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CONTENTS

Utilization of Contaminated Food Plastic Bag Waste for Fuel Oil Production through Pyrolysis Process

Woraratana Pattaraprakorn and Pornrapeepat Bhasaputra

Abstract*—** *Plastic waste, the second portion of municipal wastes in Thailand, has a potential to the utilization of wastes. Though recycle is a preferable method to utilize wastes, some types of plastic such as food-containing plastic bag, supermarket bag, are improper to this application because of contaminated substances. This research focuses on the conversion of plastic waste to fuel oil by pyrolysis process. A food-containing plastic bag, made of polypropylene, is uses as a representative of plastic waste while kaolin is a catalyst of this system. The substances such as water, soybean oil, coconut milk, soybean milk, clear soup and curry soup are simulated contaminants with plastic waste. The suitable amount of catalyst for pyrolysis has 10% wt because the larger amount of catalyst is not significant to increase the yield of oil. When amount of contaminant increases the pyrolysis oil continuously decreases. The ranking effects from the most to the least of contaminants to the production of oil are soybean milk, clear soup, curry soup, coconut milk, soybean oil and water. The reduction of oil yield is up to 51% in case that soybean milk of 13 ml is contaminated with this plastic. Moreover, the pyrolysis liquid is separated into 2 layers, from IR Spectrum confirmed that, the upper layer is the pyrolysis oil. The major portion of pyrolysis oil is the diesel about 69% and the second large portion is gasoline about 24%. According to gas chromatography technique, distributions of C-number of pyrolysis oil from plastic waste with and without contaminant are different depending on type of contaminant which might be related with the quality of pyrolysis oil. Finally, in order to do the most effective pyrolysis of the food-containing plastic bag, the food stuff should be removed as much as possible.

***Keywords*— Pyrolysis, plastic waste, liquid fuel.**

1. INTRODUCTION

The amount of municipal wastes still increases countinuously due to population growth and high standard of living. In 2008, the volume of the municipal wastes in Thailand was approximately 15.03 million ton per year or 41,064 ton per day (excluding the number of municipal wastes before they were disposed to the garbage bin)[1]. The composition in the municipal wastes consists of food waste at 63.57 % and following by plastic at 16.83% as shown in Fig.1. Plastic waste is the second portion of total municipal wastes and especially of residential and school/university (Fig.2). Though food waste is the major portion of the solid wastes, the typical management is used as animal feed or fermented to be fertilizers with the assumption that the municipal wastes are separated originally. Otherwise, the mixed wastes are dumped into sanitary landfill by local government.

The problem for plastic waste that cannot be degraded by microorganism to be soil is different with food waste; therefore, larger landfill areas with longer time are required[2-3]. Pyrolysis technology; a reaction at higher temperature under insufficient oxygen; is an alternative process for demolishing the plastic waste by transforming it into fuel oil. The liquid product may be different rely on the various kinds of plastic. Advantages of pyrolysis process are not only the reduction of waste but also the regeneration of oil from the waste.

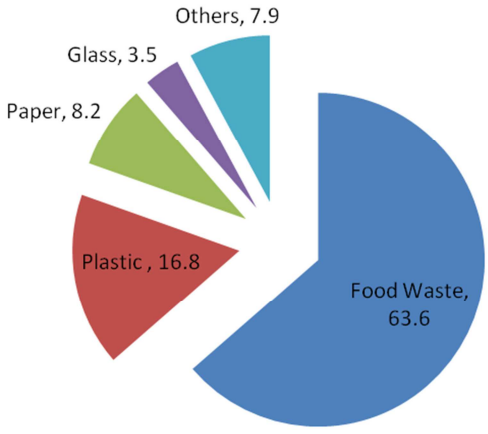

Fig. 1. The Compositions of Municiple Wastes in Thailand

However the recycle of plastic is the most preferable method, some limitations have to be concerned. Most of recycle plastic wastes have to be dry material, high density, not rotten or bad smell after keeping which usually are drinking water, goods container, etc. The other types of plastic waste are always disposed in landfill. One example of plastic waste which is not appropriate to recycle is a food-containing bag. Life style of people in urban area always buys already cooked food for dinner. Example is illustrated in Fig.3. They do not have time to

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prepare food by themselves. Plastic waste after use is mixed with municipal wastes.

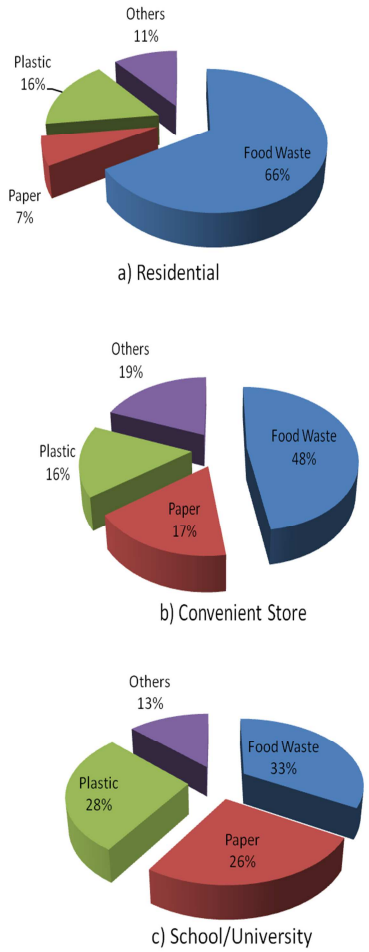

Fig. 2. Composition of Municipal Wastes Related with Type of Producer

Fig. 3. Picture of Already Cooked Food for Working Life Style

The food-containing bag is made of polypropylene, which has a potential to convert into fuel oil [4-5] but the contaminant from food might affect to the production of oil. Therefore, the purposes of this study are to study the effect of contaminant into pyrolysis process in order to produce fuel oil. The result of this study can evaluate the potential of plastic waste with food contaminant and also suggest the way to manage the food-containing bag for pyrolysis process.

2. MATERIALS AND METHODS

Plastic waste used in this research is a food-container bag, made of polypropylene (PP). Contaminant substances are water, soybean oil, soybean milk, coconut milk, clear soup and curry soup. These plastics are cut to size approximately 2 × 2 cm. In addition to, Kaolin clay (Kaolin ACROS #21174) is used as a catalyst and nitrogen gas with purity of 99.99% is used as a carrier gas in pyrolysis process.

All the experiments were carried out in the autoclave reactor type MMJ-100 (100 ml). For thermal degradation, ten grams of sample were heated in this autoclave from room temperature to 450 °C and hold at 450°C for 15 min. Nitrogen gas was connected to the autoclave for removing air before the reaction started. After that, the temperature was decreased to room temperature. In case of considering amount of catalyst and contaminant, it was mixed before heating process. Schematic diagram of the autoclave reactor is shown in Fig.4. The product was condensed, collected and analyzed while percentage of oil yield was measured and the composition and properties of oil were analyzed by thermal gravimetric analysis (TGA), Fourier Transform Infrared Spectrometer (FTIR) and Gas Chromatography (GC)[6].

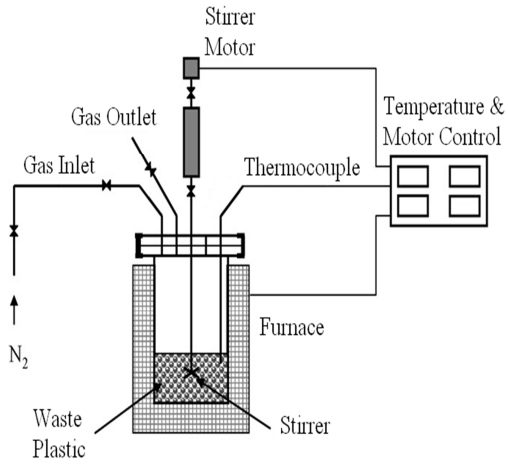

Fig. 4. Schematic Diagram of Autoclave Reactor.

3. RESULTS AND DISCUSSION

3.1 The Appropriated Amount of Catalyst

In order to identify an appropriate amount of catalyst for pyrolysis the plastic waste into oil, the amounts of catalyst are varied from 0 to 5 grams. Pyrolysis oil without using catalyst is lower than that with using catalyst between 26.1-28.4%. Thus catalyst enhances the yield of pyrolysis oil. According to the result of catalyst amount, the oil yields slightly increase with increment of catalyst as shown in Fig.5. Moreover pyrolysis oil with different amounts of catalyst reveals the similar composition as similar to [7]. Thus the amount of catalyst doesnot affect to the composition and amount of pyrolysis oil. The major composition of pyrolysis oil analyzed by TGA is diesel about 69% and the second portion is gasoline about 27%. Then one gram of catalyst or 10% wt of catalyst is chosen for the next section.

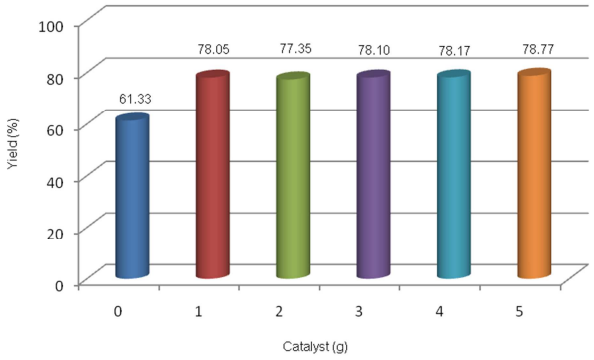

Fig. 5. Yield of Pyrolysis Oil with Different Catalyst Amount

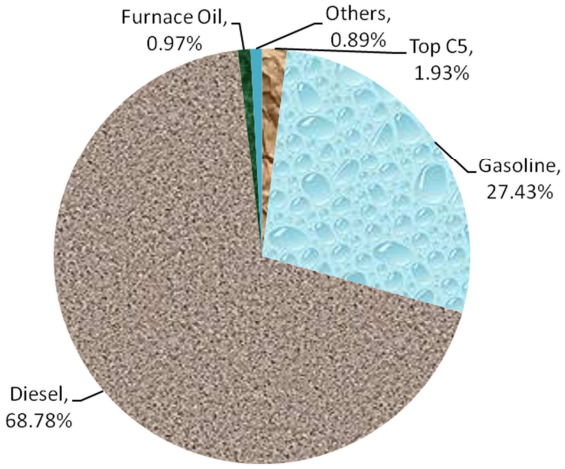

Fig. 6. Composition of Pyrolysis Oil with 10% wt Kaolin as Catalyst and without Contaminant Analyzed by TGA

3.2 Effect of Contaminant to Yield of Pyrolysis Oil

Using a food-containing bag in everyday life, the remaining food stuff is the contaminant with the plastic waste. This is the important issue to prohibit the possibility of recycle. In this section, the simulated contaminants are performed with different types and amounts of contaminants. The plastic waste with contaminant is pyrolyzed with 10%wt of catalyst and collected the pyrolysis liquid which is separated into 2 layers as illustrated in Fig.7. In this section, yield of pyrolysis oil is defined to be the upper layer due that the density of oil is lower than water or aqueous solution which the confirmation will be done later.

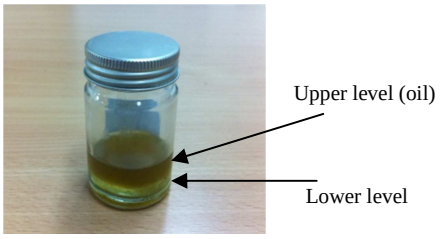

Fig. 7. Layers of Pyrolysis Liquid from Plastic Waste with Contaminant

Firstly, each type of contaminant is mixed with plastic sample to evaluate the effect of contaminant. The yields of oil from pyrolysis of plastic waste with different types and amounts of contaminant are summarized in Fig.8. With the same amount of contaminant at 7 ml, oil yields of the plastic waste with contaminant of water, soybean oil, coconut milk and soybean milk are 65.48%, 70.97%, 60.30% and 51.48%, respectively. When the amounts of contaminant are higher, the oil yields become lower. Types of contaminant also affect to the conversion of plastic to oil. The ranking of contaminant from the most to the least effect to yield of pyrolysis oil are soybean milk, coconut milk, soybean oil and water. From this study, thirteen milliliters of soybean milk reduce the yield of oil are up to 51%. Secondly, the mixed contaminant with the ratio of 1:1 are also determined the effect of contaminant. Mixture of soybean milk with water is also the most effect to the yield of pyrolysis oil (Fig.9). As a result, more than one type of contaminant much affect to the pyrolysis process. Thirdly, the actual contaminants in a food containing bag are also investigated. According to Thai's life style, two types of already cooked food are clear soup and curry soup. Main portion of clear soup is water while main portion of curry soup is coconut milk. As a result, the clear soup has more effect with the production of pyrolysis oil than water and a mixture of water with soybean oil. On the contrary that, curry soup has less effect with the production of pyrolysis oil than coconut milk and a mixture of water with coconut milk.

