogenesis (Speight, 2018).

2.4.3 Acetogenesis

Acetogenesis is the process of acetogens producing acetate, a derivative of acetic acid, from carbon and energy sources. Methanogens may utilise most of the remaining biomass to create methane as a biofuel after acetogens break down the biomass. Acetogenesis is a pre-methanogenesis phase because methanogenic bacteria can only ingest acetate, CO_2, and H_2 among all the products generated during fermentation. During acetogenesis, a species of bacteria known as acetogenic bacteria transforms organic acids with more than two carbon atoms and alcohols, which are fermentation products, to acetate, CO_2, and H_2 (Neto et al., 2018).

2.4.4 Methanogenesis

Methanogenesis is the final stage of anaerobic digestion in which methanogens create methane from the final products of acetogenesis and some intermediate products of hydrolysis and acedogenesis. In methanogenesis, acetic acid and carbon dioxide, the two primary components of the first three stages of anaerobic digestion, are used to produce methane in two different ways:

$$CO_2 + 4\ H_2 \rightarrow CH_4 + 2H_2O \qquad 2.1$$

$$CH_3COOH \rightarrow CH_4 + CO_2 \qquad 2.2$$

Despite the fact that CO_2 can be converted to methane and water in the reaction, the acetic acid pathway is the most common mechanism for methane to produced in methanogenesis. Methane and CO_2 are the two main products of anaerobic digestion (Speight, 2018). Anaerobic digestion is one of the most cost-effective and promising wastewater treatment process. By incorporating a pre-treatment technology into the process, the efficiency of anaerobic digestion can be boosted even more. Various categories of pre-treatment technologies for wastewater disposal have been researched over time. Pre-treatment technologies have been demonstrated to increase anaerobic digestion by speeding up digestion, reducing retention time, and improving biogas production (Khadaroo et al., 2019).

2.5 Pre-treatment of Palm Oil Mill Effluent (POME)

The use of palm oil mill effluent (POME) as a feedstock to manage waste produced in the agricultural sector, which comes from the palm oil industry, is being investigated by researchers. The use of POME as a biogas source benefits both the economy and the ecology, especially in developing countries (A Aziz et al., 2020). Raw materials that have not been pre-treated take a little longer to work with than raw materials that have been pre-treated. The type of pre-treatment procedure used is determined by the type of biogas substrate being used. Because POME is a lignocellulosic material, it must be thoroughly treated before being used in biogas processing. Pre-treatment is used to make input materials more palatable to microbial groups, resulting in a faster rate of reaction in anaerobic digestion and higher biogas production (A Aziz et al., 2020).

2.5.1 Pre-treatment of POME using Thermophilic Biohydrogen

Several techniques of using lignocellulosic biomass for the generation of various forms of biofuels, including biogas, biodiesel, pyrolytic bio-oil, and bioethanol, have been investigated in recent years, with biogases potentially playing an important part in enhancing energy security. In the meantime, POME and its derivatives have been identified as high-potential bio-hydrogen substrates. While POME is generally resistant to biodegradation, its significant content of carbohydrates, protein, nitrogenous substances, lipids, and minerals make it a promising bio-hydrogen substrate (Mahmod et al., 2017).

Many research have been carried on the pre-treatment of POME in order to increase its solubilization and release fermentable monomeric sugars that can be converted to hydrogen in anaerobic fermentation. POME is more likely to be processed in a thermophilic anaerobic environment with fewer challenges because it is released from the mill at high temperatures of roughly 80–90 °C. Furthermore, thermophilic anaerobic POME digestion has been shown to produce greater substrate degradation and biogas than mesophilic digestion (Fikri Hamzah et al., 2019).

Compared to mesophilic anaerobic digestion, thermophilic anaerobic digestion can achieve a higher organic loading rate (OLR) while still reducing COD and producing biogas, with little or no microbial washout. Mesophilic conditions also resulted in a larger concentration of volatile fatty acids (VFAs), which is attributed to decreased hydrogen productivity. The mesophilic condition, on the other hand, may be desirable due to increased process stability (Liu et al., 2017).

2.5.2 Pre-treatment of POME using Ozonation

The production of hydrogen from organic wastes through dark fermentation can be seen as a viable solution because it is the cleanest green energy carrier, exceeding methane, gasoline, and coal in terms of energy yields. Biological treatment methods are the most effective since they are less expensive, need less energy, and are extremely effective. Anaerobic digestion is also a very attractive bio-waste management approach for lowering emissions and recovering energy (Tanikkul et al., 2019).

Ozonation is an effective oxidizer that has been studied for its capacity to improve anaerobic digestion by breaking the colloidal structure. The ozonizing method is an intriguing way for breaking down complicated chemical substances into small organic molecules that bacteria may swiftly digest and convert to bioenergy. Biogas production from palm oil decanter cake, molasses effluent, and solid waste has been proven to increase using ozone pre-treatment procedures, as well as sludge degradation and dewatering (Almomani et al., 2017).

2.5.3 Pre-Treatment of POME using Acidified Process

During the bio-hythane phase, acidified POME is generated (Figure 2). A two-stage fermentation process produces bio-hythane, which is made up of hydrogen and methane. Hydrolysis and acedogenesis reactions form the first step, while acetogenesis and methanogenesis make up the second. The optimum pH range for the first level, according to a previous paper, is 5–6, with a hydraulic retention period (HRT) of 1–3 days. Meanwhile, the second stage necessitates a 10–15 days HRT at a pH of 7–8, which is ideal for methanogenic bacteria (A Aziz et al., 2020).

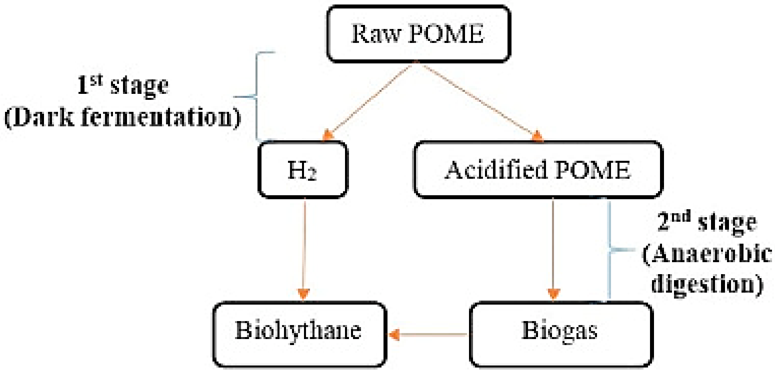

Figure 2.2 Biogas production from acidified process

Source: A Aziz et al. (2020)

POME is used to manufacture hydrogen in the first step, and the digestate produced is acidified POME with a high content of volatile fatty acids including butyrate and acetate. The acidified POME is used as a methane-producing substrate, and it has been shown to contain large amounts of biogas. The amount of biogas produced, on the other hand, varies depending on the type of bioreactor used (Sindhu et al., 2019). A continuous stirred tank reactor (CSTR) with a 5-day HRT provided 320 L CH4/kg chemical oxygen demand (COD), with 94 % of COD extracted from the acidified POME in some research (Krishnan et al., 2017).

Other research found that the lowest volume of methane emitted was 260.3 L CH_4/kg COD when the HRT was three days using an anaerobic sequencing batch reactor (ASBR). Only 71 % of COD was removed in this experiment. As a result, the amount of biogas that can be recovered from acidified POME is influenced by the used of suitable bioreactor and the HRT used (A Aziz et al., 2020).

2.6 Air stripping

Air stripping is a process that involves bringing a liquid, usually wastewater, into close contact with a gas, usually air, in order for some undesirable volatile substances present in the liquid phase to be released and carried away by the gas. These procedures create a condition in which a large surface area of the treated water is exposed to air, promoting contaminant transfer from the liquid phase to the gaseous phase.

