Option for Environmental Sustainability of the Biodiesel Industry in Thailand

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Abstract

Biodiesel, an alternative diesel fuel, is made from renewable biological sources such as vegetable oils and animal fats. In Thailand, the government has promoted the use of biodiesel with the purpose to reduce the imported fuel oil, air pollution and also to reduce global warming contribution. Despite obvious benefits of this industrial development, its production process generates waste/by-product which could have a significant impact on the environment if they are not managed properly. This research was aimed to adopt industrial ecology measures to alleviate the environmental problems encountered in biodiesel industry in Thailand. Five biodiesel factories were selected to analyze the nature of their industrial ecosystems including clean technology options and waste exchange between biodiesel industries and other economic activities. The results showed that 1 m^3 of biodiesel production generated spent bleaching earth, glycerin and wastewater equal to 8 kg, 140 kg and 0.61 m^3, respectively. All generated waste/by-product can be reuse/recycle or utilized as raw material for other industry or agricultural sector. Biodiesel factories can save their cost on waste disposal as well as increasing their waste/by-product value. For wastewater, a possible solution to reduce their impact on global warming contribution is the implement of clean technology. The following clean technology have been adopted to increase the efficiency of biodiesel production, as well as reduce the level of GHG, such as using sodium methoxide or potassium methoxide as catalyst; recovery methanol from methyl ester and crude glycerin; reuse wastewater for washing methyl ester, reduce oil loss in washing step. In addition, wastewater can be treated to produce biogas for generation electricity. Such an approach can contribute in transforming the biodiesel industry into a more environmentally friendly industrial activity and at the same time reduce global warming contribution.

Keyword : Biodiesel industry; clean technology; industrial ecosystem; GHG reduction

1 Introduction

IN recent times, the world has been confronted with an energy crisis due to depletion of fossil fuel resources and increased environmental issues such as global warming, while the demand of fossil fuel is increasing, especially diesel fuel. One measure to reduce the use of fossil fuel is to substitute with alternative clean energy. Biodiesel, an alternative fuel for diesel engines, is produced from vegetable sources or animal fats using the processes such as micro emulsions, pyrolysis and transesterification [1]. It is biodegradable and nontoxic fuel which is used in diesel engines. Currently, the vegetable oils that are used in the industries to

produce biodiesel are rapeseed, sunflower, palm oil and soybean. Each country in various regions utilizes different types of plant oil feedstock depending on abundance or availability, for example, soybean oil on US, rapeseed oil in European countries and palm oil in tropical countries. European Union (EU) countries are the largest producer and consumer of biodiesel synthesized from rapeseed oil. More than 80% of the world biodiesel productions are from rapeseed oil, while sunflower oil and palm oil takes only23% and 1% of total world productions, respectively [2]. Palm oil is a usual raw material for biodiesel production in Thailand due to its high crop yield and low production cost. A hectare of oil palm can produce four to five tons of crude palm oil per year and yields five times more biodiesel than rapeseed in 1 ha in Europe, ten times more biodiesel than soybean in 1 ha in US and higher than ten times more than sunflower in 1 ha [3] and [4]. Besides, by considering the energy balance of these vegetable oil it is found that the energy ratio of output to input from palm oil is the highest compared to rapeseed or soybean with the ratio of 9.6, 3.0 and 2.5, respectively [5].

In Thailand, the government has promoted the production and the use of biodiesel with purposes to reducing the country's importation fuel oil, reducing air pollution, and enhancing life quality of people. It was planned that in 2012, all diesel sold in Thailand will be 10% biodiesel, B10. It also was estimated that the consumption of the blend would be 85 M litres/day, assume that blend is 10% biodiesel, so the biodiesel requirement would be 8.5 M litres/day. About the amount of biodiesel represents a savings of 27 billion Baht/year ($675 million/year) [6].