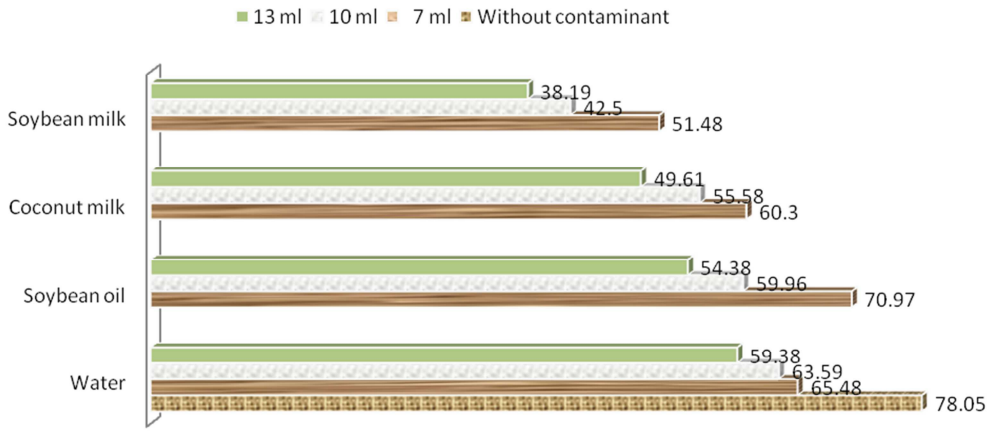

Fig. 8. Oil Yield from Pyrolysis of Plastic Waste with Different Types and Amounts of Contaminant

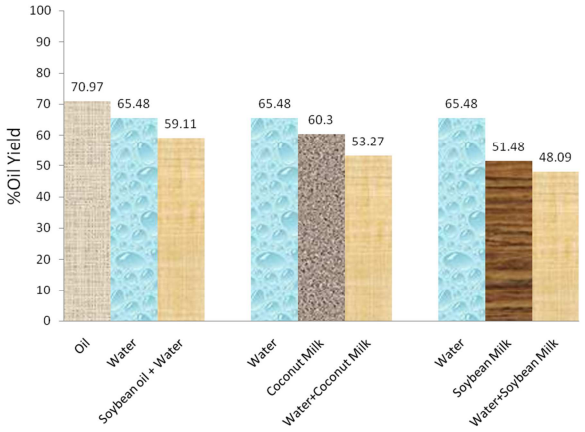

Fig. 9. Oil Yield from Pyrolysis of Plastic Waste with Mixtures of Contaminants at 7 mL

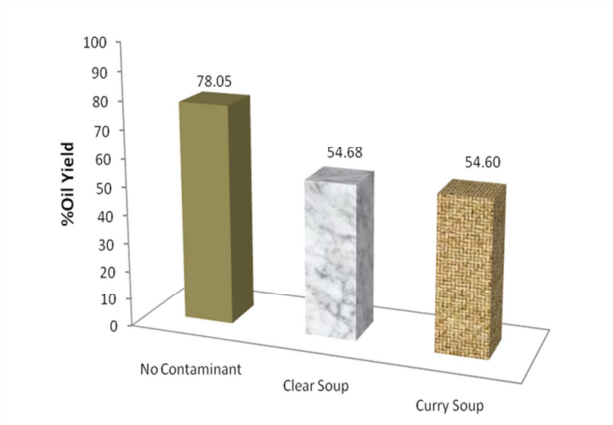

Fig. 10. Oil Yield from Pyrolysis of Plastic Waste with Real Contaminants at 7 mL

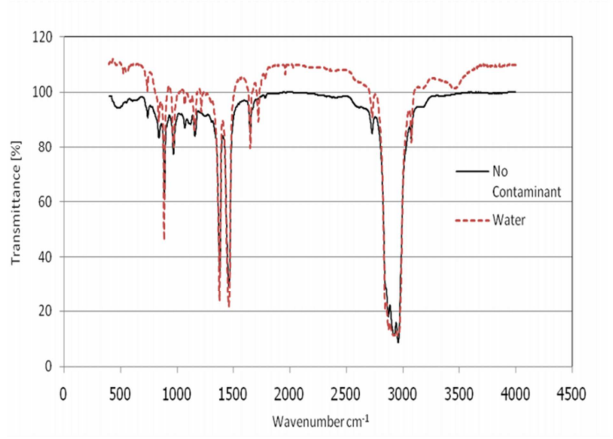

Fig. 11. IR Spectrum of Pyrolysis Oil with and without Contaminant.

3.3 Effect of Contaminant to Properties of Pyrolysis Oil

Not only yields of pyrolysis oil are investigated, but the properties of oil are also analyzed. By using FTIR technique, the comparison of spectrum with and without contaminant is made. Both IR spectrums are slightly different as illustrated in Fig.12. However IR spectrum can be identified two levels of pyrolysis liquid. IR spectrum of liquid at upper level when contaminant is water is represented as the dashed line in Fig.11 while IR spectrum of liquid at the lower level is shown in Fig.12. This can be verified that upper level of pyrolysis is the pyrolysis oil.

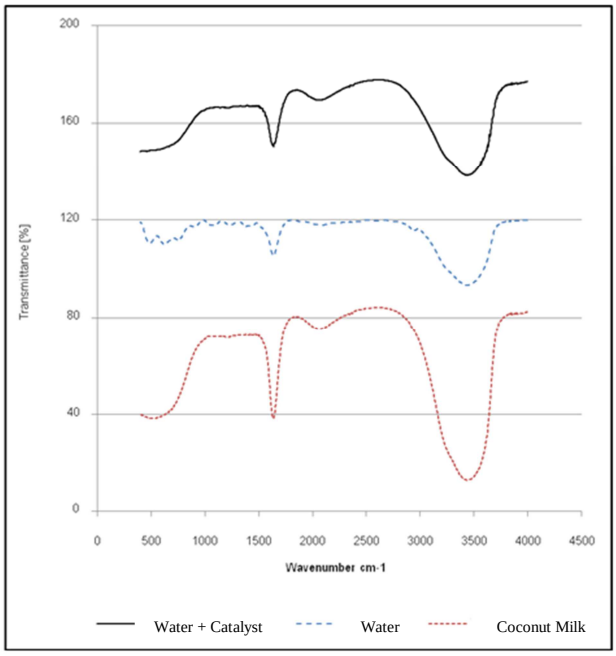

Fig.12. IR Spectrum of Pyrolysis in the Lower Level

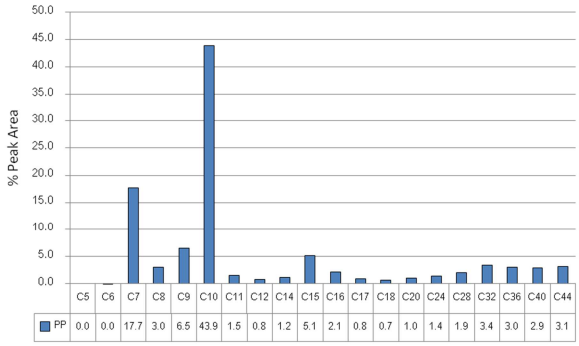

Fig. 13. Pyrolysis Oil without Contaminant Characterized by C-number (%Area)

In addition, pyrolysis oil is analyzed by GC using column of Rtx-2887 which can identify Carbon number C5-C44 by using percentage of peak areas. In case of pyrolysis oil from plastic waste without contaminant. The first and second portions of C-number are C-10 and C7 with 43.9% and 17.7%, respectively as shown in Fig.13. When the plastic waste contaminates with food, the distributions of C-number change. If the contaminant is water, the first and the second portions of C-number are C-15 and C-17, respectively. It seems to be the molecules of product are larger. While the contaminant is coconut milk, the first and the second portions of C-number are C-7 and C-9, respectively. The molecule of oil product becomes smaller. Refer to the result, the contaminant might affect to the distribution of C-number of pyrolysis oil. However it depends on type of contaminant.

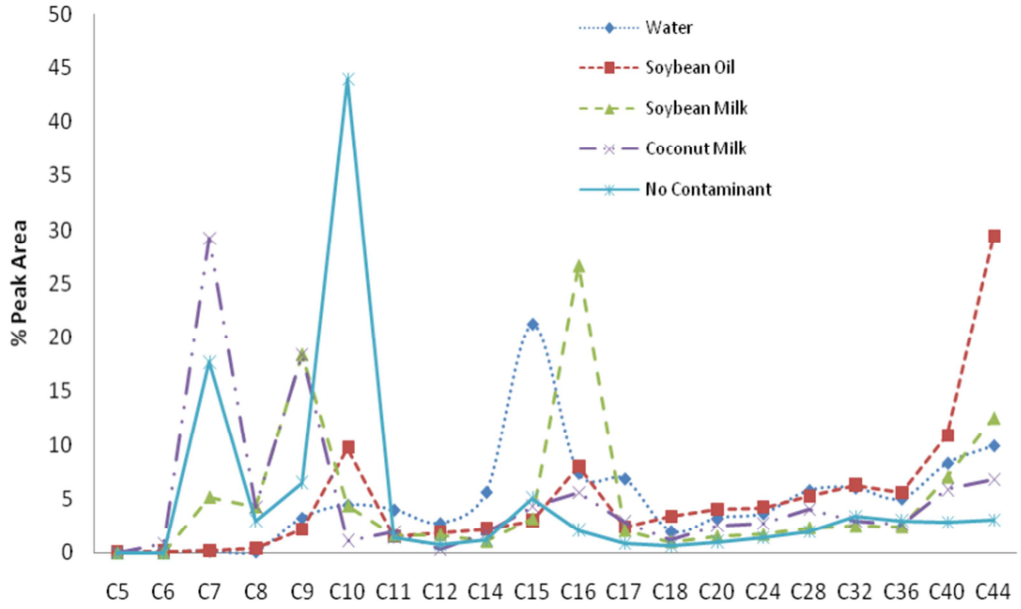

Fig. 14. Pyrolysis Oil with Contaminant Characterized by C-number (%Area)

4. CONCLUSIONS

The utilization of contaminated food plastic bag waste for fuel oil production through pyrolysis process is evaluated. Kaolin clay, used as catalyst, is important to enhance the fuel oil yield though the catalyst amount has slightly affect to the oil yield. The catalyst at 10% is the suitable amount for the pyrolysis of the food plastic bag. Liquid yield from pyrolysis process of contaminated food plastic bag is segregrate into 2 layers which the upper layer refers to the pyrolysis oil. The contaminant in the plastic bag decrease oil yield with the larger contaminant amount, the lower oil yield. The contaminant with the worst effect to the pyrolysis process is soybean milk which can be found in the everyday life. Mixtures of simulated contaminants are consistent with the real contaminants (clear soup and curry soup) which the pyrolysis oil yields are about 50%. In addition that, types of contaminant affect to C-number distribution in pyrolysis oil. The major portions of C-number from pyrolysis oil without contaminant are C7 and C10 while those from pyrolysis oil with contaminant are more different patterns. However, the pyrolysis of plastic bag contaminated with food stuff still has a potential to generate fuel oil with the appropriate management. The financial analysis should be considered in the further study. Thus, the contaminant has to be removed as much as possible prior to pyrolysis process.

ACKNOWLEDGEMENT

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Greenhouse Gas Emission from Municipal Solid Waste in Phnom Penh, Cambodia

Chhay Hoklis and Alice Sharp

Abstract— *Municipal solid waste generation in Phnom Penh has steadily increased after the civil war in 1979. Currently, Cambodia, particular Phnom Penh, is focused on methods to reduce greenhouse gas emission from the waste sector. In the actual situation, all the municipal solid wastes are dumped into landfill without any gases captured for electricity generation. GHG emission in this paper was calculated based on the Intergovernmental Panel on Climate Change (IPCC) to estimate the GHG emission from municipal solid waste in Phnom Penh in 2009. The result of this calculation shows that the GHG emissions were 338.51 Gg (CO_2 eq) for CH_4, 3.26 Gg (CO_2 eq) for CO_2, and 6.43 Gg (CO_2 eq) for N_2O. Therefore, two waste management scenarios were proposed. In the two proposed scenarios, waste materials will be recycled by separation of waste at landfill, and composting of organic wastes at landfill as well. The result from these scenarios showed that greenhouse gas emission can be reduced by 5.95% for the first scenario and 27.98% for second scenario. This study revealed that the implementation of the proposed scenarios provides tremendous benefits. It can reduce the volume of waste entering landfill site, recycle waste materials, and minimize health problem.*

***Keywords*— Cambodia, Greenhouse Gas Emission, Intergovernmental Panel on Climate Change, Municipal Solid Waste Management, Phnom Penh.**

1. INTRODUCTION

Municipal solid waste (MSW) is a complex problem influenced by political, legal, educational, and economic factors. Growth in economic, population, urbanization, and industrialization has led to a large quantity of waste generation in developing countries, including Cambodia. Recently, the municipality of Phnom Penh has been faced with serious environmental and human health problems due to high population growth rate, poor waste treatment technology, and lack of skill of officers.

Up to now, Phnom Penh has only had one sanitary landfill for municipal solid waste, and the treatment technology is still very limited. Most of the methane from landfills and dumpsites is released directly to the atmosphere. It is clear that mismanagement of municipal waste management will result in greenhouse gas emission. Methane (CH_4), Carbon Dioxide (CO_2), and Nitrous Oxide (N_2O) are the main substances of greenhouse gases.

The aim of this study is to estimate the greenhouse gas emission in Phnom Penh by using the calculator developed by the Intergovernmental Panel on Climate Change (IPCC). GHG emission was calculated based on data collected in 2009. Additionally, two waste management scenarios were developed in order to find a way to reduce GHG emission as well as the volume of waste in landfill. Each scenario is focused on a composting method due to the large amount of organic waste produced in Phnom Penh, and agriculture sector. The factors analyzed in this study include waste generation, waste collection and transportation, waste disposal, and general problems of waste management in Phnom Penh, Cambodia.

