OIL SPILL CLEANUP USING NATURAL RECYCLABLE ABSORBENTS

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CERTIFICATION OF APPROVAL

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CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

NORIZAN BINTI ALI

ABSTRACT

The aim of this study is to develop environmental friendly absorbents from natural-based products to absorb the oil spill at water surface. Sugarcane (*saccarhum officinarum*) bagasse, kapok *(Ceiba Pentandra)* and rice husk *(Oryzae Sativa)* are selected as they are easily obtained, free, efficient and biodegradable. The water absorbency, oil absorbency and optimum time are studied for these selected natural-based products as well as the commercial synthetic absorbent which made from Polypropylene (PP). This study proved that the ability of these natural-based products (sugarcane bagasse, kapok and rice husk) as oil absorbents are better than Polypropylene. Experimental works are conducted to achieve all the objectives. The experimental works are including water absorbency test, oil absorbency test and optimum time test. The oils used in this study are diesel, crude oil, engine oil and used engine oil. The results show that PP absorbs water more than the natural-based products which mean that PP is hydrophilic. Kapok has lowest water absorbency followed by SCB and rice husk but rice husk is considered failed since more than 50% were sunk in the water. In addition, from the experiments, SCB and kapok are able to absorb oil impressively compared to PP for all types of oil. Thus, it is proved that natural-based products are better than PP in the sense of hydrophobicity, oleophilicity and biodegradability.

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ABBREVIATIONS

ASTM	American Society for Testing and Materials
cm	Centimetre
EDX	Energy Dispersive X-Ray Spectroscopy
FESEM	Field Emission Scanning Electron Microscope
g	Gram
g/g	Gram per gram
L	Litre
mg	Milligram
min	Minute
ml	Millilitre
PP	Polypropylene
rpm	Rotation per minute
SCB	Sugarcane bagasse
SEM	Scanning Electron Microscope

CHAPTER 1

INTRODUCTION

1.1 BACKGROUND OF STUDY

The ever-growing use and transport of crude oil and oil products has led to an increasing amount of spillages of various scales. Oil spills may contaminate large areas of sea, as well as the shores where it is eventually washed up (Whitfield, 2003 and Suni et al., 2004). More common, however, are oil spills from ship emptying bilge water into the sea. Example of other large spill of oil which was about 12,000 tonnes on the Spanish coast of Galicia by the Prestige oil-tanker; there is now a growing worldwide concern about the urgent need to control accidental and deliberate releases of oil during transportation and storage (Adebajo et al., 2003). It is often possible to pump spilled oil from soil or in the sea in case of large-scale oil spills, but not in minor-scale accidents.

Same as Malaysia, in 1992, there was an oil tanker collision at the Straits of Malacca which cause oil spill to the coast. The collision of tanker Nagasaki Spirit resulting in the discharge of approximately 12,000 tonnes of crude oil into the marine waters just off the coast of Sumatra and the northern resort island of Malaysia. This is one of the cases that can be seen from our own Straits of Malacca, but this problem does not stop here. Since the development of oil and gas industry, oil spill has also been one of the major problems faced by the world as the coast is being polluted by the petroleum products (Rosnani, 1995).

In these cases, various sorbents are commonly used to absorb the spilled of oil (Suni et al., 2004). A wide range of materials for oil remediation have actually been employed such as dispersants, absorbents, solidifiers, booms and skimmers (Adebajo et al., 2003). Biodegradable absorbents with excellent absorption properties would be advantageous in this respect. A number of natural sorbents have been studied for use in oil spill cleanup; cotton (Choi and Cloud, 1992; Choi, 1996; Johnson et al., 1973), wool (Choi, 1996; Johnson et al., 1973; Radetic et al., 2003), bark (Haussard et al., 2003; Saito et al., 2003), kapok (Choi, 1996; Hori et al., 2000), kenaf (Choi and Cloud, 1992), even cotton grass fibre (Suni et al., 2004). Most of them have better absorption capacities than synthetic products, but they often sorb water well, which is disadvantage when used in marine environments (Wei et al., 2003).

Sugarcane (*Saccarhum officinarum*) bagasse (SCB), Kapok *(Ceiba Pentandra)* and Rice Husk *(Oryzae Sativa)* are the biodegradable materials that have the ability to act as oil absorbent since they fall under the category of lignocellulosic product. There are number of researchers have done work on natural sources. They studied the absorption capacity, high uptake capacity, high rate of uptake, retention over time, oil recovery from absorbents, and the reusability and biodegradability of the natural sources.