Although biodiesel generates low green house gas emission and has a very low toxicity, its production process may cause some environmental problems. For example, wastewater from the production processes is contaminated with water-insoluble methyl ester, methanol and by-product itself. It also contains significantly higher contents of COD of 170,000 mg/L and oil and grease of 9,000 mg/L [7]. Another waste is spent bleaching earth from removing gum and color of crude palm oil. Generally, bleaching earth is added in the amount of 0.8 – 2.0% by weight of crude palm oil [8]. Glycerin, biodiesel by-product, is theoretically generated 10% by weight of feeding oil; however, in fact, its amount is more than theoretical amount [9]. Wastes/by-product generated from biodiesel production process can have a significant impact on the environment if they are not managed properly.

Industrial ecosystem, the one opportunity for improving environmental performance, is where the waste product of one process becomes the raw materials for a second process [10]. It connects to waste minimization and cleaner production program. The benefits of waste exchange include: reduced disposal costs, reduced demand of natural resources, reduced disposal quantities, and a potential increase in waste value [11].

The objectives of this research are to study biodiesel industry in term of production process and waste generations, and to generate the possible clean technology options for environmental sustainability of the biodiesel industry in Thailand. The implement of such option is a possible solution to reduce their impact on global warming contribution.

2 Material and Method

Due to the governmental promotions of biodiesel production, several biodiesel factories have been established in Thailand, including community and commercial scales.

Currently, there are 42 commercial biodiesel plants registered with Department of Industrial Works with capacity of 4 million liters/day. Palm oil is used as raw material for industrial scale plant. In this research five biodiesel factories with different investment capital were selected to represent for one small-, three mediums-, and one large-scale factory. Their production capacity varies from 20,000 to 800,000 liters per day. The comparison of general data of five selected factories is shown in Table 1

Table 1 Comparison of general data of five selected biodiesel factories

	Factory A	Factory B	Factory C	Factory D	Factory E
Investment cost (million Baht)	36	60	61	65	300
Production capacity (lit/day)	200 000	80 000	800 000	20 000	200 000
Type of process	Batch	Batch	Batch	Batch	Continuous
Own palm oil refinery plant	No	Yes	Yes	No	Yes
Raw material	Palm stearin	Palm stearin and Palm kernel oil	RBD palm oil	Used cooking oil	RBD palm oil
Alcohol	MeOH	MeOH	MeOH	MeOH	MeOH
Catalyst	CH_3ONa	KOH	NaOH	NaOH	$NaOH/CH_3ONa$

Data on production process, sources of waste generation, and environmental impacts were collected and used to mapping the technological profile of the production process. All data collected in the previous step are used as guidelines and inspiration to generate possible options for minimization of environmental impacts from biodiesel production.

3 Result & discussion

3.1 Biodiesel production process

Generally, all biodiesel production factories have almost the same processes. They begin with the mixing process of alcohol and catalyst for homogenization. Then the mixed solution is fed to react with oil or fat in the reactor where the transesterification reaction occurs in this section. The reaction mix is kept just above the boiling point of the alcohol to speed up the reaction and the reaction takes place. The products mixture, methyl ester and glycerin, undergo a separation process before excess alcohol from each fraction is removed by distillation and is reused. The methyl ester is purified by washing with warm water to remove residual catalyst or soaps and dried prior to storage, while glycerin is sometimes neutralized with an acid and sent to storage as crude glycerin. However, each factory that has different raw material has different oil or fat preparation step. A schematic of the biodiesel production is shown in Figure 1.