Ammonium (NH_4^+) nitrogen can enter the aquatic ecosystems through both direct such as municipal effluent discharges and indirect such as agricultural activities (D. Li & Liu, 2019). Hence, the largest sources of ammonia wastewater pollution are municipal wastewater treatment plants (WWTPs), landfills, mines, agriculture, and animal rearing operations. Because of its harmful effects on aquatic life and eutrophication, NH_4^+ in municipal and industrial wastewater is a major contaminant. As a result, removing NH_4^+ from wastewater is necessary to protect the environment and human health. Besides, various methods, such as physico-chemical and biological, are used to remove nitrogen from wastewater. Because of the negative effects of high ammonium concentrations on microorganisms (during the biological treatment process), alternative methods based on physicochemical processes have been proposed (Zangeneh et al., 2021). Ammonia and air stripping are one of the physico-chemical technologies are available for nitrogen removal from wastewater.

Baldi et al. (2018) described steps in the ammonia stripping process starting with the conversion of ammonium ions (NH_4^+) to free ammonia (FA). Then, the diffusion of FA from the bulk liquid phase to the interface between liquid and gaseous phase followed by the transfer of FA across the interface into the gaseous phase and finally is the diffusion of FA into the bulk of gas phase. The gas used for stripping (also called the stripping agent) containing FA is then finally removed from the system.

From Equation 2.3, the aqueous form (NH4+) and gaseous form (NH_3) of the ammonium ion exist in equilibrium in aqueous solutions. The stripper process removes ammonium by raising the pH and converting ammonium ion (NH4+) to ammonia gaseous form (NH_3) (Kinidi et al., 2018). pH, air-water (G/L) ratio, water and ambient air temperature, contact time/stripping time, column height, NH4+ concentration of wastewater, hydraulic wastewater loading, and packing depth are some important parameters that have been reported to affect ammonia stripping performance (Kinidi et al., 2018). pH and temperature, on the other hand, are more effective. To improve the pH of ammonia stripping, caustic (NaOH) or lime is added. The ammonia removal efficiency can also be affected by the liquid temperature (Zangeneh et al., 2021).

$$\mathrm{NH_4}^{+} + \mathrm{OH}^{-} \leftrightarrow \mathrm{NH_3} + \mathrm{H_2O} \qquad 2.3$$

2.6.1 Parameter Influence the Air Stripping Process

Table 2.2 is the compilation of different publications studying the parameter influenced the ammonia removal efficiency. This table lists the pH, temperature, air flow rate, stripping time, and the ammonia removal efficiency achieved.

Table 2.2 Parameter influenced the ammonia removal efficiencies

Sources	pH	Temperature	Air Flow Rate	Stripping Time	Ammonia Removal	References
Ammonia removal form municipal wastewater by air stripping process: An experimental study	9.4 – 12.38	34 – 45.8 ˚C	-	1 to 14 hours	Ammonia removal efficiency increased from 6.6% to 98% with the range of 1 to 14 h	(Zangeneh et al., 2021)
Air stripping pre-treatment process to enhance biogas production in anaerobic digestion of chicken manure wastewater	11	80 ˚C	4.0 L/min	30 days	More than 80% ammonia removal could be achieved	(Fakkaew & Polprasert, 2021)
Effects of Ammonia Stripping and Other Physico-Chemical Pretreatments on Anaerobic Digestion of	8 – 10	40 ˚C	5.0 L/min	24 hours	Up to 97% ammonia removal could be achieved	(Folino et al., 2020)

Swine Wastewater						
Optimization of Ammonia Stripping of Piggery Biogas Slurry by Response Surface Methodology	11	30 ˚C	466.7 L/min	90 minutes	The average removal rate of ammonia removal can reach approximately 73%.	(Zou et al., 2019)
Influence of Ammonia Stripping Parameters on the Efficiency and Mass Transfer Rate of Ammonia Removal	8.5	70 ˚C	15 L/min	6 hours	Achieved the best ammonia removal rate of 63.0%	(Kim et al., 2021)

Conventional ammonia stripping processes are typically performed at a temperature between room temperature and 50˚C (Zhu et al., 2017). From table 2.2, Fakkaew and Polprasert (2021) stated that from a normal plot of the standardized effects of their research, air flow rate of air stripping is one of the parameter that had a significant effect on ammonia removal efficiency besides pH and temperature. However, the interaction between air flow rate, pH and temperature had a significant effect on ammonia removal efficiency by increasing both air flow rate and temperature or air flow rate and pH simultaneously. Increased air flow rates had no significant influence on ammonia removal efficiency at lower temperatures, whereas raising starting pH resulted in increased ammonia removal efficiencies. If the air stripping process was carried out at a low air flow rate, increasing the temperature and initial pH had no discernible effect on the ammonia removal efficiencies. However, increasing the temperatures and initial pH resulting in increasing of ammonia removal efficiencies at the higher air flow rate.

Unlike temperature and pH, the air flow rate has no effect on the FA concentration in the liquid phase. Rather than that, increasing the air flow rate maintains the FA concentration gradient between the liquid and gaseous phases, which is the driving force behind ammonia mass transfer. Besides that, ammonia recovery is increasing when the air flow rate is increase. It also increases the interfacial area, allowing for greater diffusion of gaseous ammonia from the liquid to the gas phase. On the other hand, increased flow rates can result in a decrease in liquid temperature, foaming, and liquid phase evaporation (Palakodeti et al., 2021). Furthermore, Folino et al. (2020) reported that a high ammonia removal can be achieved at a high air flow rate, between 4 and 10 L_{air} $L_{swine\ water}^{-1}$ min^{-1}, without any influence of the initial pH of the wastewater.

Apart from that, the average concentration of ammonia nitrogen will decrease with increasing stripping time, while the average removal rate increases with increasing stripping time (Zou et al., 2019). In their research, after stripping was conducted for 120 min at gas flow rate 20, 24 and 28 m^3/h, the average concentration of ammonia nitrogen falls to 189.3 ± 28.1, 150.7 ± 25.0 and 182.0 ± 25.5 mg/L from 566.0 ± 16.0, 599.3 ± 25.8 and 578.7 ± 59.9 mg/L respectively and the average removal rate is 66.5% when the stripping time is further prolonged to 120 min, the average removal rate rises by only 12.1%. However, the research stated that there is no significant difference in the average removal of ammonia nitrogen when the air flow rates are changes in the order of 24 > 28 and 20 m^3/h. As a conclusion, Zangeneh et al. (2021) stated that the operational condition of pH value 8 to 12 is to increase the removal of ammonia to 98%, hence COD and TSS will reduced while research from Folino et al. (2020) stated that 24 hours HRT with pH range 8-10 could remove ammonia up to 97%.