1.2 PROBLEM STATEMENT

Natural-based products will be developed as the oil absorbent in order to control the oil spill problem in this country because synthetic absorbent is costly. For example the most well-known commercial absorbent which is Polypropylene is costly around RM 70 to RM80 for 1 box. Natural-based product is the most economical or free of charge and efficient methods for combating oil spillage. The preferred sorbent materials are those which, besides being inexpensive and readily available, demonstrate fast oil sorption rate, high oil sorption capacity, low water pickup, good reusability, high buoyancy and biodegradability. The selected natural-based products for this study are SCB, kapok and rice husk.

1.3 OBJECTIVES AND SCOPE OF STUDY

The main objectives of this research are:

- To develop an environmental friendly absorbent from SCB and other natural-based products that can be used to absorb the oil spill at water surface.
- To determine the water absorbency, oil absorbency and optimum time for SCB, kapok, rice husk and Polypropylene, PP.
- To prove the natural recyclable absorbents is better than the synthetic absorbent which is PP.

Scope of this work is to conduct a study on natural recyclable absorbents (SCB, kapok and rice husk) which are very economical, technically feasible and environmentally acceptable for application in oil spill cleanup technology. The optimum time for absorbing process and the relations between oil absorbency and other factors such as time of adsorption and types of oil will be determined. Types of oil used in this study are crude oil, diesel oil, engine oil and used engine oil. Furthermore the study is to prove these absorbents is better than PP in the sense of water pickup capacity, oil pickup capacity, optimum time and biodegradability of the absorbent.

1.4 THE RELEVENCY OF THE PROJECT

SCB is easily found in Malaysia either from the extraction of juice industry or from sugar industry. According to the Economic and Social Development Department of Malaysia, production of sugarcane generally ranges between 1.3 to 1.6 million tonnes annually depending largely on yields. The other natural-based product, rice husk is also easily obtained in this country since Malaysia is one of the rice producers in the world. The annual production for rice is about 1.2 to 1.4 million tonnes. A part from that, kapok trees are mostly cultivated in Southeast Asia, notably in Java (hence its nickname), Philippines and also in Malaysia. Normally, kapok is used as filling in mattresses, pillows, stuffed toys and for insulation.

1.5 FEASIBILITY OF THE PROJECT

First part of the study was focused on research about the characteristic and physical properties of SCB, kapok and rice husk that can be used as oil spill cleanup. The second part was focus on experimental to determine their water pick-up ratio, oil pick-up ratio and the optimum time of absorbing process for each sample of the absorbents.

CHAPTER 2

LITERATURE REVIEW

2.1 OIL SPILLS

An oil spill is the accidental petroleum release into the environment whether into water or soil. Oil spill accidents can be caused by human mistakes and careless, deliberate acts such as vandalism, war and illegal dumping, or by natural disasters such as hurricanes and earthquakes (Lim and Huang, 2007). On land, oil spills are usually localized and thus their impact can be eliminated relatively easily. In contrast, marine oil spills may result in oil pollution over large areas and present serious environmental hazards.

The primary source of accidental oil input into seas is associated with oil transportation by tankers (as shown in Figure 2.1) and pipelines which are about 70%, whereas the contribution of offshore drilling and production activities is minimal which less than 1%. Large and catastrophic spills releasing more than 30,000 tonnes of oil are relatively rare events and their frequency in recent decades has decreased perceptibly. Yet, such episodes have the potential to cause the most serious ecological risk and result in long-term environmental disturbances and economic impact on coastal activities especially on fisheries and mariculture (Stanislav, 2009).

Figure 2.1: Oil Spill during Transportation.

2.2 SPREADING OF OIL

Oil spreads to a lesser extent and slowly on land than on water. Oil spilled on or under ice spreads relatively rapidly but does not spread to as thin as slick on water. On any surface other than water, such as ice or land, a large amount of oil is retained in depressions, cracks and other surface irregularities. After an oil spill on water, the oil tends to spread into a slick over the water surface. This is especially true of the lighter products such as gasoline, diesel fuel, and light crude oils, which form very thin slicks. Heavier crudes spread to slicks several millimeters thick. Heavy oils may also form tar balls and tar mats and thus may not go through progressive stages of thinning.

Oil spreads horizontally over the water surface even in the complete absence of wind and water currents. This spreading is caused by the force of gravity and the interfacial tension between oil and water. The viscosity of the oil opposes these forces. As time passes, the effect of gravity on the oil diminishes, but the force of the interfacial tension continues to spread the oil. The transition between these forces takes place in the first few hours after the spill occurs. The rates of spreading under ideal conditions are shown in Figure 2.2.