2. CURRENT MUNICIPAL SOLID WASTE MANAGEMENT (MSWM) IN PHNOM PENH

Municipal solid waste management in Cambodia has improved slowly. Waste collection, transportation, and disposal site management are still limited due to lack of budget, and human resources. Therefore, Cambodia needs to develop a proper waste disposal system.

Waste generation

Waste generation in Phnom Penh increased rapidly from 338,647 tons in 2003 to 438,000 tons in 2009 (Table 1), and it was estimated to be 635,000 tons in 2015 (JICA, 2005). According to the Institute for Global Environmental Strategies (IGES, 2011), waste generation per capita in Phnom Penh was 0.91 kg/person/day. This rapid growth in waste generation was attributed to population growth and economic development. It should be noted that the solid waste collection in 2004 was 227,910 tons/year which was lower than that of 2003, at 240,859 tons/year. This was not because less waste was generated, but due to low collection efficiency and data management. The waste composition of Phnom Penh city is shown in Table 2. It is revealed that food waste is the main component of waste of the organic fraction with high moisture content. This organic fraction of waste plays important role on methane gas emission.

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Waste collection and transportation

Currently, there is only one private company that is responsible for municipal solid waste management as well as for cleaning services in Phnom Penh city. This company is called CINTRI (Cambodia) Co., Ltd. It is a private waste management firm. Bunrith, S., et al, (2010), reported that CINTRI started its service in 2002, and from 2009 waste collection and transportation service in Phnom Penh has been completely provided by CINTRI. The company now has a monopoly on waste services and a contract of fifty years. Hence, CINTRI definitely fills an important need in the city. However, CINTRI's monopoly means that there is no open market for waste services and no bidding between competitors working to get prices down.

Waste collection and transportation are very useful to enhance waste management. Recently, waste collection in Phnom Penh has improved due to the aim of the Ministry of Environment (MoE) to make the city clean. According to Table 1, almost 84 % of solid waste in this city was collected in 2009. For waste transportation, the city does not have a transfer station. All the collected waste is transported directly to a disposal site.

Waste disposal

Open dumpsites and landfills are the common methods being practiced in Cambodia as well as other developing countries, such as Thailand and Vietnam. The MSWM systems start with collecting, buying, and scavenging of recyclable materials from households and commercial sectors. In Phnom Penh, informal waste pickers collect recyclable materials and sell them to recycle shop. Then, these materials such as plastic, paper, cloths, and metal, are put through a simple process (pre-recycle process) before being sent abroad for further recycling processes. If domestic recycling can be done with standardized quality, it will create economic benefits for local citizens.

In the past, most of the remaining wastes were sent to Steung Mean Chey dumpsite located in Phnom Penh, Cambodia with a total area of 6.8 ha. This disposal site is an open dumping site without environmental protection measures. The site has poor planning, and a low level of technology employed. During the rainy season, the area is flooded, and the fetid water submerges the surrounding residential areas. Waste is often burnt in a field to reduce the volume of waste.

At present, waste disposal site has changed from Steung Mean Chey dumping site (SMCDS) to the Dong Kao site. Dong Kao landfill is the first sanitary landfill which was built in Phnom Penh at a total area of 26 ha (11 ha for disposal area) and it has been allowed to be used since 2009. It has a daily soil-covering process to reduce the bad odor and protect the environment. Furthermore, leachate storage ponds have been constructed. Yet, it has no leachate treatment. The leachate is just pumped into the pond and left to evaporate.

3. PROBLEMS RELATED TO CURRENT SITUATION

Municipal solid waste (MSW), produced in Phnom Penh is growing in volume and in toxicity. The MSW recently still is improperly managed. Problems related to solid waste management are summarized as follow:

- The classification of solid waste has not yet been implemented. Mixed solid wastes (industrial and domestic wastes) are disposed of at the same dump site. Moreover, there is no waste segregation for recycling before disposal in the landfill.
- In practice, the landfill does not have environmentally sound management. The knowledge on waste treatment technology and wastewater (leachate) is still limited. Landfill produces negative effects to dwellers that live around dump sites. They cause a risk to public health directly or indirectly, especially to scavengers that seek available things at dumping sites or people who live close to dump sites.
- For the collection service, ineffective solid waste collection and insufficient number of waste collection trucks are the reasons for piles of waste in public areas and market places.
- During rainfall, solid waste and garbage were washed out and clogged sewage systems in urban area, and finally flooded adjacent low-level residential areas.
- To conclude, all of these need new approaches in order to manage municipal solid waste properly and use appropriate technology that can be easily maintained and operated.

Table 1. Waste generation and collection in Phnom Penh

Year	2003[a]	2004[a]	2005[a]	2006[a]	2007[a]	2009[b]
Daily waste generated (Tons/day)	928	986	1,043	1,101	1,159	1,200
Annual waste generated (Tons/year)	338,647	359,717	380,786	401,856	422,926	438,000
Solid waste collected (Tons/year)	240,859	227,910	266,781	324,159	343,657	366,825
Solid waste uncollected (Tons/year)	97,788	131,807	114,005	77,697	79,269	71,175
Uncollected (%)	29	37	30	19	19	16.25

[a] Phong, H., (2010)
[b] IGES 2011

4. GHG EMISSION FROM WASTE SECTOR

Municipal solid waste that is produced by human activities contributes significantly to greenhouse gas (GHG) emissions. Greenhouse gas from the waste sector has an effect on climate change that creates global problems. The GHGs that are making the largest contribution to global warming are CO_2, CH_4, and N_2O. According to Pikoń and Gaska, (2010), one ton of CH_4 emissions have the same potential effect on global climate change as 21 tons of CO_2. Thus, one ton of CH_4 emissions can be expressed as 21 tons of CO_2 eq. And one ton of N_2O has the same potential effect on global climate change as 310 tons of CO_2.

All three gases are produced during waste management and waste disposal. Emission of methane gas happens when organic waste is left to decay in anaerobic landfills.

5. GREENHOUSE GAS ESTIMATION FROM THE WASTE SECTOR

The IPCC calculator is a simple tool for GHG emission estimation that requires only input of a limited set of parameters. This method assumes that all the potential GHG emissions are released during the same year that waste is disposed of without consideration of the timing of the emissions. According to Chiemchaisri and Chettiyappan, (2008), IPCC is estimated based on the category of the waste, degradable organic carbon (OC) fraction, and methane (CH_4) gas in landfill. CO_2 and N_2O were also determined, but CH_4 is the main gas in GHG emission, following equation (1). For the estimation of GHG emission for this study, the fraction of DOC is equal to 0.1508. It is assumed that the fraction of methane in landfill gas equal 0.5. And the oxidation factor (OX) was assumed to be zero because oxidation of carbon dioxide was not taken in account. There was no recovery or generated methane gas. Thus, R was equal to zero.

Table 2. Typical composition of MSW in Phnom Penh

Year / Composition (%)	2002[a]	2003[a]	2009[b]
Food/Organic	65	63.3	70
Plastic	13.2	15.5	6
Paper & Cardboard	3.8	6.4	5
Grass & Wood	-	6.8	6
Glass	4.9	1.2	2
Metal	1	0.6	2
Rubber, Leather	0.6	0.1	-
Textile	-	2.5	3
Ceramic & stone	-	1.5	-
Other	11.5	2.1	6

[a] Bunrith, S et al., 2010
[b] IGES, 2011

$$CH_4 \text{ emissions} = (MSW_T \times MSW_F \times MCF \times DOC \times DOC_F \times F \times 16/12\text{-}R) \times (1\text{-}OX), \quad (1)$$

where

MSW_T : Total MSW generated (Gg/yr)
MSW_F : Fraction of MSW disposed of in solid waste disposal sites
MCF : Methane correction factor (fraction)
DOC : Degradable organic carbon (fraction) (kg C/kg SW)
DOC_F : Fraction DOC dissimilated
F : Fraction of CH_4 in landfill gas (IPCC default is 0.5)
16/12 : Conversion of C to CH_4
R : Recovered CH_4 (Gg/yr)
OX : Oxidation factor (fraction – IPCC default is 0)

6. SCENARIO DESCRIPTIONS

Two scenarios are proposed to develop municipal solid waste management in Phnom Penh. GHG emission estimation from each scenario and actual situation of waste management are summarized in Table 3.

Actual situation- 100% of waste is disposed of in landfill

Solid wastes are mainly disposed of in landfill, because landfill is the simplest, cheapest and most cost-effective method of disposing waste. For developing countries, almost 100% of generated waste goes to landfill. Even in many developed countries, most solid waste is landfilled. Based on current municipal solid waste management in Phnom Penh, it is assumed that 15% of total waste generation is released to open dumping sites. It is considered as uncollected waste due to road conditions and improper management. About 15% of waste generation was sent to landfill, Steung Mean Chey dumping site. Furthermore, almost 10% of total waste generation that is released to SMC site is considered for open burning, for the actual situation in 2009, Phnom Penh. The remains 5% of waste is assumed to be recycled by scavengers. About 9% of waste material is recycled as composting by some NGOs, such as Cambodian Education and Waste Management (COMPED) and Community Sanitation and Recycling Organization (CSARO). In this scenario, 100% of solid waste is released directly to landfill without separation of the waste material for recycling or gas collection. It is good if gases can be captured from landfills and converted to electricity for supplying the country.

For the other two scenarios, managed landfill and composting were considered to improve waste management and reduce GHG emission. There is no methane collection or recovered energy gas from landfill sites. Moreover, it is assumed that there is no open burning of waste at Dang Kao landfill. The aim to develop these scenarios is that the composting method should be promoted, based on the large amount of organic waste produced in Cambodia, in order to improve the agricultural sector as well as reduce the amount of waste in landfill sites. In addition, reducing waste at landfills is very important to practice in Phnom

Penh, in order to recycle waste material.

Scenario 1- Reduction of waste at landfill + 20% of organic waste for composting + landfill

Landfills have negative effects on the environment such as GHG emissions and leachate. So, many countries including Cambodia have concerns over landfill issues, such as an increasing of groundwater contamination, potential release of toxic gases, and odour. A big part of these problems comes from organic waste. That is why this scenario is applied to mix the management practice of compost to minimize these problems.

Waste reduction at landfill is very important in this scenario to remove some materials such as plastic, paper, and metal from the landfill. Recycling of these materials is useful for proper waste disposal. This can reduce energy consumption and pollution, conserve natural resources, and extend valuable landfill space. This can also have economic benefits by reducing costs associated with operation at disposal.

Therefore, it is assumed that 70% of paper, plastic, and metals are removed for recycling, and 20% of organic waste is removed for composting. Furthermore, waste material needs to be separated for recycling before release to the landfill. The remaining wastes from recycling and composting are sent to landfill without gas recovery.

Scenario 2- Reduction of waste at landfill + 50% of organic waste for composting + landfill

In this scenario, there is also waste reduction at landfill by removing recyclable materials: plastic, paper, and metal. It is assumed that 70% of recyclable materials, such as paper, plastic and metal are removed with 50% of organic waste diverted for composting. The remaining solid waste is released to the landfill. This is quite the same as scenario 1, but it uses composting as much as possible to reduce GHG emission as well as the amount of waste in landfill.

7. RESULT

This study shows that greenhouse gas estimated for the actual situation by the IPCC calculator is 338.51 Gg (CO_2 eq) for CH_4, 3.26 Gg (CO_2 eq) for CO_2, and 6.43 Gg (CO_2 eq) for N_2O in 2009. Waste management should be improved in order to reduce environmental problems as well as reduce GHG emissions. Therefore, two developed scenarios (scenario 1 and 2) were introduced to reduce the greenhouse gas emission from Phnom Penh waste dumpsite. The first scenario is that 20% of organic waste is removed for composting. In the second scenario, 50% of organic waste is removed for composting. In both new scenarios, it is assumed that there are composting and waste reductions at landfill by the removal of recyclable material: plastic, paper, and metal.

Table 4 shows the greenhouse gas emission in Phnom Penh for the actual situation and two developed scenarios. It is revealed that GHG emission can be reduced, if 70% of waste materials, such as paper, plastic and metal are removed, with 20% of organic waste for composting. GHG emission is more reduced in the case that 50% of organic waste is removed for composting. The estimated GHGs of scenario 1 is 320.64 Gg (CO_2 eq) for CH_4 and 6.84 Gg (CO_2 eq) for N_2O. IPCC calculated 233.67 Gg (CO_2 eq) for CH_4 and 17.11 Gg (CO_2 eq) for N_2O for scenario 2. It should be noticed that there is no CO_2 emission for these two developed scenarios because it is assumed that there is no open burning in landfill.

These results revealed that greenhouse gas emission reduced 5.95% for the first scenario and 27.98% for the second scenario. This is due to promoting the composting method, and reducing waste at landfill for recycling paper, plastic and metal.

