DEVELOPMENT OF RENEWABLE FUEL FROM MUNICIPAL WASTEWATER

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ABSTRACT

In this research, the electrolysis of municipal wastewater is carried out for the production of hydrogen. The municipal wastewater waste is electrolyzed to produce hydrogen. Hydrogen is considered as renewable and sustainable solution for reducing fossil fuel consumption and combating global warming. Municipal wastewater electrolysis is one of the alternative ways to produced synthetic fuel gas since it is available in plentiful supply on the earth. The objectives of this work were to characterize the municipal wastewater before the electrolysis and to characterize the electrolyzed municipal wastewater. Besides, the objectives also to determine the quantity of produced synthetic fuel gas. A number of parameters are investigated including molarities, ampere and synthetic fuel gas production. The molarities used for the electrolysis of municipal wastewater are 0.15 molar and 0.4 molar, amperes taken while running the electrolysis and the quantity of synthetic fuel gas production determined. Some laboratory testing done to characterized the municipal wastewater before the electrolysis and characterization of electrolyzed municipal wastewater. The characterization for raw municipal wastewater is in term of turbidity, suspended solid, pH, Biochemical Oxygen Demand (BOD) and Chemical Oxygen Demand (COD) while the electrolyzed municipal wastewater is characterized for BOD and COD only. Percentage removal of BOD and COD determine so that the effect of molarities to the electrolysis of municipal wastewater can be defined.

ABSTRAK

Dalam kajian ini, elektrolisis untuk sisa air sampah dapat membuktikan dalam penghasilan gas hidrogen. Sisa air sampah perlu dielektrolis untuk menghasilkan hidrogen. Hidrogen boleh dianggap sebagai satu penyelesaian di mana ia boleh diperbaharui dan secara berterusan untuk mengurangkan penggunaan bahan bakar fosil dan memerangi pemanasan global. Elektrolisis untuk sisa air sampah adalah salah satu alternatif untuk menghasilkan bahan bakar gas sintetik kerana terdapat dalam jumlah yang banyak di atas bumi. Objektif kerja ini adalah untuk menentukan ciri-ciri sisa air sampah sebelum dielektrolisis dan untuk menentukan ciri-ciri elektrolisis sisa air sampah. Selain itu, tujuan eksperimen ini adalah untuk menentukan kuantiti penghasilan bahan bakar gas sintetik. Jumlah parameter yang diteliti termasuklah kemolaran, ampere dan pengeluaran bahan bakar gas sintetik. Kemolaran yang digunakan untuk elektrolisis sisa air sampah adalah 0.15 molar dan 0.4 molar, ampere diambil semasa elektrolisis dijalankan dan kuantiti penghasilan bahan bakar gas sintetik ditentukan. Beberapa ujian makmal dilakukan untuk menentukan ciri-ciri sisa air sampah sebelum dielektrolisis dan ciri-ciri sisa air sampah yang telah dielektrolisis. Ciri-ciri untuk sisa air sampah mentah adalah dari segi kekeruhan, bahan yang tertinggal, pH, BOD dan COD sementara ciri-ciri elektrolisis sisa air sampah adalah dari segi BOD dan COD sahaja. Peratus penyingkiran BOD dan COD menentukan pengaruh kemolaran ke atas elektrolisis sisa air sampah.

TABLE OF CONTENT

3 METHODOLOGY

4 RESULT AND DISCUSSION

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

Ampere	A
Biochemical Oxygen Demand	BOD
Chemical Oxygen Demand	COD
Direct Current	DC
Dissolved Oxygen	DO
Greenhouse Gas	GHG
Hydrogen	H_2
Municipal Solid Waste	MSW
Nitrogen	N
Oxygen	O_2
Phosphorus	P
Suspended Solid	SS
Total Suspended Solid	TSS
Volt	V
Water	H_2O
World Health of Organization	WHO

CHAPTER 1

INTRODUCTION

1.1 INTRODUCTION

Crude oil such as petroleum is a complex mixture especially consists of hydrocarbons with a small number of components that containing sulfur, oxygen, nitrogen and very few components containing metals. Distillation is the process of change of crude oil into products that can be sold (marketable product) through a combination of process physics and chemistry. (Cut Fatimah, 2003, p.1).