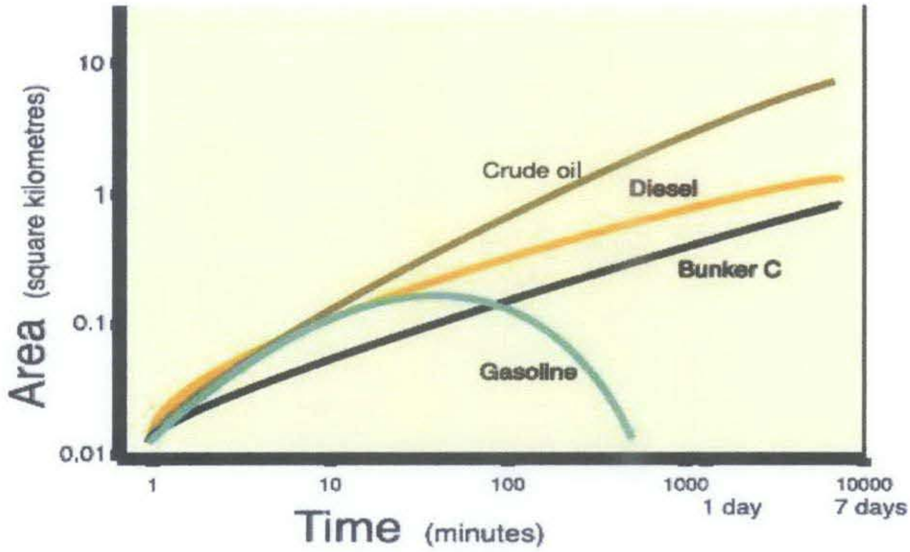

Figure 2.2: Comparison of Spreading of Different Oils and Fuels.

As a general rule, an oil slick on water spreads relatively quickly immediately after a spill. The outer edges of a typical slick are usually thinner than the inside of the slick at this stage so that the slick may resemble like a fried egg. After a day or so of spreading, this effect diminishes. Winds and currents also spread the oil out and speed up the process. Oil slicks will elongate in the direction of the winds and currents, and as spreading progresses, take on many shapes depending on the driving forces. Oil sheens often precede heavier or thicker oil concentrations. If the winds are high which more than 20 km/h is, the sheen may separate from thicker slicks and move downwind (Fingas, 2000).

2.3 OIL SPILLS AFFECT THE ENVIRONMENT

Oil is the water fast-compound, if oil entered into the ocean will form a big area oil-film on the ocean surface. This oil slick affects the ocean's system matter and the energy exchange. As a rule, pour 1 tonne into the ocean that will be 12 km^3 oil slicks on the ocean surface (Huang, 2005). This oil slick prevents the oxygen from the atmosphere into the ocean will increase the greenhouse gas like CO_2 inside the ocean. This will cause more global warming. The sea surface has the oil slick, which can increase reflectivity; reduce the solar energy into the sea water. Besides, the oil slick also can increase the temperature of ocean. Oil spills also will give problems to many marine animals because the oil floats along the top of the water into a thin layer called an oil slick. This oil gets coated on the marine animals making it difficult to fly or swim. The animals also digest the oil when trying to clean them, which can poison themselves. About hundreds of thousands birds, and mammals died every time there is an oil spill (Larry, 2004). Figure 2.3 shows a heavily oiled bird, such as this one, have little chance of survival.

Figure 2.3: Heavily Oil Bird.

2.4 MAJOR SPILLS AROUND THE WORLD

The catastrophic explosion that caused and oil spill from a BP offshore drilling rig in the Gulf of Mexico has reached the shoreline early Friday morning on 30th April 2010. The leak is currently releasing 5 000 barrels of oil per day and efforts to manage the spill with controlled burning, dispersal and plugging the leak were unsuccessful Thursday (Huffington post, 2010). This oil spill is on track become the worst oil spill in history, surpassing the damage done by the Exxon Valdez tanker that spilled 11.2 million gallons of crude oil into the ecologically sensitive Prince William Sound in March 1989 (Westermeyer, 1991). Examples of other spilling of oil include the purposeful dumping of 2.5-4 million barrels into the Gulf of Suez during the Persian Gulf War, the loss of 24,000 barrels into the Monongahela River due to a ruptured storage tank (Adebajo et al., 2003) and the demolition of oil storage tanks in Kuwait during the war in 1991 spilled several hundred million gallons of oil into the sea (Teas et al, 2001). Malaysia is also not excluded from facing this problem. Table 2.1 shows the oil spill incidents in Malaysia water from year 1975 until 2007.

Table 2.1: Oil Spill Incidents in Malaysia Water (1975-2007).