Table 3. GHG emission in Phnom Penh

GHG emission Gg (CO_2 eq)/year	Actual situation	20% compost	50% compost
CH_4	321.71	304.26	222.33
CO_2	3.26	-	-
N_2O	6.43	6.84	17.11
Total	331.40	311.10	239.44
GHG reduction (%)		3.26	27.75

8. RECOMMENDATION TO IMPROVE PROBLEMS

In MSW management practices, not only the end of pipe approach, but also a precautionary approach should be considered, such as waste prevention or waste reduction at source, in order to minimize waste in the final disposal (landfill). Moreover, this prevents emissions of many greenhouse gases, reduces pollutants, saves energy, conserves resources, and reduces the need for new landfills. Waste prevention should be promoted to reduce the amount of waste generation:

- Plan meals to avoid waste generation;
- Bring own shopping bag and use only big ones at the grocery store;
- Buy goods from local farmers' markets;
- Buy, maintain, and repair products;
- Use pink-lotus leaf instead of paper or plastic to wrap things;
- Buy only what you need.

Moreover, there are several recommendations for future improvement of solid waste management in Cambodia, especially Phnom Penh, capital city of the Kingdom of Cambodia.

- Improving public information on municipal solid waste management and waste disposal and treatment. In this case, MoE has to play in important role in collaboration with other ministries like the Ministry of Education or NGOs.
- Improving transportation and solid waste collection service: The transportation and collection

service are still weak. That is why they should consider the schedule of collection.

- Installing a sanitary landfill that has technology for treatment of waste materials: In this case, Cambodia will also gain the benefits from solid waste by collecting methane gas from landfills to be converted into electricity, which can be supplied to the country. Cambodia imports electricity from neighboring countries. Government should encourage investors like NGOs or private companies to invest in solid waste in Cambodia. In addition, the government should improve and encourage private companies or NGOs to do the composting because it can reduce the amount of organic waste. Moreover, Cambodia is an agricultural country; most farmers need compost to supply their plants.

In short, all of these need to be supported and implemented by adequate funds for technology and skilled human resources. Officials at the subnational level should be better trained in integrated solid waste management, while funds are needed for waste collection equipment and the development of MSW management. Furthermore, public awareness of MSW management issues could also be improved. Therefore, an integrated solid waste management plan should be developed; each component should be more clearly delegated to the responsible authorities. Moreover, funds should be mobilized towards implementation despite a limited national budget.

9. CONCLUSION

The calculation has shown that good waste management is the basis for reducing GHG emission and minimizing pollutants.

Since Cambodia is a developing country in Asia, the main component of the solid waste generated is organic waste. Composting can be improved and promoted for the agricultural sector. Sanitary landfill should be applied for this country due to population growth as well as increasing waste generated. Although, incineration seems to be the best method of waste management to not only protect the environment, but also get a lot of benefits. However, Cambodia does not have enough funds and skill of human resources to apply these methods. Therefore, to reduce the amount of solid waste, the government should initiate more 3R activities in solid waste management policies. The advantage is that the informal sector recycles a portion of the country's urban waste. Finally, the need to reform the solid waste management strategies is an opportunity not just to turn municipal waste into a valuable resource, but also to increase the income of the informal waste pickers, reduce poverty, and contribute towards the mitigation of climate change, by reducing GHGs emissions. Therefore, the government should consider improving the waste management system and the economic conditions of Cambodia.

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Finite Point Method for Convection-Dominated Flow Problems

Chinapat Buachart and Worsak Kanok-Nukulchai

***Abstract*—** *In this paper, the new upwinding scheme incorporate to meshfree technique has been proposed to overcome the instability issues in convection-dominated flow problem. This techniques is then demonstrated in one and two-dimensional problems using meshfree point collocation method. Numerical results for example problems demonstrate the techniques developed in this paper are effective to solve convection dominated problems.*

***Keywords*— Meshfree, point collocation, upwinding, convection-flow.**

1. INTRODUCTION

Many practical problems in engineering are governed by the so-called convection-diffusion equations, in which, there are both convective and diffusive terms. To analyze the convection-diffusion problems, the conventional finite element method (FEM), the finite difference method (FDM), or the finite volume method (FVM) has been widely used.

However, there is a well-known instability issue of convection-diffusion problem; the highly oscillatory solution will occurs when the convective term is dominated. Hence, the special treatment is required to stabilize the numerical solution. A lot of studies have been performed to solve the instability problem in conventional numerical schemes, and excellent documentation on stabilization techniques can be found in the book written by Zienkiewicz and Taylor [1].

In recent years, meshfree or meshfree methods have attracted more and more attention from many researchers in computational mechanics field, especially in computational fluid mechanics. These meshfree methods do not required a mesh to discretize the problem domain, because the shape function is constructed entirely based on a set of scattered nodes. They are categorized to be two groups. First category is based on the collocation techniques, for example the finite point method (FPM) [2] and the *hp*-cloud method [3]. Other meshfree methods are based on weak form, e.g. the element-free Galerkin (EFG) method [4], the reproducing kernel particle (RKP) method [5], the meshfree local Petrov-Galerkin (MLPG) method [6], and so on, this category of meshfree method require numerical integration to approximate the weak form. Hence, the first category is defined to be truly meshfree, *i.e.* no mesh required to perform numerical integration.

Only very few studies on solving convection dominated problems using meshfree method have been reported. Oñate *et al.* [2] applied the finite point method to the convection dominated problem with upwinding for the first derivative or with characteristics approximation. Atluri *et al.* [6] used the MLPG method with local upwinding weight to solve the convection-diffusion problems. Gu and Liu [7] proposed several adaptive support domain techniques incorporate with meshfree collocation method to solve convection-dominated problem successfully.

In this paper, techniques to stabilize the convection dominated problems are developed and investigated for finite point method (FPM). These techniques were developed based on edge stabilization with analytical solution of equivalent one-dimensional convection dominated equation. Numerical results demonstrate that using these techniques, the instability problem caused by convection term can be solved effectively via meshfree method.

2. APPROXIMATION IN FPM

Weighted-Least Square Approximation

Let suppose Ω_i is an local approximation domain (cloud) of unknown function $u(\boldsymbol{x})$ consists of *star point* $\boldsymbol{x}_i$, and set of points $\boldsymbol{x}_j$, j = 2,3,…,*np* surrounding star point as shown in Figure 1.

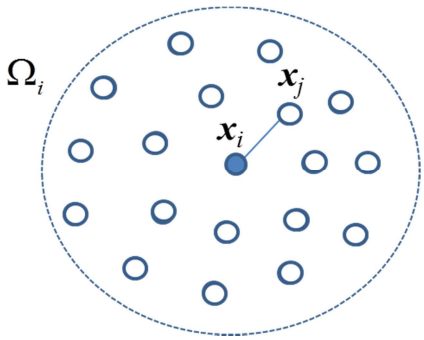

Fig.1. Local Approximation Domain in WLS.

Then, the local approximation of u can be defined by

$$\hat{u} = \sum_{l=1}^{m} p_l(\boldsymbol{x})\alpha_l = \boldsymbol{p}^{\mathrm{T}}(\boldsymbol{x})\boldsymbol{\alpha} \tag{1}$$

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where $\boldsymbol{p}(\boldsymbol{x})$ is a vector whose m-components are the terms of a complete polynomial basis functions and $\boldsymbol{\alpha}$ is a vector of coefficients which must be determined. In this work, complete quadratic polynomial bases are employed, e.g. $\boldsymbol{p}^{\mathrm{T}}(\boldsymbol{x}) = [1, x, y, x^2, xy, y^2]$ in 2-dimensional domain. Note that the point's coordinates are relative to the star point position. For each region Ω_i the number of could nodes is larger than number of parameter $\boldsymbol{\alpha}$, $np > m$. To solve for approximation parameter $\boldsymbol{\alpha}$, we define the functional

$$J_i = \sum_{j=1}^{np} \varphi_i\left(\boldsymbol{x}_j\right)\left[\hat{u}_j - u_j\right]^2 \tag{2}$$

in which $\varphi_i(\boldsymbol{x}_j) = \varphi(\boldsymbol{x}_j - \boldsymbol{x}_i)$ is a compact support weighting function centered on the star point $\boldsymbol{x}_i$ and np is the number of points in the local cloud. This procedure, known as fixed Weighted Least-Squares (WLS), can be considered as a particular case of the Moving Least-Square (MLS) method proposed by Lancaster and Salkauskas in [8]. The minimization of Eq. (2) with respect to parameter $\boldsymbol{\alpha}$ leads to the following system of equations

$$\mathbf{A}\boldsymbol{\alpha} = \mathbf{B}\boldsymbol{u} \tag{3}$$

where $\mathbf{A} = \mathbf{P}^{\mathrm{T}}\boldsymbol{\Phi}(\boldsymbol{x})\mathbf{P}$, $\mathbf{B} = \mathbf{P}^{\mathrm{T}}\boldsymbol{\Phi}(\boldsymbol{x})$, $\boldsymbol{\Phi}(\boldsymbol{x}) = \mathrm{diag}[\varphi_i(\boldsymbol{x}_j)]$, and $\mathbf{P}^{\mathrm{T}} = [\boldsymbol{p}(\boldsymbol{x}_1), \boldsymbol{p}(\boldsymbol{x}_2), \ldots, \boldsymbol{p}(\boldsymbol{x}_{np})]$. Then, the vector of unknown coefficient can be obtained by inversion of matrix $\mathbf{A}$, *i.e.* $\boldsymbol{\alpha} = \mathbf{A}^{-1}\mathbf{B}\boldsymbol{u}$, and the approximation value of $u(\boldsymbol{x})$ at the star point of the cloud is computed by Eq. (1)

$$\hat{u}_i = \boldsymbol{p}^{\mathrm{T}}\left(\boldsymbol{x}_i\right)\mathbf{A}^{-1}\mathbf{B}\boldsymbol{u} = \sum_{j=1}^{np} a_{ij}u_j \tag{4}$$

where a_{ij} is the approximation coefficient or shape function at star point $\boldsymbol{x}_i$. Having adopted a fixed weighting function, matrices $\mathbf{A}$ and $\mathbf{B}$ become constant in Ω_i, thus fist-order derivatives of the unknown function at star point are approximated in the FPM by

$$\frac{\partial \hat{u}_i}{\partial x_k} = \frac{\partial \boldsymbol{p}^{\mathrm{T}}\left(\boldsymbol{x}_i\right)}{\partial x_k}\mathbf{A}^{-1}\mathbf{B}\boldsymbol{u} = \sum_{j=1}^{np} b_{ij}^k u_j \tag{5}$$

in which b^k_{ij} is the first partial derivative of shape function a_{ij} with respect to x_k and higher-order derivatives can be obtained by successive differentiation of basis function vector. Henceforth, the WLS approximation of Laplacian operator can be computed by

$$\nabla^2\hat{u}_i = \nabla^2\boldsymbol{p}^{\mathrm{T}}\left(\boldsymbol{x}_i\right)\mathbf{A}^{-1}\mathbf{B}\boldsymbol{u} = \sum_{j=1}^{np} c_{ij}u_j \tag{6}$$

where c_{ij} is the Laplacian of shape function, defined by $c_{ij} = \nabla^2 a_{ij}$.

The Weighting Function

There exits many possibilities for choosing the functional form of a weighting function. In this paper the following normalized Gaussian (exponential) weighting function is adopted

$$\varphi_i\left(\boldsymbol{x}_j\right) = \frac{e^{-\left(wd_j/\gamma d_{\max}\right)^2} - e^{-w^2}}{1 - e^{-w^2}} \tag{7}$$

where d_j = distance between star point $\boldsymbol{x}_i$ and surrounding point $\boldsymbol{x}_j$ in cloud. The parameters w and γ govern the shape of the weighting function. In this work, we will set the value of $\gamma = 1.01$. Next, to assign the admissible range of parameter w, the effect of parameter w on the shape of Gaussian weight function is illustrated in Figure 2.

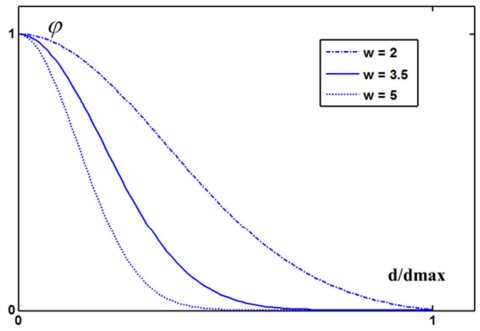

Fig. 2. Effects of the parameter w on the weighting function.

For large values of w, the shape function a_{ij} tends to the Dirac delta function (see Figure 2) and the approximation procedure tends to interpolate nodal data. Larger value w causes the error in the approximation to decrease, while the condition number of matrix $\mathbf{A}$ increased [9]. As a result, the system Equation (3) becomes more and more ill-conditioned. Hence, this parameter should be properly set. The maximum value of parameter w is set to be 3.5 in a whole domain and then it is reduced by factor 0.85 for each cloud of points whenever necessary, in order to obtain a given accuracy in the approximation or until reach the minimum value of 2.0. If the minimum value of parameter w were reached, then the influence domain will be increased by 25 percent, *i.e.* $d_{max}^{(\mathrm{new})} = 1.25\, d_{max}^{(\mathrm{old})}$, and the process to compute the proper value of w will be repeated again.