The economic growth of modern industrialized society has been based on utilization of energy stored in fossil fuels-coal, petroleum and natural gas. At present time, about 80% of the world energy demand is met by fossil fuels. Fossil fuels are storable and portable which make them excellent fuels for the transportation.

However, the consumption of the fossil fuels has become a destructive force, locally because of emissions, spills, leaks and strip mining, regionally because of pollutant dispersion and now globally because of carbon dioxide accumulation and its threatening consequences global warming, changing climate and rising sea levels. (Karl V. Kordesch and Gunter R. Simader, 1995, p.192)

Renewable fuels are fuels that produced from renewable resources. Examples include: bio fuels and hydrogen fuel when produced with renewable processes. This is in contrast to non-renewable fuels such as natural gas, LPG, petroleum and other fossil fuels and nuclear energy. Renewable fuels can include fuels that are synthesized from renewable energy sources such as wind and solar. Renewable energy have gained in popularity due to their sustainability, low contributions to the carbon cycle and in some cases lower amounts of greenhouse gases.

Hydrogen is a fuel that is considered as a future solution of the current energy problems. Hydrogen itself is not toxic and its combustion does not create any pollution or greenhouse gases. Hydrogen is a synthetic fuel which can be produced from all and any energy sources including fossil fuels, nuclear energy and renewable energy sources. Hydrogen may be used as fuel in almost any application where fossil fuels are used today, particularly in transportation where it would be offer immediate benefits in term of reduced pollution and cleaner environment. Full benefits of hydrogen as a clean, versatile and efficient fuel may be realized only if the hydrogen produced from renewable energy sources. (UNIDO-International Centre, 2008, p.309)

Hydrogen may produce from water using renewable energy sources through a process of electrolysis. Electrolysis of water is the decomposition of water (H_2O) into oxygen (O_2) and hydrogen gas (H_2) due to an electric current being passed through the water. A basic water electrolysis unit consists of an anode, cathode, power supply and an electrolyte. Although water electrolysis to produce hydrogen and oxygen has been known for long time ago and has the advantage of producing extremely pure hydrogen, its application are often limited to small scale and unique situations where access to large scale hydrogen production plants is not possible or economical.

Water electrolysis can work beautifully well at a small scales and by using renewable electricity, it can be considered as sustainable. Water electrolysis play an important role as it produces hydrogen using renewable energy as a fuel gas for heating applications and as an energy storage mechanism. The stored hydrogen can be used as a fuel gas to substitute the used of petroleum fuel in the vehicles. (Kai Zeng and Dongke Zhang, 2009, p.2)

Thus, this study is making a research to develop the renewable fuel from the municipal wastewater using the electrolysis of water. The municipal wastewater used for the electrolysis is taken from the garbage collection of Universiti Malaysia Pahang situated near the mosque area of Universiti Malaysia Pahang, Gambang, Kuantan, Pahang. The municipal wastewater uses as material in the electrolysis to produce hydrogen and the oxygen. The hydrogen gas produced is the fuel that substitutes the fossil fuel in the vehicles and can apply to cooking stove application. The hydrogen fuel produce are clean and save for the environment.

1.2 PROBLEM STATEMENT

Oil is a carbon based fuel and the primary way it used is to burn it, releasing more than its weight in carbon dioxide because of the added oxygen. Carbon dioxide is a greenhouse gas and is expected by the most scientists to be cause of the global warming. The fuel that usually used in the vehicles is running out nowadays because the production of the fossil fuel need million years before can be applied to the vehicles.

The demanding of the fuel increasing day by day that causing the increasing of the prices of the fuel and the consumption of oil is increasing at the same time the production of the fuel is falling down because the world is currently consuming 83 million barrels of oil per day. The increasing of the consumer and vehicles production nowadays that used fossil fuel tend to the increasing of the fuel price. The prices of the fuel also depend on the world economy. If the economies deteriorate, the price of the fuel may be increasing.

Therefore, the development of renewable fuel from the municipal wastewater that produces from the electrolysis of water can solve the problem of decreasing of the fuel production and reduce the environmental pollution. The municipal wastewater is treating so that it can be used for another application. The municipal wastewater goes through the electrolysis of water can produce the oxygen and hydrogen gas. The hydrogen gas can apply to cooking stove application.