2.6.2 Air Stripping Mechanisms

Research regarding ammonia stripping has continued unabated. Recent advancements in ammonia stripping include reactor modifications, membrane contactors, membrane distillation, ion exchange stripping loops, and microwave-assisted ammonia stripping. Therefore, some researchers have suggested the usage of innovative ammonia stripper reactors as a solution for efficient removal of ammonia. Among the ammonia stripping reactors proposed were rotating packed bed, water-sparged aerocyclone reactor, and semibatch jet loop reactor (Kinidi et al., 2018).

i. Rotating Packed Bed Reactors

The purpose of conducting ammonia removal via air-stripping in a rotating packed bed reactor was to improve the high volumetric gas-liquid mass transfer coefficients, as well as to reduce the fouling problem, the equipment size, and the associated cost, in an attempt to overcome the shortcomings identified in the conventional ammonia stripping technique. The rotating packed bed reactor appeared to be extremely efficient at process intensification due to the high efficiency of gas-liquid mass transfer achieved through strong centrifugal acceleration. Indeed, this method has been used in a variety of industrial applications, including absorption, biodiesel synthesis, hydrogen sulphide removal, and nanoparticle synthesis. The rotating packed bed system is comprised of a rotating packed bed, gas and influent controls, an effluent analyzer, and a neutralizer for effluent gas.

ii. Water-Sparged Aerocyclone Reactor

The removal of ammonia via a water-sparged aerocyclone reactor was initially designed to increase the mass transfer rate and its suitability for treating wastewater containing suspended solids. The water-sparged aerocyclone gas-liquid contactor can be used to address two significant shortcomings of the conventional packed tower, namely process performance and fouling issues during extended operation. The water-sparged reactor is made up of two concentric right-vertical tubes and an upper section with a cyclone header. Wastewater is pumped into the porous inner tube and sprayed into the water-sparged aerocyclone reactor's centerline. Following that, air is drawn into the aerocyclone located at the inner tube's top header.

iii. Semibatch Jet Loop Reactor

A jet loop reactor was used to remove ammonia via air stripping in a semibatch jet loop reactor in order to reduce the construction and operating costs associated with the conventional ammonia stripping process. Additionally, it has a higher mass transfer coefficient and is easier to adapt from pilot to industrial scale. Historically, the jet loop reactor was used to catalyse chemical or biochemical reactions. For mass transfer applications, the jet loop reactor provides exceptional mixing performance at a low energy cost. In general, jet loop reactors were constructed in a variety of configurations in terms of apparatus, nozzle dimensions, draught tube, and jet stream entry position. The jet loop reactor's principle is based on the use of the kinetic energy of a high-velocity liquid jet to entrain the gas phase, as well as to produce fine dispersion between the gas and liquid phases.

2.7 Parameter Test for Effluent

Water pollution caused by wastewater is one of the most serious global threats to the environment today and one of the sources of wastewater is POME which is by-product of palm extraction process. Malaysia is the world's second largest producer and exporter of palm oil, which is why a significant amount of POME is produced each year (Kamyab et al., 2018). POME is considered as the primary source of water pollution in Malaysia due to its high biochemical oxygen demand (BOD) and chemical oxygen demand (COD), which reduces aquatic ecosystem biodiversity and ability (Mishra et al., 2017). The laboratory tests for wastewater effluent mainly focused on four major categories (Kiepper, 2020):

i. Organics - A measurement of the concentration of carbon-based (i.e., organic) compounds with the goal of determining the relative strength of wastewater (for example, Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Total Organic Carbon (TOC), and Oil and Grease) (O&G).
ii. Solids - A measurement of the concentration of particulate solids which can dissolve or suspend in wastewater such as Total Solids (TS), Total Suspended Solids (TSS), Total Dissolved Solids (TDS), Total Volatile Solids (TVS), and Total Fixed Solids (TFS).
iii. Nutrients - A calculation of the concentration of specific nutrients such as nitrogen and phosphorus that can accelerate eutrophication (i.e., the natural ageing of water bodies)
iv. Physical Properties and Other Impact Parameters - Analytical tests that assess a wide variety of constituents have such a significant effect on wastewater treatment (e.g., temperature, color, pH, turbidity, odor).

2.7.1 Chemical Oxygen Demand (COD)

The quantity of oxidant consumed is expressed in terms of its oxygen equivalence. Because of its unique chemical properties, the dichromate ion (Cr2O72– is the specified oxidant in Methods Section 5220B, Section 5220C, and Section 5220D; it is reduced to the chromic ion (Cr3+) in these tests. The Chemical Oxygen Demand (COD) is an estimation of the amount of oxygen that can be absorbed by reactions in a given solution. It is a measure of the amount of organic, nitrite, sulphide, ferrous salts, and other reducing substances in water, with organic being the most abundant. COD is generally calculated as the mass of oxygen absorbed divided by the volume of the solution. The theory of COD detection is that under acidic conditions, virtually all organic compounds can be completely oxidized to carbon dioxide using a strong oxidizing agent. The amounts of organics in water can be easily quantified using COD detection. The higher the COD value, the more extreme the organic matter contamination by water would be. COD is most widely used to assess the sum of oxidizable contaminants present in surface water or wastewater (D. Li & Liu, 2019).

2.7.2 Total Suspended Solids (TSS)

Total suspended solids (TSS) testing determines the total concentration of suspended (non-soluble) solids in an aeration stabilization basin or effluent. Total suspended solids (TSS) data is critical in determining a waste treatment system's operational behavior. It is usually a legal test, and solids should be kept to a minimum. TSS are solids in water that can be trapped by a filter. The water sample is filtered through a pre-weighed filter to measure TSS. The residue on the filter is dried in an oven at 103–105°C until the weight of the filter does not change. The TSS is represented by an increase in the weight of the filter (Ismail et al., 2019).

The filter's weight increase represents the total suspended solids in the sample. Large floating particles or submerged agglomerates of nonhomogeneous materials from the sample may be excluded from total suspended solids measurements if their presence is determined to be unrepresentative of the entire sample. The sampling size should also be limited to yielding no more than 200 mg residue (Galinha et al., 2018).

2.7.3 Ammonia Nitrogen

Ammonia nitrogen, which is composed of both unionised and ionised ammonia, is a crucial characteristic for understanding the nitrogen cycle and determining water quality (Lin et al., 2019). There are a few analytical methods for determining ammonia nitrogen in natural waters that were published between 2014 to mid-2019. These methods include spectrophotometric, fluorometric and electrochemical methods. In this study, the salicylate method is used which using spectrophotometric in measuring ammonia nitrogen in POME.

The salicylate method is one of the ammonia quantification methods that has been widely utilised in the literature to quantify ammonia in the new field of nitrogen. The salicylate method is a variation of the indophenol technique that uses sodium salicylate as the phenolic component, sodium hypochlorite as the hypochlorite source, and sodium nitroprusside as the catalyst. Aqueous samples, non-aqueous samples, air samples, soil samples, (micro)biological samples, pervaporation samples, and acidic digests of vegetal materials have all been utilised extensively using the salicylate method (Giner-Sanz et al., 2020).

Ammonia is one of the main sources of nitrogen pollution, alongside nitrogen oxides. It reacts with sulphates and nitrates in the atmosphere to generate secondary fine particulate matter (PM2.5). PM2.5 has been shown to be hazardous to both human health and the environment. The nitrification and eutrophication of aquatic systems can both be aided by ammonia. A major effect of ammonia pollution on biodiversity is the impact of nitrogen accumulation on plant species diversity and composition within affected habitats. Ammonia pollution also effects species composition through soil acidification, direct toxic damage to leaves and by altering the susceptibility of plants to frost, drought and pathogens. At its most serious, certain sensitive and iconic habitats may be lost.

CHAPTER 3

METHODOLOGY

3.1 Introduction

This chapter discussed the details of the study that was conducted in order to attain the goal outlined in Chapter 1. Methodology in research is characterized as a systematic approach to resolving a research problem by collecting data using various techniques, interpreting the data gathered, and drawing conclusions about the research data. This chapter will describe the method, instruments and materials use in this experiment to treat Palm Oil Mill Effluent (POME) using air stripping pre-treatment with a sample collected at the first pit from Felda Lepar Hilir 3 Palm Oil Mill. At the end of experiment, the chemical oxygen demand (COD), total suspended solids (TSS) and ammonia nitrogen (NH3-N) of POME before and after pre-treatment were compared to determine the optimum initial pH and stripping time of air stripping pre-treatment of POME. Characteristics of the POME samples such as COD, TSS and NH3-N were determined according to the Standard Methods no. 5220-D, 208-E, and 8155, respectively and the NH3-N were measured using Salicylate Method. The DR 5000 Spectrophotometer is used in reading COD and NH3-N of POME.