Consistency of Approximation

It is usual practice in meshfree method to associate the ability of approximation coefficients to reproduce a given polynomial of order p and its derivatives in an exact way. A set of approximation coefficients a_{ij}, b_{ij}^k and c_{ij} from WLS approximation have to satisfy following conditions

$$\begin{aligned}
&\sum_{j=1}^{np} a_{ij}\boldsymbol{p}_j = \boldsymbol{p}\left(\boldsymbol{x}_i\right) \\
&\sum_{j=1}^{np} b_{ij}^k\boldsymbol{p}_j = \frac{\partial \boldsymbol{p}\left(\boldsymbol{x}_i\right)}{\partial x_k} \\
&\sum_{j=1}^{np} c_{ij}\boldsymbol{p}_j = \nabla^2\boldsymbol{p}\left(\boldsymbol{x}_i\right)
\end{aligned} \tag{8}$$

where $\boldsymbol{p}(\boldsymbol{x})$ is a complete polynomial base of order p and $\boldsymbol{p}_j = \boldsymbol{p}(\boldsymbol{x}_j)$. Due to the fact that the weight function use to construct WLS approximation is fixed, the shape function and its derivatives are discontinuous. It is *only* possible to satisfy the consistency requirements (8) at the star point where the center of weighting function is located.

3. MODEL GOVERNING EQUATIONS

Two-Dimensional Convection-Diffusion Problem

Consider the advection-diffusion equation in two-dimensional space [10]:

$$\frac{\partial \phi}{\partial t} + \boldsymbol{u} \cdot \nabla \phi = \kappa \nabla^2 \phi + f \tag{9}$$

where $\phi(\boldsymbol{x},t)$ is the dependent variable, a scalar-valued function of the spatial coordinates $\boldsymbol{x}$ and time t. The advection velocity field is denoted by $\boldsymbol{u}(\boldsymbol{x})$ and the positive coefficient $\kappa(\boldsymbol{x})$ represent diffusivity. The body source term denoted by $f(\boldsymbol{x},t)$.
We allow the essential and natural boundary conditions (diffusive flux), respectively:

$$\phi(\boldsymbol{x},t) = g(\boldsymbol{x},t), \forall x \in \Gamma_g \tag{10}$$

$$\boldsymbol{n} \cdot \kappa \nabla \phi(\boldsymbol{x},t) = h(\boldsymbol{x},t), \forall x \in \Gamma_h \tag{11}$$

where $\boldsymbol{n}$ is the unit outward normal vector to the boundary $\Gamma = \Gamma_g \cup \Gamma_h$ and g and h are prescribed functions. The steady-state solution is defined by $\phi(\boldsymbol{x})$ when time derivative term in Equation (9) equals to zero.

4. THE MESHFREE FPM SOLVER

Spatial Discretization

The scalar variable ϕ and derivatives are approximated by the WLS scheme as described in section 2. Therefore, for each star point $\boldsymbol{x}_i$ we have the following numerical approximations

$$\begin{aligned}
\hat{\phi}(\boldsymbol{x}_i) &= \hat{\phi}_i = \sum_{j=1}^{np} a_{ij} \phi_j^h \\
\frac{\partial \hat{\phi}(\boldsymbol{x}_i)}{\partial x_k} &= \frac{\partial \hat{\phi}_i}{\partial x_k} = \sum_{j=1}^{np} b_{ij}^k \phi_j^h \\
\nabla^2 \hat{\phi}(\boldsymbol{x}_i) &= \sum_{j=1}^{np} c_{ij} \phi_j^h
\end{aligned} \tag{12}$$

It is importance to note that the nodal parameters ϕ^h do not coincide with the approximated ones $\hat{\phi}$ because in the WLS approximation the shape functions do not interpolate nodal data. These values are related by first line of Equation (12), which implies that a linear system have to be solved in order to obtain the nodal parameters ϕ^h. Experiment shows that this equation system can be solved by a few iterations of a Gauss-Seidel method or similar [11, 12]. Then, taking advantage of the partition of nullity (PN) property of the shape function derivatives, it is possible to infer

$$\sum_{j=1}^{np} b_{ij}^k = 0 \rightarrow b_{ii}^k = -\sum_{j \neq i} b_{ij}^k \tag{13}$$

and replacing Equation (13) into second line of Equation (12) the following expression for first derivative of scalar variable is obtained

$$\frac{\partial \hat{\phi}_i}{\partial x_k} = \sum_{j \neq i} b_{ij}^k \left(\phi_j^h - \phi_i^h \right) \tag{14}$$

However, Equation (14) is unstable and needs to be stabilized. For that purpose, a more suitable equivalent form is proposed [11, 12, 13], which is given by

$$\frac{\partial \hat{\phi}_i}{\partial x_k} = 2 \sum_{j \neq i} b_{ij}^k \left(\phi_{ij} - \phi_i^h \right) \tag{15}$$

where ϕ_{ij} is a mean value of scalar variable at the midpoint of the line segment connecting the star point $\boldsymbol{x}_i$ to another point $\boldsymbol{x}_j$ in cloud. This stabilized value ϕ_{ij} is calculated by concerning the equivalent one-dimensional exact solution of convection dominated equation. The stencil of points used in the calculation of Equation (15) is presented in Figure 3. The theoretical issue of stabilized variable will be described in the next section.

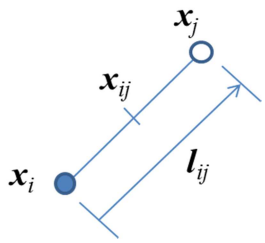

Fig. 3. The one-dimensional stencil of points.

Upwind Computation of First Derivative

The general solution of the steady-state equivalent one-dimensional convection-diffusion equation with no source term is represented by the exponential form [14]:

$$\phi = A + Be^{\alpha \xi} \tag{16}$$

where $\alpha = \boldsymbol{u} \cdot \boldsymbol{l}_{ij} / 2\kappa$ is the stencil Peclet number and the normalized coordinate $-1 \leq \xi \leq 1$. Substituting the essential boundary conditions at both ends, namely $\phi(-1) = \phi_i$ and $\phi(1) = \phi_j$, we obtain

$$2A = \phi_i + \phi_j - \left(\phi_j - \phi_i\right)\coth\alpha$$
$$2B\sinh\alpha = \left(\phi_j - \phi_i\right) \tag{17}$$

Hence, the mean value ϕ_{ij} can be expressed by average integral of solution in Equation (16) over the line segment as shown in Figure 3:

$$2\phi_{ij} = \phi_i + \phi_j - \zeta\left(\phi_j - \phi_i\right) \tag{18}$$

where ζ is the stencil *dissipation* coefficient, which its magnitude less than or equal to one. Using the value of coefficients *A* and *B* from Equation (17), we obtain the *optimal upwind scheme* (OU):

$$\zeta = \coth\alpha - \frac{1}{\alpha} \tag{19}$$

A simplified scheme which avoids the calculation of hyperbolic cotangents and maintains second-order accuracy [15] is given by

$$\begin{aligned}\zeta &= -1 - 1/\alpha, && \alpha < -1,\\ &= 0, && -1 \le \alpha \le 1,\\ &= 1 - 1/\alpha, && 1 < \alpha,\end{aligned} \tag{20}$$

We refer to Equation (19) as the *critical upwind* scheme (CU). Moreover, the most simple *full upwind scheme* (FU) defined by

$$\begin{aligned}\zeta &= -1, && \alpha < 0,\\ &= 0, && \alpha = 0,\\ &= 1, && \alpha > 0,\end{aligned} \tag{21}$$

which results in the first-order accuracy scheme. Thus, the approximation of convection term in governing equation (9) at star point *i* can be expressed as follow:

$$\boldsymbol{u}\cdot\nabla\hat{\phi}_i = u_1\frac{\partial\hat{\phi}_i}{\partial x_1} + u_2\frac{\partial\hat{\phi}_i}{\partial x_2} \coloneqq 2\sum_{j\neq i} d_{ij}\left(\phi_{ij} - \phi_i^h\right) \tag{22}$$

in which $d_{ij} = u_1 b_j^1 + u_2 b_j^2$, the algebraic divergence operator. Further simplify of Equation (22) using the result from (18), obtain the stabilized convection flux (denoted by dF_i) as follow:

$$dF_i = \boldsymbol{u}\cdot\nabla\hat{\phi}_i \coloneqq \sum_{j\neq i} d_{ij}\left(1-\zeta\right)\left(\phi_j^h - \phi_i^h\right) \tag{23}$$

The stabilized flux in expression (23) will be used to compute the convection term in next section

Discretization in Time

From the governing equation (9), expressions (12) of the WLS approximation procedure, and the discretization of the first derivatives, equations (14), (15) and (23) we obtain the following semi-discretization form for the unknown at each star point *i*:

$$\sum_{j=1}^{np} a_{ij}\frac{\partial\phi_j^h}{\partial t} = r_i \tag{24}$$

$$r_i = -dF_i + \kappa\sum_{j=1}^{np} c_{ij}\phi_j^h + f_i$$

In which , represented the right-hand-side or residual term at current time. Integrate equation (24) in time using Euler scheme with critical time step size [11, 12] for each star point *i* leads to the incremental equation as follow

$$\sum_{j=1}^{np} a_{ij}\Delta\phi_j^h = \Delta t r_i \tag{25}$$

where $\Delta\phi_j^h = \phi_j^h\left(t+\Delta t\right) - \phi_j^h\left(t\right)$, the difference of nodal unknown parameter between current and next time step. Equation (24) can be solved iteratively by adding unknown parameters at star point *i* on both sides:

$$\Delta\phi_i^{h,(n+1)} = \Delta t r_i + \Delta\phi_i^{h,(n)} - \sum_{j=1}^{np} a_{ij}\Delta\phi_j^{h,(n)} \tag{26}$$

where n = 0, 1, 2, …; denotes number of iterations, and $\Delta\phi_j^{h,(0)} = 0$. The iterative form in Equation (26) typically converges within few iteration steps [12, 13].

5. NUMERICAL EXAMPLES

Numerical solutions presented here onwards have been obtained with a FPM based on WLS approximation, taken from literature [2, 16]. Half-size of critical time step is used in time integration process.

One-dimentional*: *Sinusoidal Source Term

The one-dimensional convection-diffusion problem with homogeneous *boundary condition* at both ends is investigated. Twenty-one equally spaced points have been used to discretize unit length domain. Convective velocity u = 1 m/s and diffusivity parameter κ = 0.01 m^2/s.

Figure 4 shows the steady-state results for equation (9) with a sinusoidal source term f = sin πx using three schemes, namely OU, CU and FU as described in previous section. The values of unknown parameters ϕ_i^h solved by optimal and critical upwind show no different and very close to analytical solution. A small over diffusion appears for FU scheme.

One-dimentional: Discontinuous Initial Profile

The transient one-dimensional convection-diffusion problem, which represents contaminant transport phenomena, is simulated following the detail in Yim and Mohsen [16]. The domain length is 200 ft. Convective velocity u = – 0.1 ft/day and diffusivity parameter κ = 0.01 ft^2/day. The numerical simulations are performed

using time step equals to 0.2 day, incorporate with CU scheme in Equation (20) to compute stabilized convective flux.

Results from two sets of equally spaced grids are shown in this example. First grid, which is called *coarse* grid, discretized using hundred-one equally spaced points. Second grid has been more refined by twice. Figure 8 shows the results for t = 200, 400 and 600 days and their corresponded analytical solution from [16]. The over diffusion results are observed. However, the result from finer grid produces less diffusion phenomena. Note that all numerical results predict peak position absolutely correct.

Two-dimentional case

The next example is analysis of two-dimensional thermal convection-diffusion a square domain under a uniform heat source f = 10 using a regular square grid of 8 × 8 points with diagonal convective velocity $u_1 = u_2$ = 1 m/s and diffusive coefficient κ = 0.005 m^2/s. A prescribed zero value, *i.e.* homogeneous boundary condition, of the temperature at the boundary has been taken. Figures 5 and 6 show the results for the unknown parameters ϕ_i^h. The numerical solution is free of oscillations and coincides with the expected result [2] for all stabilized schemes. The slightly over diffusion solution from FU scheme can be clearly seen from Figure 7, which shown profile plot along diagonal line of two dimensional solutions from Figures 5 and 6.

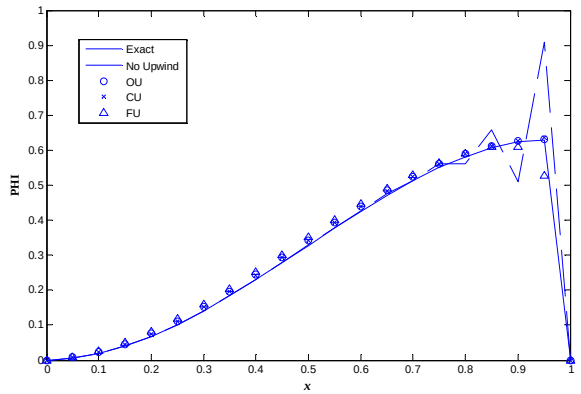

Fig. 4. One-dimensional solution with various stabilized schemes.

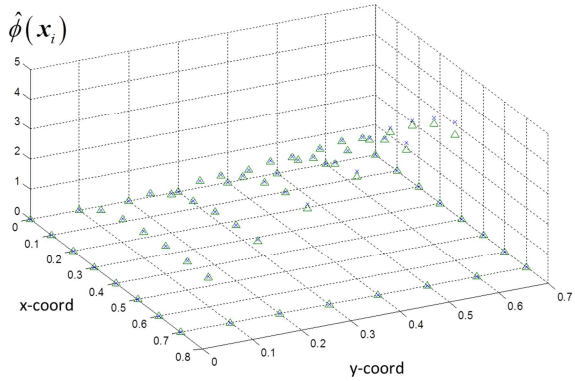

Fig. 5. Two-dimensional solution with diagonal velocity field.

