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論文名      **Assessment of the Potential of Biodiesel Fuel Utilization for Tourist Boats in Ha Long Bay, Vietnam**

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## Summary

There has been an enormous increase in the global demand for energy in recent years as a result of industrial development and population growth. Since the early 2000s the demand for energy, especially from liquid fuels, and limits on the rate of fuel production has created the current energy crisis. Besides, the world is facing today of environmental pollution, increasing with every passing year and causing grave and irreparable damage to the Earth. Environmental pollution consists to five basic types of pollution, namely, air, water, soil, noise and light. Beyond that, high level of pollutants is causing serious global environmental problems: climate change and ozone depletion. The human race has become capable of affecting the atmosphere that encircles the Earth, and the very planet itself. One of the very important tasks of human in the future is to limit the risk of climate change to mitigate the natural disasters such as hurricanes, floods, tsunamis, landslides, melting ice, tornadoes, etc.

From the above reasons, many countries tend to find cleaner energy sources and renewable as biofuels to replace fossil fuels which are depleted day by day. Biofuels,

generally defined as liquid fuels derived from biological materials, can be made from plants, vegetable oils, forest products, or waste materials. The raw materials can be grown specifically for fuel purposes, or can be the residues or wastes of existing supply and consumption chains, such as agricultural residues or municipal garbage. Biofuels has many environmentally friendly features, such as reducing greenhouse gas emissions and less harmful to the environment. Nowadays, about 50 countries worldwide product and employ in different levels, with the top of U.S., Brazil and E.U... Global biofuels production is expected to increase to almost 42 bnl by 2020. The European Union is expected to be by far the major producer (51%) and user (57%) of biofuels.

In the context of the whole world in the situation above, in Viet Nam, dated 20/11/2007, the Prime Minister approved "Scheme on development of biofuels up to 2015, with a vision to 2025" in order to ensure energy security, protect environment and promote economic development in rural areas. The scheme includes the activities of government organizations and businesses to develop an itinerary for utilization of biofuel in Viet Nam such as the legal framework, policies to encourage the production and construction of test model and distribution of biofuels, as well as the investment projects of the Government to develop biofuels by 2025. Viet Nam will promote the development of biofuels. The target is expected to product and put into use E5 (95% mineral and 5% ethanol gasoline) and B5 oil (95% petroleum diesel and 5% biodiesel) in nationwide, enough to meet market demand in 2025.

In addition, according to Situation Report on pollution of coastal areas in Viet Nam, surface waters and coastal sediments in Ha Long Bay, one of the world natural heritages, have high oil- pollution level as much as eighteen times higher than Vietnamese standard limits. The development of economic society, especially the rapid growth of the tourism industry and shipping in recent years, has led to dramatically increase the tourist boats which are operated and anchored in Ha Long Bay. About 600 tourist boats are operating, but only 20 percent of them are equipped with waste treatment standards, account for much of oil-pollution. The fact that oil pollution caused by maritime activities in coastal Viet Nam is a matter of particular concern because of its seriously impacts on the coastal environment, directly related to aquaculture, tourism services and seaport operations, especially critical in Ha Long Bay. In order to solve this problem, we propose utilization of biodiesel fuel for the tourist boats in Ha Long Bay as a solution not only for environmental improvement but also for greenhouse gas emissions mitigation.

This study gave the assessment of the potential of biodiesel fuel utilization for tourist boats in Ha Long Bay, Viet Nam. The research not only compared the impacts between

petroleum diesel and biodiesel fuels on microorganisms in seawater and on metal materials used in the manufacture of the tourist boats, but also evaluated the social potential through the willingness to pay for biodiesel fuels utilization for tourist boats in Ha Long Bay. On the other hand, this research appreciated the value of carbon sequestration of *Jatropha curcas*, a tropical tree cultivates for biodiesel fuels production, contributed to develop the carbon credit project with *Jatropha curcas*.

The first chapter is the background of research as well as the review of available report on the utilization of biofuels in Viet Nam.

In second chapter, the effects of petroleum diesel and biodiesel fuels on four kinds of microorganisms on seawater and sea sediment. The seawater and sea sediment were taken in Ha Long Bay, Viet Nam. The microorganisms in the research are aerobic bacteria, anaerobic bacteria, yeast and mold fungi. The experiment results showed that the petroleum diesel affected to remove the microorganisms in seawater. In sea sediment environment, petroleum diesel inhibited the growth of aerobic bacteria but made the yeast and mold fungi develop. In the anaerobic condition, all fuels prevented the growth of anaerobic bacteria but the petroleum diesel inhibited strongly more than the biodiesel fuel. The biodiesel fuel did not prevent the development of microorganisms in the sea water as well as in sea sediments but this fuel prevented the growth of anaerobic bacteria in the anaerobic condition. In the opposite side, this biodiesel fuel became the food resource for feeding microorganisms. There were no differences in the effects of two types of biodiesel fuel on microorganisms. The experiment results showed the potential of using microorganisms or biological agents for bioremediation to clean up the oil pollution in the seawater.