3.2 Methodology Flow Chart

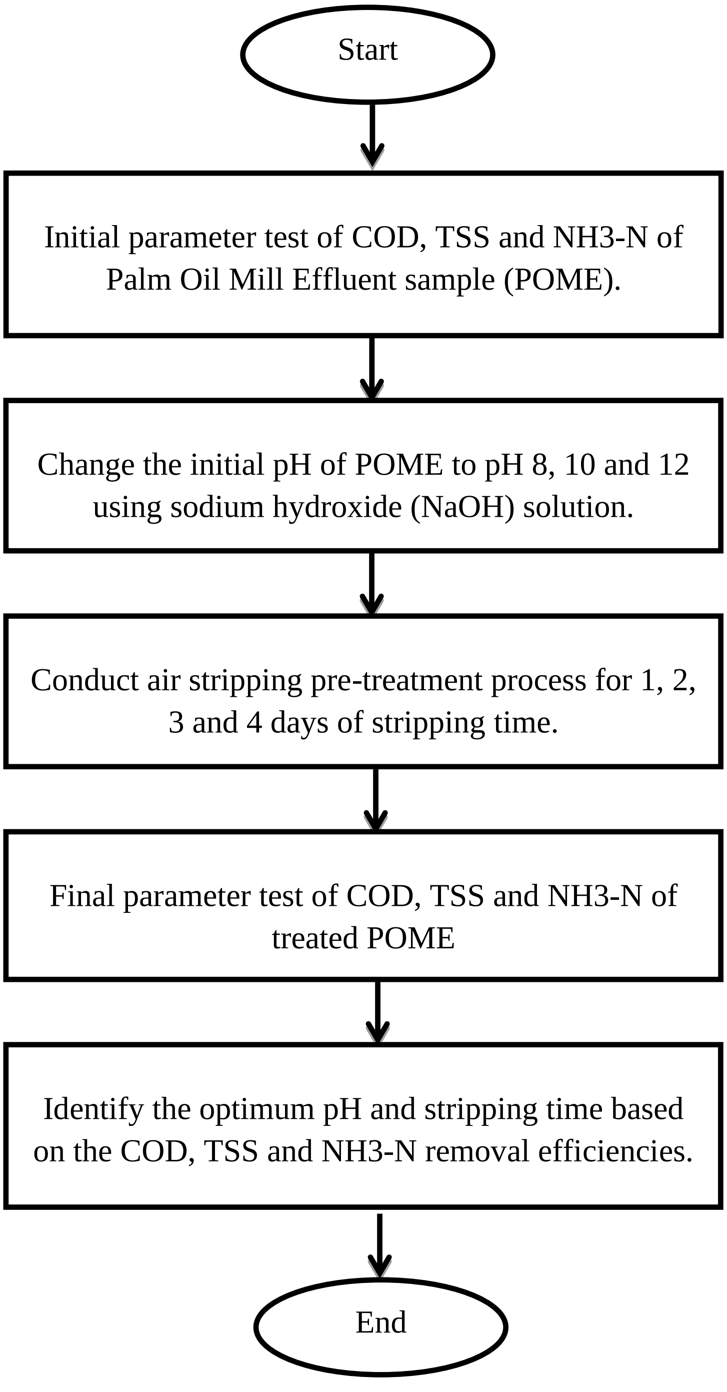

Figure 3.1 Flow chart

3.3 Materials

i) 4.0 L/min Aerator
ii) Nalophan bag
iii) Water Heater
iv) Glass Bottle
v) 25L tong
vi) Box container
vii) Silicon tube
viii) Funnel

3.3.1 Chemical Oxygen Demand

POME is a thick brownish liquid that contains high amounts of total solids, oil and grease, chemical oxygen demand (COD), and Biochemical Oxygen Demand (BOD). A few analytical tests have been developed and are used to determine the concentration (typically in milligrams per liter, mg/L or the equivalent unit of parts per million, ppm) of the various forms of solids can exist within a wastewater sample. The COD contents of POME samples were determined in this study.

The COD is a parameter used to assess the quality of water and wastewater. The COD test is frequently used to determine the efficiency of water treatment plants. This test is based on the fact that a strong oxidizing agent can completely oxidize almost any organic compound to carbon dioxide under acidic conditions. The COD value represents the amount of oxygen consumed during the chemical oxidation of organic water contaminants to inorganic end products. The COD is often measured using a strong oxidant such as potassium dichromate, potassium iodate, potassium permanganate under acidic conditions. A known excess amount of the oxidant is added to the sample. Once oxidation is complete, the amount of oxidant remaining in the solution is used to determine the concentration of organics in the sample. This is typically accomplished through titration with an indicator solution. COD is measured in milligrams per liter, which represents the mass of oxygen consumed per liter of solution.

In COD parameter test, HI 839800 COD digestion reactor is used. The experiment was started with preheat the COD Reactor to 150°C and the safety shield was placed in front of the reactor. Firstly, 2 mL of POME samples was diluted with 70 mL of distilled water because it is a high concentration sample. The caps from two

COD Digestion Reagent Vials were removed and the first vial was hold at 45-degree angle and 2.00 mL of diluted sample was added to the vial by using a clean volumetric pipette and the second vial was used as a blank by adding 2.00 mL distilled water to the vial by using a clean volumetric pipette. The vials were then capped tightly and wiped with a clean towel. The vials were inverted gently in several times to mix and they were placed in the preheated COD Reactor for 2 hours as shown in Figure 3.2. The reactor was then turned off and waited for 20 minutes for the vials to cool at 120°C or less. Each vial was inverted several times while still warm and were placed into a rack to be cooled at room temperature.

Figure 3.2 HI 839800 COD reactor

For calorimetric procedure, DR 5000 Spectrophotometer is used. It started with program 435 COD HR by pressing Hach Programs button > 435 COD HR > Start. Then, the outside of the vials was cleaned with a towel to remove fingerprints or other marks and the blank was placed into the cell holder. After that, zero button was pushed until the display shows 0 mg/L COD. Then, the prepared sample was clean and inserted into the cell holder. Read button was pushed and the result showed in mg/L COD.

3.3.2 Total Suspended Solids

Solids in wastewater can be viewed in two basic ways which are particulate size or particulate composition. The TSS test is based within the category of particulate size and is represented in Formula 3.1. As the formula shows, total solids (TS) in a wastewater sample can be separated based on particulate size into total suspended solids (TSS) and total dissolved solids (TDS) fractions. To accomplish this separation, a laboratory bench-scale filtration system is utilized under pressure to pull a measured volume of wastewater through a filter disc. Solids that remain on the disc are TSS, while solids that pass thru the disc and end up in the capture flask below are TDS.

The experiment was started with the preparation of glass-fiber disk. The glass fibre was inserted with wrinkled side up in filtration apparatus. Then, the disk was applied with vacuum as shown in Figure 3.3 and was washed with three successive 20 mL portions of reagent-grade water and the suction was continued to remove all traces of water. Then, the filter was removed from filtration apparatus and was transferred to an inert aluminium dish and kept into the oven for drying at 103°C to 105°C for 1 hour. After 1 hour, the aluminium dish was kept into the desiccator for cooled and balance the temperature and weight. The analytical balance was turn on and weight the filter and aluminium dish (in unit mg) and the result was recorded. Then, the filtering apparatus and filter was assembled, and the suction process was begun. The filter was wet with a small volume of distilled water to seat it.