Cross-point shows results from OU and CU schemes; Triangular marks represent FU result.

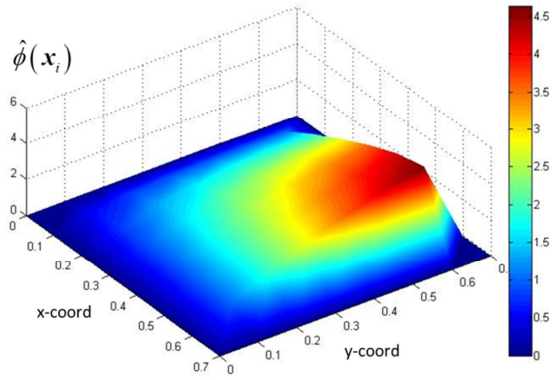

Fig. 6. Contour of two-dimensional solution with diagonal velocity field, the optimal upwind (OU) scheme.

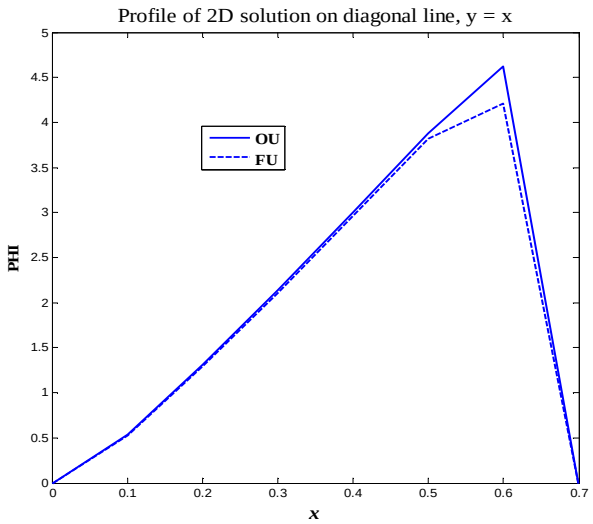

Fig.7. Profile of solution along diagonal line (y = x) for two-dimensional problem with diagonal velocity field.

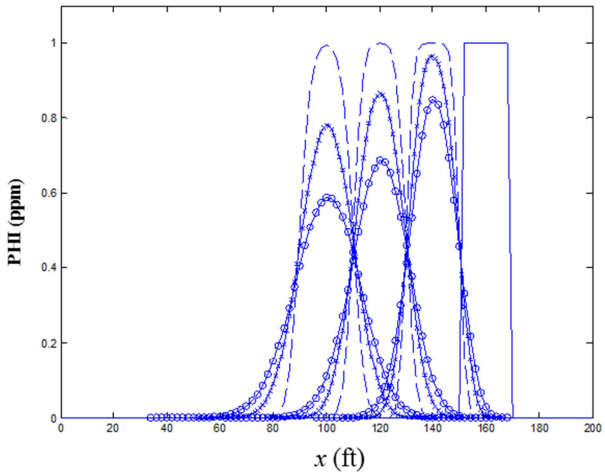

Fig. 8. Solution of transient 1D discontinuous initial profile (solid ine) at t = 200, 400 and 600 days. Dash line represent exact solutions, circle (o) and cross (x) points show coarse and fine grids result, respectively.

6. CONCLUSION

The finite point method (FPM) with upwind discretization of first derivatives to solve convection-dominated flow is presented. The advantage of the method compared with standard finite element method (FEM) is to avoid the necessity of mesh generation and compared with classical finite difference method (FDM) is the facility to handle the non-structured distribution of points.

The results from numerical examples show that present FPM are sufficiently accurate. Steady-state solutions are perfectly matched with analytical solution. Transient solutions with simple Euler time stepping scheme show over diffusion results. In this case, point refinement might be used to improve accuracy. Searching for method to reduce over diffusion should be interested research topic. Extension of this method to solve other specific fluid mechanic problems should be further investigated.

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Tourist Satisfaction on Tourism Growth and Tourism Site Development in VangVieng District of Vientiane Province, Lao PDR

Khamtanh Saliankham, Bounlouane Douangngeune, and Zhang Bin

Abstract— *This study attempts to understand tourist satisfaction on their visit for recreation and leisure purposes in Vangvieng of Lao PDR. Here, tourist satisfaction is measured in tourists' perceptions and opinions on tourism site development and services they receive during their stay in Vangvieng. The data collected for purposes of this study were provided by tourists through the use of questionnaire where the tourists were asked to express their opinions and perceptions on economic, social and cultural benefits received from their stay in Vangvieng. Tourist statisfaction is one condition for achieving sustainable tourism development. In recent decades, Lao PDR has been a very attractive tourist destination, indicating that the satisfaction levels of the tourists would be high. This study will show results for this hypothesis. It is found that tourists are generally satisfied in their visits to Vang Vieng although personal characteristics of the tourists cause significant variations in the satisfaction levels.*

Keywords— **Tourism improvement management, tourism growth, communities' benefit, residents, visitor, public sectors, accommodation entrepreneur.**

1. INTRODUCTION

VangVieng is one destination for visiting in Laos. Vangvieng tourism is composed of many activities, industries and services organized towards delivering travel experiences. Vangvieng tourism facilities involve accommodations, restaurants, bars, entertainments, local product shopping areas, transportations, activity facilities and other hospitality services.

Tourism in Vangvieng has made significant contributions to economic development and has become one of the major growth industries in Vangvieng. The advantage of Vangvieng tourism is generally referred to a good combination of its magnificent natural landscape and highly cultivated farmland mixed with rich cultural and traditional values of the local residents.

A survey conducted in 2012 by sector of culture, information and tourism of Vangvieng district involving 128,276 foreign visitors found that 50% of the visitors were from Europe, 30% from Asia and 20% from other continents *(VangVieng Tourism Office, 2012).* The survey also found that the main features attracting foreign visitors into VangVieng were natural environment mixed with unique customs of minorities. VangVieng, like other parts of Lao PDR has started to promote investment policy, focusing on promoting tourism related businesses such as hotels, guesthouses, restaurants, tour services. Thus, tourism facilities in VangVieng have grown rapidly, and currently there are 9 hotels, 11 resorts, 111 guesthouses, 82 restaurants and 3 entertainments, 1000 tubs services, 173 Kayakings, 1 balloon service, 110 bicycle services, 150 motorbikes, 6 textile souvenir shops, 17 massage centers and 11 internet cafes. The values of investment in hotels have reached about 267 billion Kip (about US$33.44 million) and in restaurants have reached about 3.67 billion Kip (or US$453,611 *(VangVieng Tourism Office, 2012).*

Theoretically, the growth of tourism sector in VangVieng described above, it should bring benefits to all concerned people including local community members, business people, public sector, and tourists. The benefits are measured in four facets such as economic, social, cultural, and environmental benefits as described in Kishore Shah, Jan McHarry and Rosalie Gardiner (2003). This paper focuses only on measuring benefits of the tourists, particularly foreign tourists. Benefits are measured by subjective perceptions and opinions of foreign visitors in VangVieng, which are referred in this paper as tourists' satisfactions. The study finds that tourists are generally satisfied in their visits to VangVieng although personal characteristics of the tourists cause significant variations in the satisfaction levels.

2. LITERATURE REVIEW

Increased access to travel was accompanied by other developments in society, and this contributed to the growth in demand for and provision of tourism. A variety of important factors contributed to the development of tourism during the nineteenth and early part of the twentieth century. Mason (1990) suggested five major reasons for the growth of tourism. These are as follows: (1) A rise in industrial output associated with the industrial revolution that in turn led to an increase in the standard of living. (2) Improvements in transport technology, which led to cheaper and more accessible

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travel. Railways and ocean liners appeared in the nineteenth century and cars and aircraft in the first half of the twentieth century. (3) The introduction of annual holidays towards the end of the nineteenth century.(4) Changing perceptions of the environment. Locations that were once viewed as hostile were now seen as attractive. (5) An increasing desire to travel. This was related partly to improvements in education and also to greater overseas travel, which was mainly the result of war. This created interest in foreign locations and also overseas business travel.

Responsible tourism is not a brand or type of tourism. Rather, the term refers to a "tourism management strategy embracing planning, management, product development and marketing to bring about positive economic, social, cultural, and environmental impacts" (DEAT 2003). More specifically, Husbands and Harrison (1996) define responsible tourism as "a framework and a set of practices that chart a sensible course between the fuzziness of ecotourism and the well-known negative externalities associated with conventional mass tourism." To them, the idea of responsible tourism provides an effective approach to conceive social and eco-cultural tourism products in the real world.

The visual and understanding of visitor perspective are different point of view. Thus, while the term of quality tourism experience is commonly used in the sustainable tourism literature (Boyd, 2002; Moscardo, 1996; Ross & Wall, 1999; Ryan, 1998). The concept has not been explicitly defined. Generically, these studies associate quality tourism experiences with tourism based on cultural, historic and natural attractions, which involves extensive interaction between tourists and local residents and results in high satisfaction and enrichment to tourists. A key indicator of a high quality visitor experience is visitors' level of satisfaction with their experience.

Natural environment ; According to Jones and Sasser (1995) mentioned of satisfaction: there are four basic elements affect tourists (customers) satisfaction for basic of product or service, basic support services, a recovery process for counteracting bad experience and extraordinary service. The importance of delight has additionally been recognized in the area of quality by Deming (1986) The studies have show: Swarbrooke, (1999) mentioned tourism also benefited the natural environment by providing motivation for its environment, Mathieson and wall,(1982) Tourism extends an appreciation for the natural world and heightens environment knowledge for both the host communities and visiting tourists.

Economic impact, Matarrita- Casante and Luloff. (2008) indicated the economic restructuring results from the changing direct, indirect and induced employment generated from changing conditions and often newcomers have different socioeconomic status as evidenced by their higher levels of education and income than those of long-term residents. The relationship between the tourism impact (tourists support economic) and communities they refer to the tourism growth and tourism arrival for visiting to lead the development of many things to have new version. Var & Kim,(1990) mentioned services of all kinds are established and offered to tourist, which in turn also serve local residents and tourism the impetus to improve and further development communities infrastructure and communities service.

Many words of social impact and many rural developments were attracting destinations, the tourism growth and tourism arrival. According to many studies indicated that: the social impacts of tourism fall into three different categories. It is concerned with tourist, the host and tourist-host interrelations (Affeld, 1975, P.109). Burdge, (1998:47) mentioned the socioeconomic characteristics may result in the perceptual changes among different resident types, different socioeconomic characteristic affect how newcomers perceive the community and how the community perceives the newcomers. The relationship between the tourism impact and local \ resident in term of social support by tourism growth and tourists arrival which led to change the communities which will be the reducing poverty and contribution to sustainable development into rural area.

The tourism growth in term of cultural resident impact which was led to the positive and negative points for the patterning of development as well as Sustainable tourism development, According to the meaning of cultural tourism there are many thing to many people and herein lies its strengths and its weaknesses (ICOMOS 1996: 17). The defining cultural tourism, it can mean different things to different people such as cultural attraction/objects mean different things and have other meanings than for other people(Understanding the Behavior of cultural tourists, (Rami Isaac, 2008 P: 16). Sethna & Richmond (1978) indicated The Virgin Islanders exhibited consensus that tourists seem to respect local traditions and cultures and want to know more about them.

The tourism growth is characterized by a sort of 'Baume's disease', since the 'productivity' of natural and cultural capital hardly increases over time (Baume and Baume, 1985). Buckley (1993) identifies a systemic scenario in which tourist sector linkages with environmental and cultural capital assets and linkages between consumption (number of foreigner visitors) and investment ((Number of Hotels, Guesthouses, Resorts, Restaurants and Entertainment) as they arise in the Environment of tourism development.

3. STUDY APPROACH

In order to capture tourist satisfactions on tourism growth and tourism site development in VangVieng. This study developed a questionnaire for collecting two types of data, such as the first data on personal characteristics of foreign tourists in VangVieng and the second data on their satisfactions of tourism growth and development, there in terms of economic, social, cultural, and environmental benefits. The latter are measured in a Likert scale ranging from 1 through 5; where 1= strongly dissatisfied and 5= strongly satisfied. The data were collected during July 2013 involving a sample size of 200 foreign tourists. The analyses in this study are mainly based on descriptive statistics. Quantitative

statistics such as t-statistics and F-statistics are used to supplement the analyses.