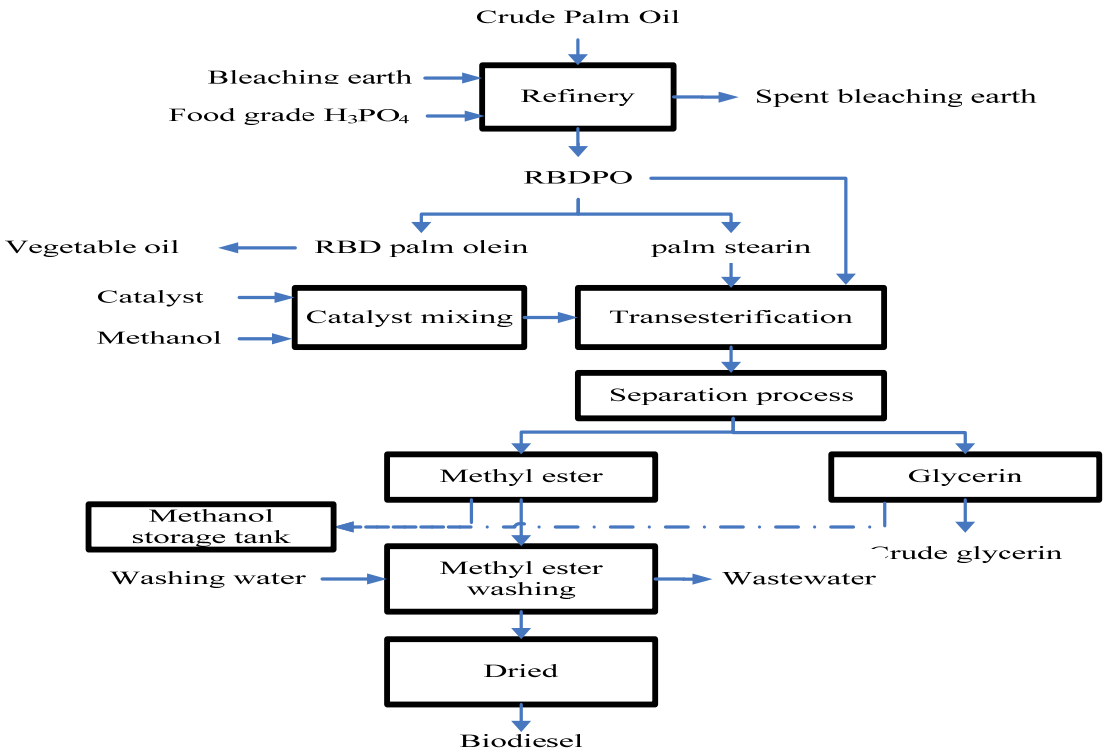

Figure 1 Flow chart of biodiesel production process.

3.2 Waste management in the biodiesel industry

Biodiesel factories generate large amounts of by-products and wastewater. Result from five case studies in Thailand showed that each 1 m^3 of biodiesel production generates 140 kg of glycerin and 0.61 m^3 of wastewater. Biodiesel factories with own their refinery process generally produce 8 kg of spent bleaching earth/ 1 m^3 biodiesel as waste. It is estimated that in 2012, a total of 0.43 million ton of glycerin, and 1.9 million m^3 of wastewater was generated by the Thai biodiesel industry. Biodiesel factories in Thailand are developing number industrial eco-system practices for waste recycling. Most of this waste/by-products can be sold or reused in the production process or by other industries, such as purify glycerin and sell as pharmaceutical grade; reuse of crude glycerin as fuel; recycle of crude glycerin as raw material for other industries via chemical reaction; and reuse of spent bleaching earth as soil conditioning substance in agricultural sectors.

3.3 Improving environmental performance of the biodiesel industry in Thailand

Over 90% of the biodiesel production in Thailand uses palm oil as raw material through a transesterification reaction method using alkali catalysis. In the final process of biodiesel production, water is usually introduced into the produced biodiesel in order to remove impurities. Therefore, there are still a number of pollution problems in the production process, such as the high oil content in wastewater, high organic content of the wastewater

and emission of greenhouse gasses. To convert palm oil into biodiesel large amount of water are consumed in the methyl ester washing step. At the same time, factories generate 0.62 m^3 of effluent for every m^3 biodiesel production. The total yield of biodiesel production in Thailand in 2008 was 1.5 million litter/day. The estimated total pollution load in term of COD from the entire biodiesel production was 91 million kg. Besides, oil loss in wastewater was equal to 4.1 million kg/ year, with a value of 100 million Baht. Several clean technology options can be implemented in order to increase production efficiency and to reduce oil loss and waste generation from production process as well as reduce the level of GHGs emission from wastewater. The important options are using sodium methoxide (CH_3ONa) or potassium methoxide (CH_3OK) as catalyst; recovery methanol from methyl ester and crude glycerin; reuse wastewater for washing methyl ester, reduce oil loss from washing by using acidic washing water. In addition, wastewater can be treated to produce biogas for generation electricity. as shown in Fig. 2.