Figure 3.3 Apparatus set up for TSS

In a beaker, POME sample was stirred with a magnetic stirrer at a speed to shear larger particles. While stirring, 5 mL sample was transferred onto the seated glass-fiber by using a measuring cylinder. Filter was washed with three successive 10 mL volumes of distilled water, allowing complete drainage between washing and suction was continued for about 3 min after filtration was complete. After that, filter was removed from filtration apparatus and transferred to aluminium dish as a support. The filter was dried for at least 1 hour at 103°C to 105°C in an oven, cooled in a desiccator to balance temperature and weighed. The weight of filter, dish and residue were recorded as (unit in mg) and the cycle of drying, cooling, desiccating, and weighing were repeated until a constant weight was obtained.

$$\text{mg TSS/L} = \frac{(\text{A} - \text{B}) \times 1000}{\text{Sample volume, mL}} \quad 3.1$$

Where:

A = weight of filter + dried residue, mg

B = weight of filter, mg

3.3.3 Ammonia Nitrogen

The salicylate method is an indophenol method modification in which sodium salicylate is used as the phenolic component, sodium hypochlorite is utilised as the hypochlorite source, and sodium nitroprusside is used as the catalyst. The salicylate technique has been widely employed in a variety of applications, including aqueous and non-aqueous samples, air and soil samples, (micro) biological samples, pervaporation samples, and acidic digests of vegetal materials. The salicylate method turning the sample into a green colour solution if ammonia nitrogen is present, which can then be measured using visible spectrometry.

The DR 5000 Spectrophotometer is used to read the NH3-N content in POME samples. The DR 5000 Spectrophotometer was started with program 385 N by pressing Hach Programs button > 385 N, Ammonia, Salic > Start. The sample was prepared by diluted 2 mL of POME samples with 250 mL of distilled water because the spectrophotometer can only read the presence of NH3-N from 0.01 mg/L to 0.50 mg/L. Then, the sample was filled in a round sample cell to 10 mL mark while the second sample cell was filled with 10 mL distilled water and was used as a blank. Each cell was added with one Ammonia Salicylate Powder Pillow as shown in Figure 3.4 and the cells were shaken to dissolve the powder.

Figure 3.4 Adding Ammonia Salicylate Powder into the sample cell

Then, the timer icon on the spectrophotometer was touched to begin the three-minute reaction period. When the timer beeps, one Ammonia Cyanurate Reagent Powder Pillow was added to each cell and the cells were shaken to dissolve the reagent. The timer icon was touched again to begin the 15-minute reaction period and a green colour will develop if ammonia nitrogen is present. When the timer beeps, the blank cell was placed into the holder. The outside of the cell was cleaned with a towel to remove fingerprints or other marks. After that, zero button was pushed until the display shows 0 mg/L NH3-N. Then, the prepared sample was clean and inserted into the cell holder. Read button was pushed and the result showed in mg/L NH3-N.

3.4 Air Stripping Pre-Treatment

The air stripping process is based on the mass transfer principle. It is a process of transferring volatile components of a liquid into an air stream. In this experiment, the sample was collected from the first pit at Felda Lepar Hilir 3 Palm Oil Mill and was first tested for its pH, COD, TSS and NH3-N. Then, the air stripping process was conducted by changing the pH of 550 ml POME sample. The pH value of the POME sample was adjusted to 8 by adding sodium hydroxide solution (NaOH) into the sample and the sample was filled into a glass bottle. The glass bottle then connected with nalophan bag and aerator using silicone tube to supply 4 L/min of air flow rate.

The glass bottle containing POME was put inside a water bath with temperature of 35°C during air stripping pre-treatment process. The water bath is used to adjust the temperature of the experiments while the nalophan bag is used to trap ammonia gas arise from the pre-treatment process from released to the environment. All the connection between silicone tube with bottle and nalophan bag are secured so that there is no gas is being released to the environment. Figure 3.5 shows the scheme of the experimental setup used for the tests on the systems treating POME.

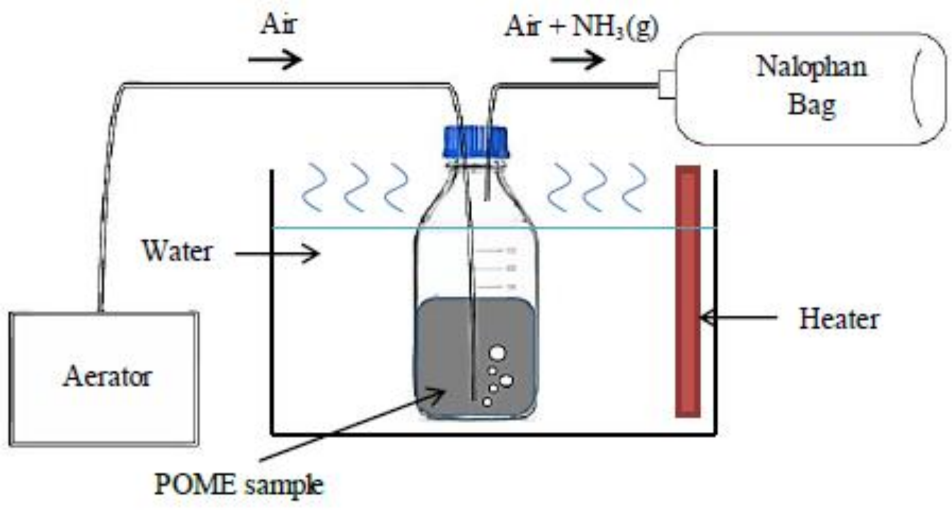

Figure 3.5 Schematic diagram of air stripping pre-treatment

The air stripping pre-treatment process was conducted with 1 days of stripping time. After the air stripping pre-treatment process, the treated POME was tested for its pH, COD, TSS and NH3-N. Then, the results of parameter test before and after air stripping pre-treatment process were compared. The air stripping pre-treatment process was repeated with different pH value which is 10 and 12 and different stripping time which is 2, 3 and 4 days. An operational condition of pH value from 8 to 12 with 24 hours of stripping time can remove up to 97% of ammonia thus reduce the COD and TSS in POME. Apart from that a high ammonia removal can be achieve at a high flow rate, between 4 and 10 L/min.

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Introduction

POME is a generic term that refers to the effluent from the last stages of palm oil mill manufacturing. It includes a mixture of fluids, dirt, residual oil, and suspended solids. Hence, air stripping is needed to increase the recovery of water and natural issues of POME and as a pre-treatment for anaerobic digestion in producing biogas. Air stripping is a treatment procedure that involves the movement of air through polluted groundwater or surface water in an above-ground treatment system. Air stripping is used to eliminate undesirable substances present in the liquid phase so that it can be released and carried away by the gas. This study investigated the performance of air stripping in reducing chemical oxygen demand (COD), total suspended solids (TSS) and ammonia nitrogen (NH3-N) of palm oil mill effluent (POME). The relationships among pH, stripping time, temperature and flow rate were examined during the air stripping of palm oil mill effluent, because these parameters can influence the COD, TSS and NH3-N removal efficiency, reagent cost and biological treatability. The results of the analysis are discussed in this chapter.

4.2 Characteristics of Palm Oil Mill Effluent

The characteristics of the palm oil mill effluent used in this study have been summarized in Table 4.1. The temperature of palm oil mill effluent is 45 ˚C since fresh fruit bunces (FFB) are sterilised using steam remove the palm fruit from the bunch, and also deactivates any enzymes during the processing at the mill. According to Kamyab et al. (2018), fresh POME is hot with acidic pH range between 4 and 5. The pH of POME samples taken from Felda Lepar Hilir 3 Palm Oil Mill was 4.71 which is below the standard discharge limit by the Malaysian Department of Environment (DOE). In research from Kamyab et al. (2016), the raw or partially treated POME has an extremely high content of total solids which is in the range of 40,500 – 75,000 mg/L and high content of COD with normally 50,000 – 100,000 mg/L. The value of totals suspended solid of POME in this study was 3400 mg/L which is exceed the standard discharge limit by the Malaysian Department of Environment. While the COD value of POME sample is 1027 mg/L. Normally, the properties of POME may vary considerably for various batches, days and factories, depending on the processing procedures and the age or kind of fruit as well as the discharge limit of the plant, climate and condition of the palm oil processing (Kamyab et al., 2018).