4. RESULT

4.1 Sample profile

VangVieng is a world most famous tourism destination receiving many domestic and foreign tourists every year. A majority of the tourists are young people as they are in the age of seeking new experiences. In this current study, we also found that 67.4 percent of the samples are in the age of lower than 31 years. The oldest stratum of tourists (60 years old and older) accounted for only 4.4 percent. In terms of their income levels, about one half of the sampled tourists fall in the lowest income group (up to US$3000 per month) and one quarter of the sampled tourists earn between US$3000-US$6000 per month. These results show that a majority of the tourists fall in the two low income groups, with the remaining 25 percent earn more than US$6000 per month. Such income distribution is reasonable as about two-thirds of the sample tourists are young. In terms of their education qualification, we found that about 33 percent have completed higher diploma and 32 percent have a bachelor degree. These people are most likely in young ages and earn low incomes. About 45 percent of the sampled tourists are from Europe, 35.4 percent are from the Asia-Pacific region, about 17 percent are from America and less than 3 percent are from Africa and the Middle East. Among the tourists from each continent, we also found that a majority of the tourists are in their young ages and earn low incomes per month. For example, 41 out of 43 Asian-Pacific tourists of the up to 30 year-old group earn not more than US$6000 per month. Likewise, such 41 persons account for about 79 percent of all Asian-Pacific tourists in the first two income groups (the up to US$3000 group and the US$3001-US$6000 group). For the European tourists, 41 out of 44 tourists in the up to 30 year-old group earn not more than US$6000 per month, or such 41 persons account for about 67 percent of all European tourists in the first two income groups (the up to US$3000 group and the US$3001-US$6000 group).

4.2 Tourists' benefits from their visit to VangVieng

It is difficult to quantify the benefits each tourist receives from a particular tourist destination. In this study, we follow the literature reviewed in Section 2 in equating the tourists' benefits from visiting VangVieng to their satisfaction in terms of economic, social, cultural and environmental satisfactions. The satisfaction on the environment includes satisfaction in both natural and built environments. Here, we also attempt to compare tourists' benefits or satisfactions by age group; 30 years old and younger, 31 – 40 years old, 41 – 50 years old, 51 – 60 years old, and 60years old and older. We also compare the benefits across different income groups such as below or equal to US$3000, US$3001-US$6000, US$6001-US$9000, US$9001-US$12000, and > US$12000. The results are shown in Table 1.

Table 1 Mean satisfactions and statistical tests for differences in satisfaction by age and income groups

	Satisfaction factors	Sample size	Mean score	p-value for age	p-value for income
1	Total 1: Natural environment satisfaction	181	3.58	.218	.890
2	Total 2: Built environment satisfaction	181	3.42	.092	.814
3	Total 3: Economic satisfaction	181	3.80	.707	.683
4	Total 4: social satisfaction	181	3.43	.374	.425
5	Total 5: Culture satisfaction	181	3.57	.342	.644

As can be observed in Table 1 above, it can be stated that although VangVieng is one most popular world tourist destination, the tourists under study were only moderately satisfied to highly satisfy with their visits to VangVieng. Specifically, they are moderately satisfied with their natural environment benefits, built environment benefits, social benefits and cultural benefits. They showed high satisfaction only for the economic benefits, which may be due to cheap prices compared with the prices at other tourist destinations in other parts of the world. When we compare the benefits in each of the five components in the table above across tourists in different age groups and in different income groups, (based on the one-way ANOVA test for comparing more than two means) we cannot reject the null hypothesis that the tourists of different age groups or the tourists of different income groups have the same level of benefits for each of the five components.

These results suggest that local authorities concerned and local communities have to improve their tourism sites and services in order to provide more environmental, cultural and social benefits to the tourists. Such improvements are important for sustainable tourism growth and tourism site development in VangVieng. On the other hand, if the tourists continue to receive moderate benefits from their visits to VangVieng, tourism in VangVieng may decline in the future. As described in the introductory part of this paper, tourism is one main contributing factor to socio-economic development in VangVieng. Therefore, if tourism declines due to a decline in the tourist number, living conditions of local residents of VangVieng will be disturbed unless alternative livelihoods are developed.

5. CONCLUSION

Tourism is a very important sector contributing to socio-economic development in VangVieng, one world famous tourism site in Laos. Particularly, in recent decades, after

the announcement of Lao Tourism Year in 2000, tourism in VangVieng has grown steadily. Foreign tourists make up a majority of visitors and bringing most of the tourism-related benefits to the local community and public authorities in VangVieng. Therefore, in order to ensure sustainable tourism growth and tourism site development in VangVieng, it is important to understand and maintain high benefits or satisfactions of the tourists who visit that town. This current study attempts to quantify such tourists' benefits by collecting the data on tourists' satisfactions on tourism growth and tourism site development in VangVieng. The results show that the tourists in VangVieng are mainly young people in low income groups and most of them are from Europe, Asia-Pacific and America. The tourists are moderately satisfied with both natural and built environments, cultural and social landscape of VangVieng. They show high satisfaction only for the economic aspects which may be due to low costs. Such results show some risks of tourism decline in VangVieng. In order to prevent such risks to materialize, local communities, tourism-related entrepreneurs and local authorities need to seek ways to improve tourism services and attractions in VangVieng. Such improved services and attractions will be necessary for maintaining VangVieng as a world tourism site and ensuring that local communities and entrepreneurs continue to gain benefits from tourism development.

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Consumer Perception and Attitude Study for Market Development of Hommali Organic Rice Products from Thung Kula, Thailand

Pensri Jaroenwanit and Pornpirat Kantatasiri

Abstract— *This research aims to study consumers' perceptions and attitudes toward Hommali Organic Rice Products for the purposes of market development in Thailand. Hommali Organic Rice Products from Thung Kula, Roi-Et Province were used for the case study in this quantitative research. Field survey research was conducted using questionnaires to collect data from 440 test subjects who were Thai Hommali Organic Rice Product consumers; 240 people were surveyed in Bangkok, 100 people in Khon Kaen, and another 100 people were in Roi-Et. Test subjects were selected using purposive sampling. Descriptive statistics and inferential statistics were used in the data analysis. The research found that all research subjects knew of and had consumed Hommali Organic Rice Products; however, only 56.8% knew of Hommali Organic Rice Products specifically from Thung Kula. They had a low level of awareness in terms of differences between Hommali Organic Rice Products from Thung Kula and from other areas and knew little about the distribution of such products from Thung Kula. This study suggests that marketing communication should be developed in order to build positive perceptions and attitudes towards Hommali Organic Rice Products from Thung Kula. As consumers pay a lot of attention to their health, the selling points of these products should focus more on the benefits of consumption, lack of poisonous substances,and relatively aromatic and soft qualities when compared to Hommali Rice from other areas. Development of product distribution, marketing, and the domestic market are needed in order to expand the product's reach and to be accessible for the target group.*

Keywords— **Attitude, Market Development, Organic Rice, Perception.**

1. INTRODUCTION

Consumer behavior in terms of willingness to pay or purchase organic products depends on consumers' perceptions and attitudes [1], [2], [3], and [4]. Specially, at present consumers are interested in the relationship between diet, food and health [5] and have concerns about the risks of illness and disease from food [6] because today many countries are spreading information about risks from the chemical synthesis on food products [4] and [7]. In addition, many research studies have revealed that consumers are increasingly aware and protect their health by consuming organic products instead the conventional food products [2], [3], [4], [6], [8], [9], [10]. These changes in consumer perceptions and attitudes about organic products are correspondingly important for companies to be aware of and employ in their marketing strategies.

Organic agriculture products are a popular choice for many consumers who are aware of their health [11]. Organic products are not associated with chemical synthesis in contrast to typical, agro-chemical products [12]. The International Federation of Organic Agriculture Movement (IFOAM) [13] and USDA Organic [14] determined the definition of organic agriculture to be:

"Organic Agriculture is a production system that sustains the health of soils, ecosystems and people. It relies on ecological processes, biodiversity and cycles adapted to local conditions, rather than the use of inputs with adverse effects. Organic Agriculture combines tradition, innovation and science to benefit the shared environment and promote fair relationships and a good quality of life for all involved [13]*."*

In Thailand organized organic production began in the early 1980s when a group of farmers and local Non-Governmental Organizations (NGOs) came together to establish the Alternative Agriculture Network (AAN) (Anderson, Lonmo, Schaan, & Schenk) [15], [16], and [17]. The network aimed to foster sustainable agriculture activism in Thailand [17]. In Thailand, the main sources of agriculture are rice, vegetables, and fruits [15], [16].

The expansion of organic rice production in Thailand is supported by The Ministry of Agriculture and cooperatives, especially Hommali Organic Rice, which is famous around the world [15]. Khao Hom Mali Thung Kula Ronghai is a very famous and unique Jasmine rice variety known by Thai consumers since it can grow in limited area only and has high quality with special fragrance and attributes [18]. Hommali Organic Rice is grown in the Thung Kula Rong Hai area that contains five provinces: Roi-Et, Mahasarakham, Surin, Srisaket, and Yasothon. Government policy has increased the volume of Hommali Organic Rice production by two hundred and five tons from the Thung Kula Rong Hai area, distrubuted amongst the five provinces (i.e. a rice yield of 75,000 tons from the Surin area and 15,000 tons

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from the Yasothon area) [19] Hence, the Hommali organic rice's market is expanding the volume in domestic market and making most of Thai people better know about the special of it.

Although Hommali Rice is a famous kind of rice in Thailand and most people known about this, Hommali Organic Rice is quite new in the market and different product attribute from general Hommali Rice because it was produced without chemical substances involving in the production process [19]. This distinction raised the research question of how consumers perceive and feel towards general Hommali Organic Rice and Hommali Organic Rice from Thung Kula Rong Hai. Roi-Et is the major production area of Hommali rice since more than 30% of Thung Kula Rong Hai area with thousands rice growers are in Roi Et province. This led Roi-Et province got much more supports from government and private organizations for many years and resulted in more advance developed in production and marketing process especially on organic system and products than other provinces. Therefore, Hommali Organic Rice products from Roi-Et Province were used for this study. The objective of this paper is to study consumers' perception and attitude toward Hommali Organic Rice and Hommali Organic Rice from Thung Kula Rong Hai, Roi-Et Province. The results from this study will be useful for developing marketing strategies. Following the introduction part, this paper contains a literature review, description of methodology, findings, conclusions, and further discussion.

2. LITERATURE REVIEW

2.1 Organic Rice Definitions

Organic rice is a natural growing rice that is minimally processed and free of synthetic preservatives, artificial sweeteners, colors, flavors and other artificial additives, growth hormones, antibiotics, hydrogenated oils, stabilizers, and emulsifiers while grown [14] and [20]. Specially, this rice is grown without the use of synthetic fertilizers or pesticides for at least three years prior to harvest [13], [14], [16], [17], [20] and [21]. Furthermore, cover rice seed, compost and other natural fertilizers are used for maintaining soil fertility, while biological control and natural pesticides are used for pest control [14], [15], and [17]. Organic livestock production requires that animals are fed organic feed, have access to a pasture or the outdoors, and prohibits the use of antibiotics and hormones [14] and [22]. Moreover, most organic rice products have an organic label to ensure consumer confidence in their origin [14], [17], [23], [24] and [25]. Therefore, organic rice definition refers to the process and product of organic rice production.

2.2 Hommali Organic Rice from Thung Kula

Khao Hom Mali Thung Kula Rong Hai is the rice variety produced in the Thung Kula Rong-Hai area, extending across five provinces of northeast region, Thailand. Hommali Organic Rice can be brown or white (milled rice) [15] and [16]. Thung Kula Rong Hai is an area that used to be an expansive, harsh, and dry place in the middle of the region. It covers 5 provinces, which are Roi Et, Surin, Srisaket, Yasothon, and Maha Sarakham. One-third of the area is in Roi Et province [19] and [26].

There is a legend that says the Kula people were traders in ancient times who were also great fighters with excellent stamina. However, they cried when they got to Thung Kula Rong Hai because it was such a desolate place without water and big trees. Presently the area is fertile due to the efforts of the government to develop it and it is suitable for agriculture especially growing rice [26].

2.3 Consumer Perception

Consumer behavior is a dynamic phenomenon that depends heavily on consumers' perceptions. This is the most important psychological factor in the marketing field because consumers must have a perception or attitudes about a product before they are interested in purchasing it [27], [28], and [29]. Organic products in Asian markets are less recognized than in the EU market [7] and knowledge about such products has a slow rate of diffusion. For example, in Bangkok people who had bought organic products knew only about organic fresh vegetables [30] and were aware of a little market selling these organic products [31]. Thus, consumer's perception affects to marketing strategy [32] that can be induced the consumers' needs, especially, after consumer perceives the risk from food, they are always try to find the better [33] and [34].

Culture's influence consumption

Hofstede's culture definition refers to the dynamic process that can drive human social beliefs, create attitudes, perceptions, thoughts, and responses[13]. Hofstede discussed one dimension of culture that is particularly relevant here: individualism and collectivism. These play a key role in consumer perceptions and attitudes [35]. Western cultures (e.g. England, Australia) and Eastern cultures (e.g. Thailand, China) differ in ways that can be classified following Hofstede's cultural dimensions. Western cultures tend more towards individualism than those in the East, so a consumer in Eastern cultures who is part of a collectivistic society has more impetus to follow social trends [36] in the terms of consuming organic food [37]. In this way many researchers reveal that culture is an important factor which affects consumers' perceptions, attitudes, and consumption of a new product in the market [37] and [38].

Cognitive consumption behavior

Many research studies have found that not only gender and age but also consumer perception and attitude have an effect on food consumption behavior [39]. In particular, consumers who purchase organic products are often cognitive of the relationship between food and health [40]. Different opinions about this affect consumer perception [41], and statistically women are more likely than men to use information about how to be healthy for changing their behavior [40] and [42]. In general, women make decision to purchase products

while comparing the benefits from different choices [5] and [43]. Overall people who are aware of their health will pay extra to get food products with higher and safer standards than conventional products [5]. Consumers who regularly purchase healthy products have personal tendencies and cognitive reasoning that lead them to choose healthy food brand products [44] and [45]. On the other hand, this group of people is only one segment of the initial market for new food products [46]. In this way, consumers' perception is related to their cognitive reasoning, which in turn affects their behavior to consume the organic products [47] and [48].