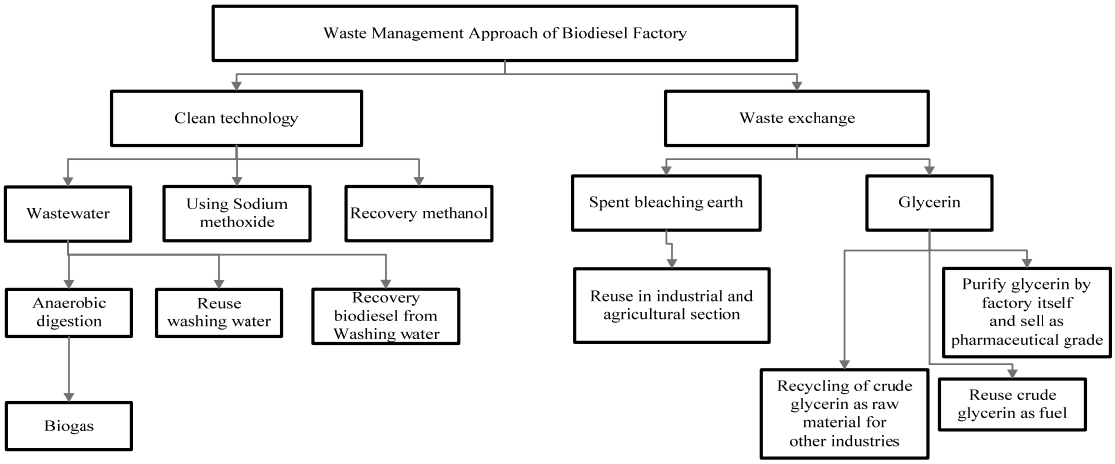

Figure 2. Waste management options for improving environmental performance of a biodiesel factory.

3.4 Biogas recovery and anaerobic treatment

However, significant amounts of wastewater have to be treated properly before disposal or discharge. The biodiesel wastewater contained the high contents of COD and O&G due to the contamination with oil feed stock, soap, methanol and glycerol. The contaminants in wastewater are varying due to the way for the adoption of clean technology approach by the factory. Methanol concentration was found to be range from 6,300 to 66,300 mg/L, while residual O&G was from 325 to 9,030 mg/L. Most biodiesel wastewater treatment plants have been constructed to meet a BOD concentration limit of 20 mg/L in the effluent. The applications of different treatment systems for biodiesel wastewater are anaerobic pond and oxidation pond, anaerobic pond and aeration lagoon and activated sludge system. In addition, the anaerobic ponds produce methane and carbon dioxide. These gasses are released into the

air. Carbon dioxide and methane are so called greenhouse gases (GHGs), which contribute to global warming. Biogas production from biodiesel wastewater on a lab- bench scale using an anaerobic baffle reactor (ABR) with a capacity of 20 liters, HRT of 10 days generated 0.38 m^3 biogas /kg COD removed with 74.5 % methane. It is estimated that biogas generation was 0.34 m^3/ m^3 biodiesel produced (or 0.25 m^3 methane / m^3 biodiesel). To compare with other studies of biogas production from other wastewater sources, it is found that biodiesel wastewater has high potential for biogas production.

The total wastewater generation from biodiesel production in Thailand in 2008 was 0.33 million m^3, so the biogas release to the atmosphere was 0.18 million m^3/year. The methane can be used for fuel in the boiler of for power generation. The electricity can be sold to Electricity Generation Authority of Thailand. Another advantage of reuse methane as fuel is reduction in GWP about 155 ton CO2-eq/year.

4. Conclusion

Thailand has high potential biodiesel production from palm oil. The combination of clean technology, industrial ecology and appropriate waste treatment is a good approach in the improvement of environmental performance of the biodiesel industry in Thailand. Such an approach can transform biodiesel in an environmental friendly industry and also to make biodiesel production in Thailand more sustainable.

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