Table 4.1 Characteristics of palm oil mill effluent samples and its respective standard discharge limit by the Malaysian Department of Environment

Parameter	Unit	Raw POME	Standard Limit
Temperature	˚C	45	45
pH	-	4.71	5-9
COD	mg/L	1027	-
TSS	mg/L	3400	400
NH-3	mg/L	0.42	150

Source: (ENVIRONMENTAL QUALITY (PRESCRIBED PREMISES) (CRUDE PALM-OIL) REGULATIONS 1977 ARRANGEMENT OF REGULATIONS, 1977)

4.3 Effects of pH, Stripping Time, Temperature and Air Flow Rate on Air Stripping Pre-Treatment

COD, TSS and NH3-N removal efficiencies obtained from the experiments at various air stripping conditions are shown in the Table 4.2. The air stripping pre-treatment of POME was conducted using 550 mL of POME sample and the operating condition were controlled at temperature of 35 ˚C and flow rate of 4.0 L/min. Air stripping pre-treatment processes are typically performed at a temperature between room temperature and 50 ˚C (Kim et al., 2021). According to Fakkaew and Polprasert (2021) high efficiencies of air stripping pre-treatment process can be achieved if conducted in high temperatures and air flow rate because the substances in the POME become more vapored and could easier be removed with supplied air.

Table 4.2 Results of COD, TSS and NH3-N of POME after air stripping pre-treatment

Stripping Time (Day)	pH		COD (mg/L)		TSS (mg/L)		NH-3 (mg/L)	
	Initial	Final	Initial	Final	Initial	Final	Initial	Final
1	8	7.47	1027	977	3400	2854	0.42	0.34
2		7.38		969		2599		0.18
3		7.93		912		2540		0.27
4		7.58		874		2196		0.10
1	10	7.84	1027	973	3400	2383	0.42	0.27
2		7.69		980		2379		0.20
3		8.25		851		1965		0.10
4		8.18		802		1976		0.07
1	12	7.85	1027	1017	3400	1970	0.42	0.11
2		7.72		869		1949		0.09
3		7.93		806		1798		0.07
4		8.13		795		1700		0.03

Since the COD, TSS and NH3-N removal efficiencies were influenced by the stripping pH and stripping time hence, various operating condition was used to identify the best pH and stripping time for air stripping. Based on the results obtained on Table 4.2, the highest removal efficiencies obtained after the air stripping conducted for 4 days. The study from Kinidi et al. (2018) found that higher ammonia removal rate was achieved after 12 hours of air stripping. Besides that, according to Zangeneh et al. (2021), the air stripping efficiency increasing from 6.6% to 98% within 1 to 14 hours of stripping time. Hence, longer duration of stripping time indicates higher COD, TSS and NH3-N removal of POME. Normally, conventional air stripping operations are carried out at pH range of 10 – 12 (Zhu et al., 2017). According to Zangeneh et al. (2021), the efficiency of air stripping process increased from 6.6% to 98% as the pH increase from 9.4 to 12.38. In order to determine the performance of air stripping efficiencies on POME, the effect of air stripping on the COD, TSS, NH3-N removal was observed. The results can be viewed in graph form from Figure 4.1, 4.2 and 4.3.

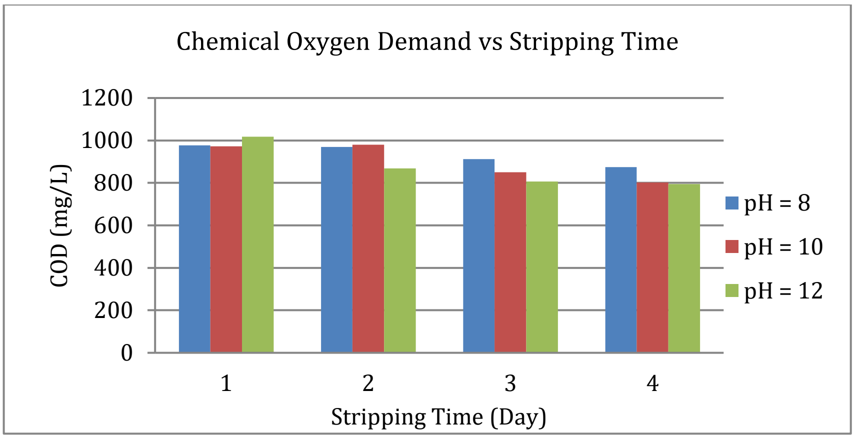

Figure 4.1 Graph of COD removal

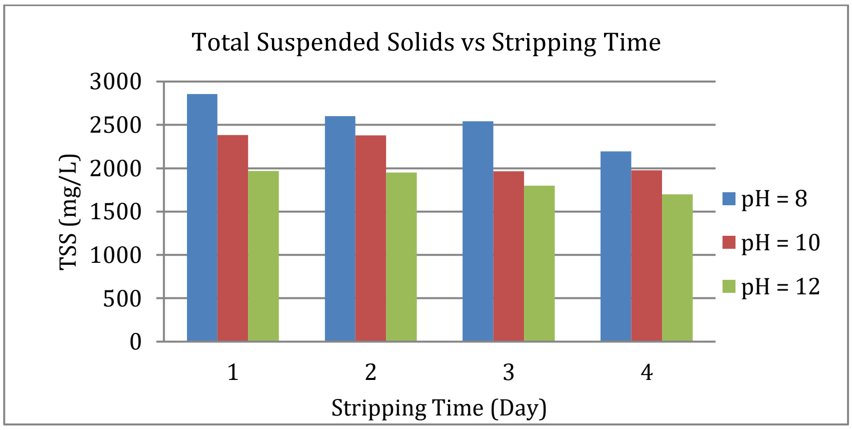

Figure 4.2 Graph of TSS removal

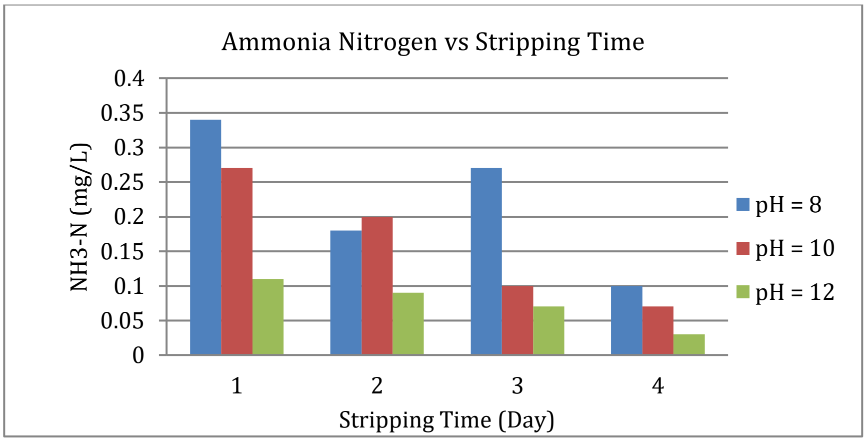

Figure 4.3 Graph of NH3-N removal

4.3.1 Chemical Oxygen Demand (COD)

The samples of POME taken from Felda Lepar Hilir 3 palm oil mill consists of 1027 mg/L COD. After the air stripping pre-treatment was conducted, the reading of COD in POME samples was decreasing. The graph of COD removal after air stripping pre-treatment is shown in Figure 4.1. The overall COD removal rate was in the range of 1% to 22.5%. The highest COD removal rate was 22.5%, achieved under the condition of pH value of 12 and stripping time of 4 days. While the lowest removal rate was 1%, under the condition of pH value 12 at 1 day of stripping time. pH value and stripping time influence the COD removal. When pH was increased, the ammonia fraction also increased, resulting in higher removal efficiency and mass transfer rate (Kim et al., 2021). Apart from that, the study reported by Smaoui et al. (2020) showed that the use of air stripping improved COD and BOD removal which may improve the volume of biogas released. Thus, the increase of pH and stripping time resulting higher COD removal in air stripping pre-treatment.