The chapter three aims to investigate the corrosion of variety metal materials, such as aluminum cast, aluminum alloy, copper alloy, steel and stainless steel in the mixture of biodiesel fuel and petroleum diesel with the concentration of 0, 5, 10, 20 and 100% corresponding to B0, B5, B10, B20 and B100 at the temperature of 40°C by immersion test. Thereby helping the manufactures have better orientation in the selection of materials in system designed to store, transport and utilize fuel, especially for marine transportation. The mixtures of biodiesel fuel and petroleum diesel are capable corrosive impacts of various metals. For the steel, stainless steel and aluminum alloy, the corrosion was not found. The corrosion of aluminum cast was in low level. Copper and copper zinc 20% brass are affected significantly by the corrosiveness of fuel. The survey results showed that petroleum diesel is capable lowest corrosion, the corrosion increased proportional to the concentration of biodiesel fuel in the test fuel. The materials in systems designed to store, transport and utilize fuel necessitate high corrosive resistance. Copper and brass must be replaced with steel.

Aluminum had better avoid when we design systems that utilize biodiesel fuel.

In chapter four, the contingent valuation method was used in studying the willingness to pay for utilization of biodiesel fuels for tourist boats in Ha Long Bay, Viet Nam. The survey of 100 distributed questionnaires in the form of direct interviews and 100 e-mails sent out with the rate of 46% returned for three groups of respondents: the local governments, tourist boat companies and visitors. The average value of willingness to pay for biodiesel fuel is about 5% extra to convert using the biodiesel fuel. The group of governments decided pay one time the wage of a day 200,000 VND or 13,000VND/month. The business sector concerns that technical area of biodiesel is possible applications for machines; they are willing to pay more if biodiesel really does not negatively affect existing machinery. The tourists had some concerns if biodiesel fuels really improve the environmental sea water quality or not. Some of them offered to return to Ha Long Bay if the environment there is improved in the near future.

The chapter five was carried out to estimate carbon sequestration potential of *Jatropha curcas*, a tropical tree cultivated for creation new energy sources to replace the fossil fuel. Planting *Jatropha curcas* can also contribute to a reduction of greenhouse gases, and is a measure of contribute to mitigate reduce climate change by its potential of carbon sequestration. Applying the allometric equation helps to estimate the dry biomass of a *Jatropha* tree from its basal diameter. The 0.5 rule of thumb showed that the carbon content of dry wood to be 50%. The case of this study, *Jatropha* trees cultivated in Ba Vi, Hanoi, Vietnam can absorb 3.2 tCO<sub>2</sub>eq/ha. However, the carbon sequestration of *Jatropha* trees can increase by increasing the planting density of *Jatropha* trees per hectare. For example, with the same conditions of site, selected the best origin of *Jatropha* seed which had the good parameters of growth and seed yield, planting density of 2,500 trees/ha, *Jatropha*'s carbon sequestration can reach to be near 10 tonnes per hectare. The results of this study on estimation of carbon stocks can contribute to develop the carbon credit project with *Jatropha curcas* in Viet Nam.

In the last chapter, general conclusions of this research were given.

## 審査結果の要旨

本論文は、ベトナムにおけるバイオディーゼル燃料（BDF）の生産・利用に関するプロジェクトにおいて、サブテーマの一つとして取り上げられている、ハロン湾で就航している観光船の燃料として **BDF** を使用した際に予想される、さまざまな効果や課題に対して多面的に評価を行ったもので、以下の成果が得られている。

(1) 船舶から燃料が海域に漏れた場合、海水中ならびに海底泥中に生息する微生物にどのような影響が及ぶかを、軽油と **BDF** を用いて比較実験し、海水中、海底泥中ともに、軽油の流出では好気性細菌群は死滅し、イースト菌、糸状菌もほとんど増殖しないのに対し、**BDF** の流出では、好気性細菌群、イースト菌、糸状菌ともに増殖することを明らかにした。

(2) 船舶の燃料システムで使用されるさまざまな金属に対し、**BDF** の接触が金属腐食を引き起こすかどうかを実験的に調べ、アルミニウム鋳物、アルミニウム合金、鉄、ステンレス鋼については、腐食は起こらないものの、銅および銅合金である真ちゅうについては腐食が起これ、**BDF** を利用する際、材料選定時に銅材料の使用について注意する必要があることを明らかにした。

(3) ハロン湾の観光船に **BDF** を利用するとした際、観光客や観光船業者がどの程度の支払意思を持っているかを仮想評価法（**CVM : Contingent Valuation Method**）を用いて推定し、現在の旅行代金に対して、ベトナム人観光客で **3-5%** の上積み、欧米人観光客で **8-10%** の上積みが見込めること、現在の燃料代に対して観光船業者は **5%** 程度の上積みが見込めることを明らかにした。

(4) ハノイ近郊の山地において、**BDF** 原料樹種であるジャトロファを植林した際にどの程度炭素を固定する可能性があるかを現地での植林実験のデータを基に推定し、植林実験条件では、二酸化炭素換算で **1** ヘクタール当たり **3.2t-CO<sub>2</sub>** の炭素固定が見込めること、植林密度を上げた場合には、**1** ヘクタール当たり **10t-CO<sub>2</sub>** まで炭素固定効果を上げられる可能性があることを明らかにした。

以上の研究成果は、ベトナムハロン湾における観光船への **BDF** 利用に際し、様々な効果と課題を示したという点で非常に有益であるとともに、申請者が自立して研究活動を行うに必要な能力と学識を有することを証したものである。学位論文審査委員会は、本論文の審査ならびに最終試験の結果から、博士（工学）の学位を授与することを適当と認める。

以上