The use of hydrogen is because the hydrogen is easily produced from the electrolysis of water and also can use the renewable water. The equipment to produce of hydrogen is cheap and easy to handle.

1.3 OBJECTIVES

The objectives for this study:

1. To characterize the municipal wastewater in term of pH, turbidity, suspended solid, BOD and COD before the electrolysis.

2. To characterize the electrolyzed municipal wastewater in term of BOD and COD.

3. To determine the quantity of produced synthetic fuel gas.

1.4 SCOPE OF THE STUDY

The scope of study for this project is to produce hydrogen gas that can substitute the use of the petrol in the vehicles that effect to the environment or can apply to the cooking stove application that can reduce the environmental pollution. The productions of the hydrogen gas are from the use of the municipal wastewater taken from garbage collection of Universiti Malaysia Pahang near the area of the mosque of Universiti Malaysia Pahang, Gambang, Kuantan, Pahang and run into the water electrolysis. The quantity of the municipal wastewater uses is 0.7 liter for each sample while varying the molarities from 0.15 molar and 0.4 molar and the municipal wastewater electrolyzed for 120 minutes or two hours to produce hydrogen. Every 15 minutes, the sample of municipal wastewater taken for the laboratory experiment to characterize the electrolyzed municipal wastewater to find the value of COD and BOD. The electric power uses for the electrolysis is 12 volt and the ampere taken every 15 minutes while the electrolysis running. Before that, the laboratory testing done with the sample of raw municipal wastewater to find the value of suspended solid, BOD, COD, pH and turbidity. This result used as control.

1.5 THESIS ORGANIZATION

There are five chapters in this thesis and was organized as follow. For each chapter, there are sub-topics in it.

In chapter 1, the introduction consists of describing of the hydrogen in a scientific way, problem of the using fossil fuel as a fuel for the transportation, the studies of the projects and the purpose of the studies. In addition, this section also includes the objective of the study and the scope of the study.

Chapter 2 is to gather all the useful information from the journal, book and article that are relate to the study. All the information gathered from this chapter will be reviewed to develop the renewable fuel from the municipal wastewater by using electrolysis.

Chapter 3 is about the methodology of the research development. This includes a methodology to complete this study such as do the experiment in the laboratory and other particular procedure used to complete this study.

Chapter 4 is about to analysis of collected data from the result based on the experiment. Each of the result will be analyzed and the result will be used to run the projects.

Chapter 5 will discuss about the achievement of the study and also recommendation regarding the project for the benefits in the future task.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

The purpose of this chapter is to collect the information from the journal, book and article that are related to the development of renewable fuel from municipal wastewater that involved in this project. Basically, this literature review will cover all about the process to develop the renewable fuel from the municipal wastewater including the definition of the hydrogen and the process of the water electrolysis. This chapter will describe the definition of the hydrogen, municipal wastewater, water electrolysis and the process to develop the renewable fuel from the municipal wastewater by using the electrolysis process. All the sources for this chapter are from the journal of Science Direct, books, article and newspaper.

Hydrogen is an important raw material for the synthesis of chemical compounds for processing of mineral oil and is an essential fuel for space transportation. Hydrogen has the highest gravimetric energy density of all known fuels. Experiment has shown that hydrogen gas will not present any problems of transportation, distribution and utilization as a source of thermal energy. As a motor vehicle fuel, whether as a gas at room temperature or liquid stored at cryogenic temperature, hydrogen has the characteristics which make it meet all the normal transportation fuel requirements. For the most part it is free from pollutants with the exception of NOx.