COD is an estimation of oxygen necessary to oxidize the organic matter in wastewater, as well as the amount of oxygen used by organic matter in boiling acid potassium dichromate solution (Khan & Ali, 2018). If COD levels in wastewater are high, aerobic and anaerobic biological treatment, filtration, coagulation, and flocculation should be utilized to remove organic and inorganic particles. Hence, air stripping pre-treatment is used. However, in this study, the air stripping pre-treatment are not fully treated the POME sample. When treated wastewater is released into the environment, it can contribute pollution in the form of organic matter into receiving waterways. High levels of wastewater COD indicate organic quantities that might deplete dissolved oxygen in the water, resulting in significant environmental and regulatory repercussions.

4.3.2 Total Suspended Solid (TSS)

POME normally consists of 40,500 – 75,000 mg/L of suspended solids. The samples of POME used in this study contain 3400 mg/L of total suspended solids. After the air stripping pre-treatment was conducted, the reading of TSS in POME samples was decreasing. The overall TSS removal rate was in the range of 16% to 50% after air stripping pre-treatment. The reduction of TSS after air stripping pre-treatment is shown in Figure 4.2. The highest TSS removal rate was 50%, achieved under the condition of pH value of 12 and stripping time of 4 days. While the lowest removal rate was 16%, under the condition of pH value 8 at 1 day of stripping time. The TSS value of POME sample was calculated based on Formula 3.1 shown in Chapter 3. Below is the calculation of TSS after air stripping pre-treatment was conducted at initial pH 12 and 4 days of stripping time.

$$\text{mg TSS/L} = (\text{A} - \text{B}) \times 1000)/(\text{Sample volume, mL})$$

Weight of filter + dried residue (A) = 20, 869 mg

Weight of filter (B) = 20, 860.5 mg

$$\text{mg TSS/L} = (20{,}869\ \text{mg} - 20{,}860.5\ \text{mg}) \times 1000)/(5\text{mL})$$

$$\text{mg TSS/L} = 1700\ \text{mg/L}$$

Air stripping removes contaminants from water by contacting clean air with the contaminated water, causing the Volatile Organic Compounds and other contaminants to move from the water into the air (Fischer, 2019). Based on the results analysis, the highest TSS removal of POME was at pH value 12 after 4 days of air stripping process which removed 50% of TSS. Hence, pH value and stripping time influence the TSS removal. According to Zou et al. (2019), the average removal rate increases with increasing stripping time. Under the same stripping time, the average of removal rate increases with increasing pH during the air stripping pre-treatment process. Hence, higher pH and stripping time increase the potential of TSS removal. However, the TSS of POME is still high according to standard limit set by Department of Environment (DOE) as stated in Table 4.1. Since this study is for pre-treatment, there will be next process to reduce the TSS concentration before the effluent being released to the environment.

4.3.3 Ammonia Nitrogen (NH3-N)

Typically, POME consists of 250 – 120 mg/L of NH3-N. The sample used in this research consist of 0.42 mg/L of NH3-N. During the laboratory test of NH3-N for POME sample, the salicylate method turning the sample into a dark green colour solution as shown in Figure 4.4 which shows the ammonia nitrogen is presence in POME sample. After being treated by air stripping pre-treatment, the reading of NH3-N was found decreased. The removal rate of NH3-N after POME being treated was in the range of 19% to 92.8%. Figure 4.3 shows the graph of NH3-N removal after air stripping pre-treatment was conducted. The graph shows the highest removal rate of NH3-N was under condition of pH value of 12 and 4 days stripping time with 92.8% of removal rate. The lowest removal rate was when air stripping conducted at pH value of 8 and 1 day of stripping time. Besides, the POME sample turns to light green during the laboratory test using salicylate method which indicate lower presence of NH3-N after air stripping pre-treatment.

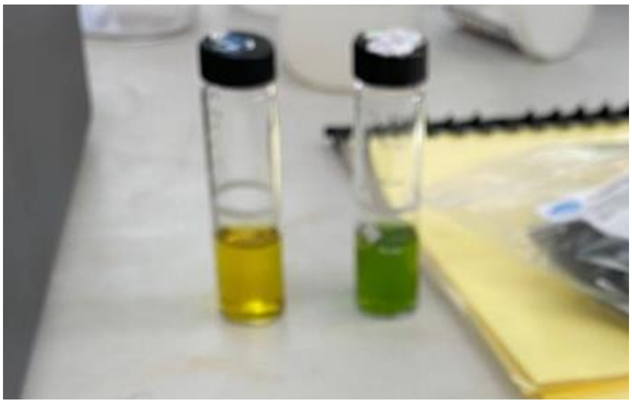

Figure 4.4 The POME sample turns to dark green

Baldi et al. (2018) described steps in the ammonia stripping process starting with the conversion of ammonium ions (NH4+) to free ammonia (FA). Then, the diffusion of FA from the bulk liquid phase to the interface between liquid and gaseous phase followed by the transfer of FA across the interface into the gaseous phase and finally is the diffusion of FA into the bulk of gas phase. The gas used for stripping (also called the stripping agent) containing FA is then finally removed from the system. In aqueous solutions, the ammonium ion exists in equilibrium in its aqueous form (NH4+) and gaseous form (NH3). The stripper process of removing ammonium by increasing the pH and converting ammonium ion (NH4+) to ammonia gaseous form (NH3) (Kinidi et al., 2018). When pH was increased, the ammonia fraction also increased, resulting in higher removal efficiency and mass transfer rate (Kim et al., 2021).

Smaoui et al. (2020) observed that the ammonia concentration cause 50% reduction of methane generation by ranges between 1.7 and 14 g/L. High ammonia concentration can inhibit microbial activities which reduce the methane production during anaerobic digestion process. Yang et al. (2018) demonstrated that when the ammonia concentration exceeded 2 g/L, more than 20% of methane production was lost in mesophilic reactors. Furthermore, Zhang and Zhang (2019) demonstrated an increase in biomethanization of piggery effluent after 80% ammonia was removed using air stripping treatment.

4.3.4 pH

Air stripping at natural pH was applied to observe the efficiency of the process to remove COD and TSS. Three pH values were selected in conducting air stripping pre-treatment of POME which are 8, 10 and 12. According to Jia et al. (2017), the gas - liquid ratio is linear to the stripping efficiency at strongly alkaline. Besides, the pH is above 9.5 and stripping after 6 hours can guarantee more than 50% of the blowing efficiency. After the completion of the air stripping process between 1 to 4 days of stripping time, the pH of all samples was found decreasing to pH 7 to 8 ± 0.18. The study reported by Kim et al. (2021) showed that the final pH values were decreased due to the removal of free ammonia gas.

The treated POME has a suitable pH for anaerobic digestion process in order to produce biogas. The optimum pH range in an anaerobic digester is 6.8 to 7.2. However, the process can tolerate a range of 6.5 up to 8.0 (Janesch et al., 2021) .At a pH of 3.5 to 4.5, the wastewater has a lot of organic matter in it. Anaerobic digestion could be a good way to clean up wastewater that has a lot of organic material in it. It also makes less sludge and generates biogas, which is a renewable source of energy. Neutral pH is usually good for anaerobic microorganisms to work in. by pH lower than 5, the metabolism of methanogenic communities could be slowed down (Widyarani et al., 2018).