2.4 Consumer Attitude

An attitude is a psychological tendency that is expressed by evaluating a particular entity with some degree of favor or disfavor [2]. In addition, it involves an overall evaluation that expresses how much we like or dislike an object, issue, person, or action. Attitudes are learned, and they tend to persist over time [49]. In other words, attitudes reflect the consumers' overall evaluation of something based on associations linked to it [50] and [49]. However, attitude is important because it guides our thoughts (the cognitive function), it influences our feelings (the affective function, or emotion), and it affects our behavior (the conation function) [51] and [52].

Furthermore, attitude can be described in terms of five main characteristics: favorability, attitude accessibility, attitude confidence, persistence, and resistance [53] and [54]. This research emphasizes the consumers' attitude as it results in behavior. Attitude is understood as a rational, choice-based evaluation of the consequences of a behavior or a behavior's subjective utility, as well as an estimate of the likelihood of expected outcomes [55] , [56] and [57]. Hence, an attitude includes affective (e.g. enjoyable or unenjoyable) and instrumental (e.g. benefit or harmful) evaluation toward a behavior that have contributed to the level a person possesses a desirable or non-desirable estimation or behaviour-based appraisal in question [57], [58], [59], [60] and [61].

2.5 Market Development and Hommali organic rice market in Thailand.

The body of consumers willing to purchase or actively seeking organic products is a new market, which is developing to suit consumers' needs [62], and [60]. Moreover, it has been found that more information about the organic food market, which increases consumers' organic food knowledge, is important because it positively influences consumers'attitudes towards organic food products [2], [63], and [64]. The success of market development absolutely bases on strategy of consumers' perception and attitude creation. Hommali organic rice is high price premium product in domestic market. It can add value to Hommali rice and expand market potentials as well as increase competitive advantage for doing rice market.

Growth of Hommali organic rice market in Thailand has been gradually increase for some years with Roi-Et province as the production leader. Although Roi-Et province has several attempts to expand Hommali organic rice market but it has not been much accepted by Thai consumers because of low perception and attitude.

3. METHODOLOGY

Field survey research was conducted using questionnaires to collect data from 440 test subjects who were Thai Hommali Organic Rice Product consumers; 240 people were surveyed in Bangkok(the capital city), 100 people in Khon Kaen (the biggest city in the Northeastern region of Thailand), and another 100 people were in Roi-Et (the land of Thung Kula). The Hommali Organic Rice is a premium product that has more value of quality and price than normal Hommali Rice products, so the samples should live in the big provinces and have high education. Hence, Bangkok and Khon Kaen was selected because there are many people with high education and high income living there, and Roi-Et was selected because it is the growing land of Hommali Organic Rice. The test subjects were the consumers who regularly buy packed rice and aware about organic rice. Purposive sampling was used for test subjects selection with screening questions pass before interview. Only Hommali Organic Rice Products from Roi-Et Province were used for this study.

The data obtained from the survey is analyzed using fundamental descriptive and inferential statistical methods. The meaning of the mean value in talbe 2,3,4 is definded as follow :

1.00-1.80 refers to lowest
1.81-2.60 refers to low
2.61-3.40 refers to moderate
3.41-4.20 refers to high
4.21-5.00 refers to highest

4. FINDING

A. Personal Data of Test Subjects

74.5% of test subjects were female and 86.6% of these were married. Each household consisted of 3-4 members on average, with 55.7% of households meeting the average. 39.3% had an income around 10,000-20,000 Baht per month. 21.8% had been educated up to a high school or vocational level. Also, 28.6% were running their own business and 45.7% had loyal and sincere personality.

B. Consumers' Perception of Hommali Organic Rice Products from Thung Kula

All test subjects knew of and had consumed Hommali Organic Rice Products; however, only 56.8% knew of Hommali Organic Rice Products from Thung Kula. Most test subjects who didn't know of Hommali Organic Rice Products from Thung Kula were young and single with low income and their education was at a high school or vocational level or lower.

The cultivated areas of Hommali Organic Rice where most test subjects familiar with were Roi-Et Province, followed by Surin and Yasothorn Province respectively.

Most test subjects had received information about Hommali Organic Rice Products from Thung Kula at exhibitions, followed by seeing the products themselves, media advertisements, such as brochures, internet and television respectively.

Most test subjects could not recognize the Hommali Organic Rice brand. For those who did, Sue Sat was the most recognized brand of Hommali Organic Rice Product from Thung Kula, followed by Moral Rice and Rakbankerd brand. The brands they had ever bought are shown in Table 1.

TABLE 1: Number and Percentage of test subjects that purchased various Hommali Organic Product Brands from Roi-et Province

Provinces / Product brand	Bangkok		Khon Kaen		Roi-et		Total	
	Number	Percentage	Number	Percentage	Number	Percentage	Number	Percentage
Sue Sat brand	21	14.1	1	0.7	0	0.0	22	14.8
Rakbankerd brand	15	10.1	2	1.3	0	0.0	17	11.4
Khoa Phen Ya brand	21	14.1	11	7.4	6	4.0	38	25.5
Unrecognized	32	21.5	24	16.1	16	10.7	72	48.3
Total	89	59.7	38	25.5	22	14.8	149	100.0

Note: Subjects could choose more than 1 answer

When buying Hommali Organic Rice products, most test subjects normally look at the label to ensure that the rice they buy is Hommali Organic Rice. Sometimes they receive information from retailers and advertisements. The majority of test subjects buy Hommali Organic Rice from the supermarket, followed by grocery stores and then by Hommali Organic Rice Product Shops.

The test subjects had a high level of awareness about Hommali Organic Rice and also had confidence in the quality and price of Hommali Organic Rice Products from Thung Kula but they paid little attention to the origin of the product. However, they had a low level of awareness in terms of differences between Hommali Organic Rice Products from Thung Kula and Hommali Organic Rice from other areas and knew little about the distribution of Hommali Organic Rice Products from Thung Kula. The results are shown in Table 2.

C. Consumers' Attitude of Hommali Organic Rice Products from Thung Kula

The test subjects had a positive attitude toward Hommali Organic Rice because it was produced without chemical fertilizers, plant growth regulators, herbicides, insecticides, or additional hormones, and was not genetically modified (GMOs).

The production process of Hommali Organic Rice was considered environmentally friendly and helpful in reducing pollution. Hommali Organic Rice Products do not contain poisonous substances and are good for consumers' and producers' health. Most test subjects tended to buy Hommali Organic Rice Products from Thung Kula and would recommend it to other people.

The test subjects were highly satisfied with the widespread and wide range of products (as shown in Table 3).

TABLE 2: Mean and Standard Deviation of Consumers' Perceptions of Hommali Organic Rice from Roi-et Province

No.	Consumers' perceptions	Mean	SD	Level of Consumers' perceptions
1.	I know Hommali Organic Rice, but I didn't pay attention to its origin.	3.44	1.171	High
2.	I know Hommali Organic Rice from Roi-et Province.	3.37	1.085	Moderate
3.	I know Hommali Organic Rice from Thung Kula.	3.35	1.040	Moderate
4.	I often receive information about Hommali Organic Rice from Roi-et Province.	3.04	0.920	Moderate
5.	Information about Hommali Organic Rice from Roi-et Province is interesting and attracts consumers' attention.	3.24	0.897	Moderate
6.	I saw Hommali Organic Rice Products from Roi-et Province in shops and supermarkets.	3.07	1.076	Moderate
7.	I'm confident about the quality and price of Hommali Organic Rice from Roi-et Province.	3.48	0.846	High
8.	I can differentiate Hommali Organic Rice from Roi-et Province and Hommali Organic Rice from other provinces.	2.87	1.216	Moderate
9.	I can easily find Hommali Organic Rice from Roi-et Province.	3.11	1.174	Moderate
10.	I tend to buy Hommali Organic Rice from Roi-et Province.	3.18	1.087	Moderate

Table 3 Mean and Standard Deviation of Consumers' Attitudes towards Hommali Organic Rice from Roi-Et Province

No.	Consumers' Attitudes	Mean	SD	Level of Consumers' Attitudes
1.	I satisfied with the widespread availability of Hommali Organic Rice from Roi-et Province.	3.85	0.808	High
2.	I satisfied with the Channel of Distribution of Hommali Organic Rice from Roi-et Province and these products are easy to find.	3.79	0.848	High
3.	I satisfied with the variety of brands of Hommali Organic Rice from Roi-et Province.	3.31	0.746	Moderate
4.	I satisfied with the price of Hommali Organic Rice from Roi-et Province. (about 60-80 Baht per kilogram)	3.17	0.909	Moderate
5.	I satisfied with the taste and smell of Hommali Organic Rice from Roi-et Province. (only for those who had it before)	3.90	0.670	High
6.	I satisfied with the packaging of Hommali Organic Rice from Roi-et Province.	3.77	0.761	High
7.	I satisfied with the information and details on the label of Hommali Organic Rice from Roi-et Province.	3.62	0.901	High

Moreover, they expressed that the products were tasty and smelled good with nice packaging and labels that provided information and details about the product.

The features of Hommali Organic Rice that the test subjects prefer include its healthy benefits, environmentally friendly and safe to eat (as shown in Table 4)

TABLE 4 Mean and Standard Deviation of Customers' Decision-making Factors

No.	Customers' Decision-making Factor	Mean	SD	Level of Significance
1.	I pay attention to my health.	3.75	0.720	High
2.	I decide to buy products that are good for my health.	3.65	0.913	High
3.	I decide to buy good quality products regardless of price.	3.26	1.227	Moderate
4.	I decide to buy familiar brand products regardless of safety.	2.87	1.224	Moderate
5.	Good products are products that aware of environmental effects.	3.72	0.850	High
6.	I decide to buy products which are considered environmental friendly.	3.32	1.023	Moderate
7.	I decide to buy products which are considered to use animal friendly processes.	3.29	1.181	Moderate
8.	I will buy products whose quality I have confidence in regardless of environmental effect.	2.72	1.238	Moderate

5. CONCLUSIONS

It can be concluded from the results of the field survey research as follows:

1) Most test subjects had loyal and sincere Personality. This will be very good opportunity for Hommali Organic Rice Products from Thung Kula to satisfy them and build up good relationship with them and then make them to be loyal consumers in the near future.

2) About half of consumers knew of Hommali Organic Rice Products from Thung Kula. This shows that there is low accessibility and coverage. Thus, it need more efforts to develop wider markets.

3) Most test subjects who didn't know of Hommali Organic Rice Products from Thung Kula were young and single with low income. This is because young generation cuttently do not pay attention so much about their health and find safe products to consume. However, they will increase their care about health and food when they grow up. The marketers should not ignore these group and should try to find their demand and deep information.

4) Consumers had a positive attitude toward Hommali Organic Rice. They tended to buy Hommali Organic Rice Products from Thung Kula and would recommend it to other people. This result can lead marketer to do the good word of mouth marketing.

5) From Table 3, Consumers had moderate satisfaction with brands and price of Hommali Organic Rice Products. This shows that success of brand might influence good pricing policy. Thus, building good brand image can make the products to get high price.

6. RECOMMENDATIONS

Recommendations are drawn from this research study to sustainably increase competitiveness of Hommali Organic Rice Products from Thung Kula as follows:

1) Appropriate marketing communication should be developed in order to build more positive perceptions and attitudes toward Hommali Organic Rice Products from Thung Kula since most consumers currently cannot recognize the brands of Hommali Organic Rice and the differences between Hommali Organic Rice Products from Thung Kula and from other areas. It will be the good opportunity for Hommali Organic Rice from Thung Kula if it can build up high consmuers' perception at present.

2) Development of product distribution, marketing, and the domestic market are needed in order to expand the product's reach and to be accessible for the target group. Hommali Organic Rice from Thung Kula should be distributed to cover all modern food channels such as healthy products shop, convenience store, hypermarket and supermarket. This could be available in the modenn shop aroun the contry and sustainably increase the competitiveness of Hommali Organic Rice Products from Thung Kula.

3) As consumers pay a lot of attention to their health, they need safe products. The selling points of Hommali Organic Rice Products from Thung Kula that should be good benefits for consuming, no poisonous substances, and its relatively aromatic and soft qualities when compared to Hommali Rice from other areas.

4) A variety of products for examples a rice germ, drink powder, germinated rice milk, and rice facial scrub powder, etc. should be available in order to meet consumers' demands. Packaging and attractive labeling should also be taken into account to make the good image and give valuable information for the consumers.

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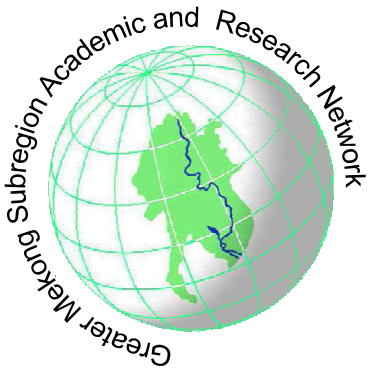

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