Other fuels have no particular safety advantages if compared with hydrogen. Hydrogen is either toxic or radioactive and thus will not be the cause of any damages. Hydrogen only requires a small amount of energy to ignite and tend to propagate rapidly especially in closed rooms. Hydrogen has high diffusivity in air and lighter in weight inflammable mixtures dilute rapidly or burn out quickly. (Ibnel Waleed Ali Hussien, 2006, p.18)

2.2 WASTE

2.2.1 Definition

Waste known as rubbish, trash, refuse, garbage or junk is unwanted or unusable material. In living organisms, waste is the unwanted substances or toxins that are expelled from them. More commonly, waste refers to the materials that are disposed of in a system of waste management. There are many types defined by modern systems of waste management, notably including:

- Municipal solid waste
- Construction wastes and demolition waste
- Institutional waste, commercial waste and industrial waste
- Medical or clinical waste
- Hazardous waste, radioactive waste and electronic waste
- Biodegradable waste

Solid waste can be defined as the useless and unwanted products in the solid state derived from the activities of and discarded by society. It is produced either by product of production processes or arise from the domestic or commercial sector when objects or materials are discarded after use. In an average person, solid waste is usually being said as the following terms:

- Garbage is principally refered to the food waste but may include other degradable organic wastes.
- Rubbish is consists of combustible and non-combustible solid waste excluding food wastes.
- Refuse is the collective term for solid wastes includes both garbage and rubbish.
- Litter are odds and ends, bits of paper, discarded wrappings and bottles. Its left lying around in public places.

2.2.2 Municipal Solid Waste (MSW)

Municipal solid waste (MSW) is a type of waste that includes predominantly household waste (domestic waste) with sometimes the addition of commercial waste collected by a municipality within a given area. They are either in solid or semisolid form and generally exclude industrial hazardous wastes. Residual waste referred to the waste that left from household sources containing materials that have not been separated out or sent for processing.

Inhabitants of the city need to be realized the importance of recycling and reuse, whereas the city council should think the management style from solely dumping to the recovery of energy from waste by incinerating and only dumping the inert ash into the landfill. An important point to success of a waste management plan is the need for accurate and up to data on the quantity and quality of the waste that is generated in the area. With this data, the proper management strategies can be planned and put into action. (Sivapalan K., Muhd Noor M.Y., Abd Halim S., Kamaruzzaman S., & Rakmi A.R., 2002, p.2)

Table 2.1: Municipal Solid Waste Generated in Kuala Lumpur

Year	Population in Kuala Lumpur	MSW Generated (tones/day)	Sources
1970	-	98.8	1
1980	-	310.5	1
1990	-	586.8	1
1998	1446803	2257	2
2000	1787000	3070	3
2005	2150000	3478	3

Generation of waste; person per day; in Malaysia may decrease or increase based on the economic status of particular area. Normally, generation of waste for one person per day is estimated to be 1 kg/day. However, the rate is increased to 1.1 until 2.0 kg/ day per person. (Source MHLG).

2.2.3 Construction Wastes and Demolition Waste

Construction and demolition debris are generated regularly in urban areas as a result of new construction, demolition of old structures and regularly maintenance of buildings. These wastes contain cement, bricks, asphalt, wood and other construction materials which are typically inert. In addition, mainly in industrialized countries, they may contain some hazardous materials such as asbestos. City authorities need to avoid disposal of these wastes in streets since these locations can become mini-dumps. Some practices for demolition wastes are based on the concept of prevention, reuse and recycling of waste.

Construction wastes are big issues in most villages and city. Most of the construction wastes are not hazardous but construction wastes can be problem for many reasons. Wastes that are not considered hazardous when discarded at a big city landfill can be harmful when discarded at a village unmanaged dumpsite. One of the biggest problems that construction wastes cause is the big volume dumped over a short period of time. A competent contractor can make a good estimation of the type and amount of waste that will generated. A waste disposal plan allows managing the construction and demolition wastes. As a general estimate for total construction wastes will be generated in the project, the table below can be used to estimate the construction waste for the management:

Table 2.2: The Total Weight Table

	Residential Construction (pounds/square foot)	**Non-Residential (pounds/square foot)**
New Construction	4.38	3.89
Renovation	Varies	17.67
Demolition	115.00	155.00

(Source: Franklin Associates, "Characterization of Building-Related Construction and Demolition Debris in the United States," U.S. Environmental Protection Agency, 1998, p.2-2, 2-3, 2-6, 2-7, 2-8, 2-9, 2-10, and A-5.)