CHAPTER 5

CONCLUSION

5.1 Introduction

In this chapter, the conclusion was made based on the objectives stated in Chapter 1after the analysis of this research is completed. The recommendations also included in this chapter for future project so that a better result can be obtained.

5.2 Conclusion

In conclusion, the air stripping pre-treatment was successfully reducing the chemical oxygen demand (COD), total suspended solid (TSS) and ammonia nitrogen (NH3-N) of Palm Oil Mill Effluent (POME) for anaerobic digestion process. The results of this study show that the air stripping conditions, such as the initial pH and stripping time, have a significant impact on COD, TSS, and NH-3 removal efficiencies. To achieve the COD, TSS and NH-3 removal efficiency of 22.5%, 50% and 92.8%, the optimum operating conditions for the initial pH, and stripping time were found to be 12, and 4 days, respectively at control operating condition of 35 ˚C temperature and 4.0 L/min of flow rate. The results of this study showed that the higher pH and stripping time provide a higher COD, TSS, NH3-N removal efficiencies. The use of air stripping improved COD, TSS and NH3-N removal which may improve the POME biodegradability and improve the volume of biogas release by anaerobic digestion. Air stripping solutions are eco-friendly because they employ aeration to drive dangerous chemicals out of water sources, safeguarding the user of the water or the place where the water is released back into the environment. However, the POME sample in this study are not fully treated using air-stripping pre-treatment. Therefore, discharging such partially treated wastewater is hazardous due to the high concentration of the carcinogenic colorants.

5.3 Recommendation

Based on this study, there are several recommendations to improve the results of future project. The higher temperature and flow rate can be used to increase the effectiveness of the air stripping pre-treatment. Apart from that, a bigger size of gas sampling bag is needed to trap the ammonia gas from release to the environment Besides, depending on the influent, the location and the installation, extra measures may be needed to prevent odour and noise problems.

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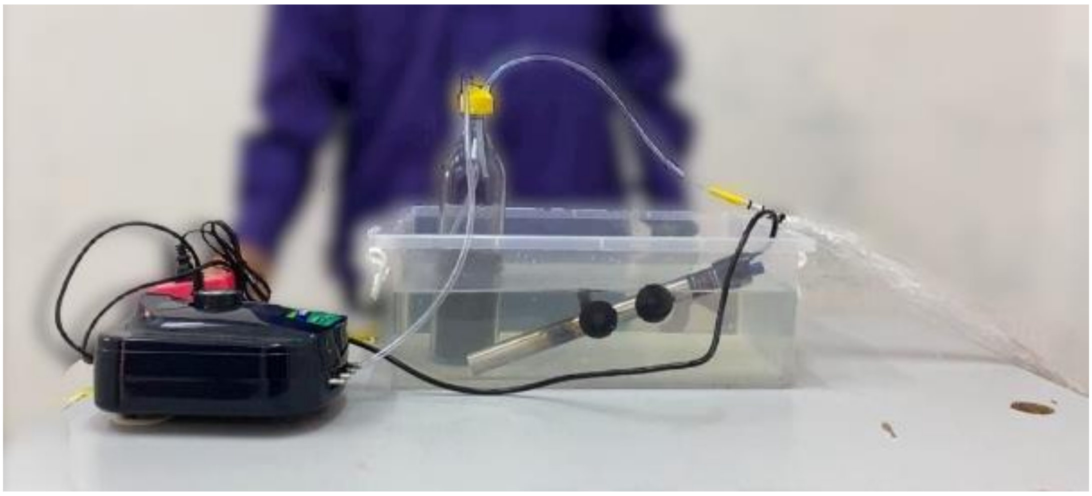
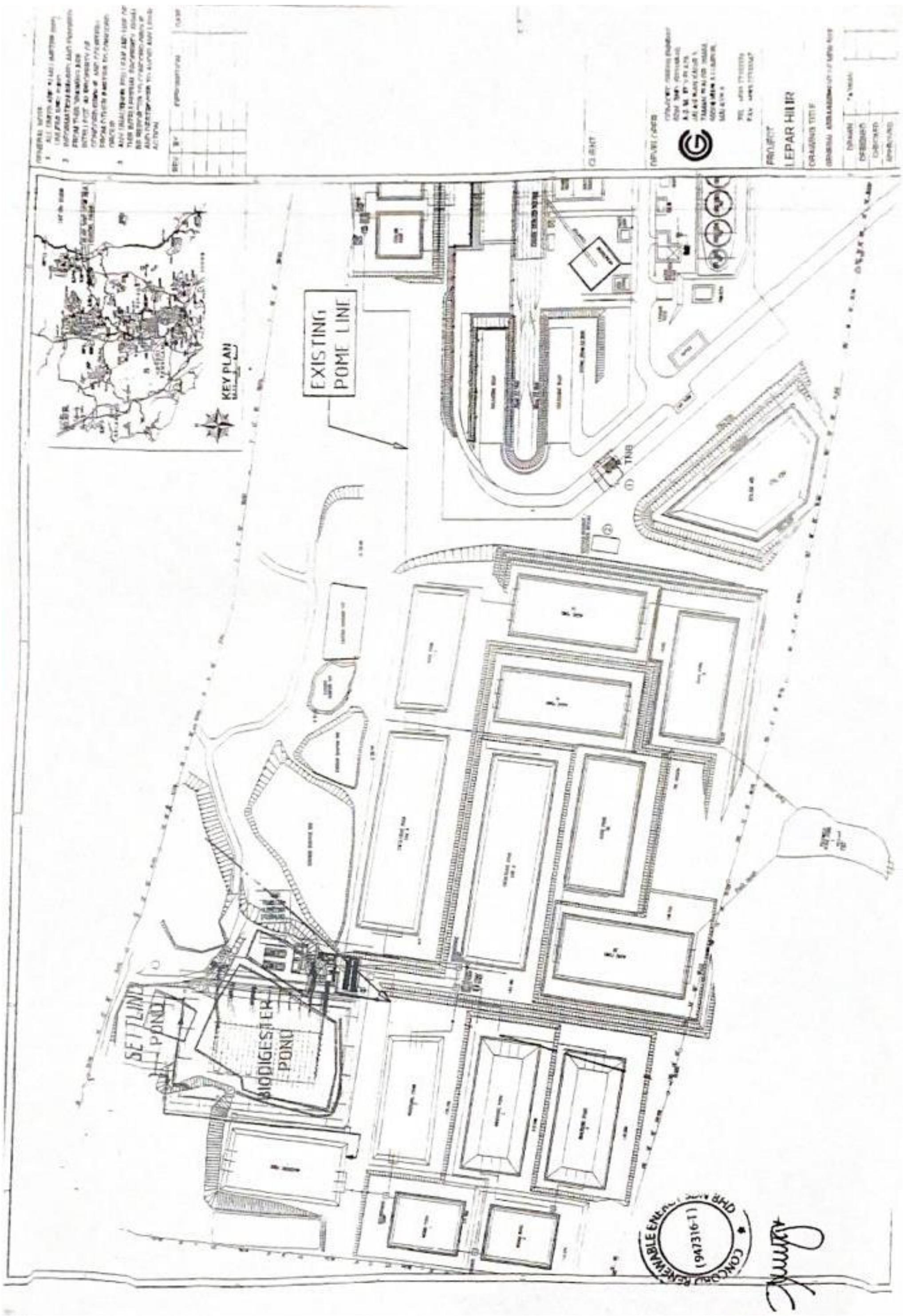
APPENDICES

Appendix A: Experimental Setup of Air Stripping Pre-Treatment



Appendix B: Plan of Felda Lepar Hilir Palm Oil Mill



Appendix C: Palm Oil Mill Effluent Plant at Lepar Hilir Palm Oil Mill