2.2.4 Industrial Waste

Manufacturing industry has played an important role in Malaysia's economic growth for the past four decades. Malaysia continues to maintain the manufacturing industry as the main sector for the country's development process and economic growth. This sector also provides services and products that changed the way of life and the quality of life for Malaysia people and its ecosystem. However, the rapid change in industrialized generates huge amount of wastes and this signaled the need for new way of looking at solid waste management.

The existing management system in Malaysia for industrial wastes gives priority to end-of-pipe approach and promotes the use of treatment and disposal method, rather than recovery. But this approach has been found creating many environmental problems such as illegal dumping, the need for new land for the establishment of disposal facilities, among others. There are many cases of illegal dumping of industrial waste which have a significant impact to human and environment health. Table 2.3 listed important incidents of illegal dumping of industrial waste in Malaysia, creating social and environmental issues. (Ahmad Faiz Mohamed, Institute for the Environment and Development)

(Source: Recycling Point Dot Com (2003), the Star, (2003)

Table 2.3: Reported Incidents of Hazardous Wastes Illegal Disposals in Malaysia

Year	Location	Amount and Type of Wastes	Company
1989	Pantai Remis, Perak	1500 tones of toxic wastes	Unknown
1993	Bukit Merah, Perak	Radioactive wastes	Asian Rare Earth Plant, Mitsubishi Kasei
1995	Pangkor Island, Perak	41 drums of highly toxic potassium cyanide	Unknown
1995	Penang Island	28 drums of trichiorofluoromethane	Unknown
2001	Ulu Tiram, Johor	1000 tones of metal ashes	Foreign based smelting company
2003	Ijok, Selangor	500 drums of paint sludge and glue	Unknown

2.2.5 Solid Waste Impacts on Climate Change

Climate change is caused by deforestation and human activities that release huge amounts of carbon dioxide. However, many people do not realize that solid waste is a part of the loop that contributes to climate change. Climate change is caused by the emission of greenhouse gases (GHG). Some of these emissions have a direct link to solid waste. The manufacturing, distribution and use of products as well as waste generation result in GHG emissions and affect the Earth's climate.

The Earth's atmosphere contains many types of gases which includes GHG. GHGs absorb and retain heat from the sun. They regulate the Earth's climate by holding heat in an atmospheric blanket around the planet's surface. Scientists call this phenomenon as "Greenhouse Effect". Without GHGs, the average temperature on Earth would be - 2°F instead of current 57°F. However, certain human activities have released additional GHGs, hence upsetting the natural atmospheric balance of GHGs and directly increasing global temperature.

Solid waste affects climate change through landfill methane emission. The main source of manmade methane gas is from landfills. Emission of methane gas happened when organic waste is left to decay anaerobically in landfills which produce methane gas. The methane gas is 23 time more potent at trapping heat in the atmosphere rather than the common GHG that is carbon dioxide.

Source: Smart Ranger (2009-2010)

2.3 WASTEWATER

2.3.1 Definition

Wastewater is sewage, storm water and water that have been used for various purposes around the community. Unless properly treated, wastewater can harm public health and the environment. Most communities generate wastewater from both residential and non-residential sources. In USA, sewage varies regionally and from home to home based on such factors as the number and type of water using fixtures and appliances, the number of occupants, their ages and even their habits such as type of food that eat. However, when compared to the variety of wastewater flows generated by different non-residential sources, household wastewater shares many similar characteristics overall.

There are two types of domestic sewage; black water which is wastewater from toilets and gray water that refers the wastewater from all sources except the toilets. Black water and gray water have different characteristics but both contain pollutants and disease causing agents that require treatment. Non-residential wastewater in small communities is generated by such diverse sources as offices, businesses, department stores, restaurants, schools, hospitals, farms, manufacturers and other commercial, industrial and institutional entities. Storm water is a non-residential source and carries trash and other pollutants from streets as well as pesticides and fertilizers from yards and fields.

The variety of non-residential wastewater characteristics need the communities to assess each source individually or compared similar type to ensure that adequate treatment is provided. For example, public restrooms may generate wastewater with some characteristics similar to sewage but usually at higher volumes and different peak hours. The volume and pattern of wastewater flows from hotels and recreation areas often vary seasonally as well. Laundries differ from many other non-residential sources because produce high volume of wastewater containing lint fibers.