Year	Name of Ship	Location	Cause	Type of Oil	Quantity (ton)
1975	Showa Maru	Straits of Singapore	Grounding	Crude	4,000
1975	Tola Sea	Straits of Singapore	Collision	Fuel	60
1976	Diego Silang	Straits of Malacca	Collision	Crude	5,500
1976	Mysella	Straits of Singapore	Grounding	Crude	2,000
1976	Citta Di Savonna	Straits of Singapore	Collision	Crude	1,000
1977	Asian	Straits of Malacca	Collision	Fuel	60
1978	Esso Mersia	South China Sea	Collision	Fuel	505
1978	Fortune	South China Sea	Collision	Crude	10,000
1980	Lima	Straits of Singapore	Collision	Crude	700
1981	MT Ocean Tresure	Straits of Malacca	Human Error	Fuel	1,050
1984	Bayan Platform	South China Sea	Human Error	Crude	700
1987	MV Slolt ADV	Straits of Singapore	Grounding	Crude	2,000
1987	Elhani Platform	Straits of Singapore	Grounding	Crude	2,329
1992	Nagasaki Spirit	Near Medan	Collision	Crude	12,000
1997	Evoikos	Straits of Singapore	Collision	Fuel	25,000
1997	An Tai	Straits of Malacca	Material Fatigue	Fuel	237
2000	Natuna Sea	Straits of Malacca	Grounding	Crude	7,000
2007	MV Sahelderberg	Straits of Singapore	Collision	Crude etc	-

Sources:

(http://www.marine.gov.my/service/kp_oil.html)

(http://www.pcs.gr.jp/doc/esymposium/2002/2002_Ian_Ferguson_E.pdf)

(http://ms.wikipedia.org/wiki/Tumpahan_minyak_di_Selat_Melaka_2007)

2.5 METHODS OF CONTROL

The present methods for oil spill removal are enormous. However, it is usually divided into three categories; physical methods, chemical methods and biological methods (Bordeson, 2004).

2.5.1 Chemical Methods

A) Dispersant

Special chemicals such as soaps are called dispersants and can be used to break up or dissolve oil. Besides, gelling agents are used to react with oil to form a rubbery solid which can then be removed from the water. However, special chemicals might hurt the environment and living organisms. Thus, it is not the best choice along coastlines or populated areas.

B) Burning

This method is simply burning spilled oil while it is still floating on the water. Burning is not a suggest method. It causes the effects both air pollution and toxicity from the residue of combustion.

2.5.2 Biological

In nature, many microorganisms such as bacteria and fungi break down oil into a harmless substance. It is also called Bioremediation. Biological agents are chemicals or organisms that speed up the rate of the biological breakdown of oil. These microorganisms and agents are being researched and have the potential to provide cleanup in sensitive areas such as shorelines and wetlands without further harming the environment. For example, *Bacillus Subtilis* was found to be a hydrocarbon degrader. *B. Subtilis* had higher potential to utilize diesel oil as carbon source (Nwaogu et al, 2008). However, time using in degradation is its disadvantage since the degradation process takes a long time.

2.5.3 Physical Methods

A) Booms

Booms are the floating barriers which placed around the oil or around whatever is leaking the oil. Booms contain the oil so skimmers can collect it. Figure 2.4 shos the small section of Booms while Figure 2.5 shows that booms retained oils in calm water.

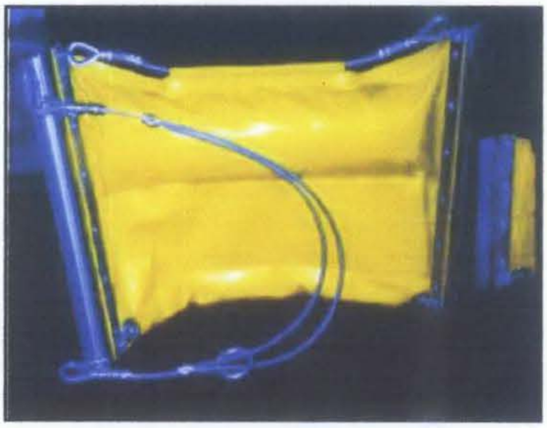

Figure 2.4: Small Section of Booms.

Figure 2.5: Booms contain Oils.

B) Skimmers

This method involves physically removing the oil from the water. Boats, vacuum machines and oil-absorbent plastic ropes that skim spilled oil from the water's surface after booms have corralled it. The skimmer collects oil into a container so it can be easily removed. Figure 2.6 shows how the Skimmer works together with Booms when collecting the oil spills.

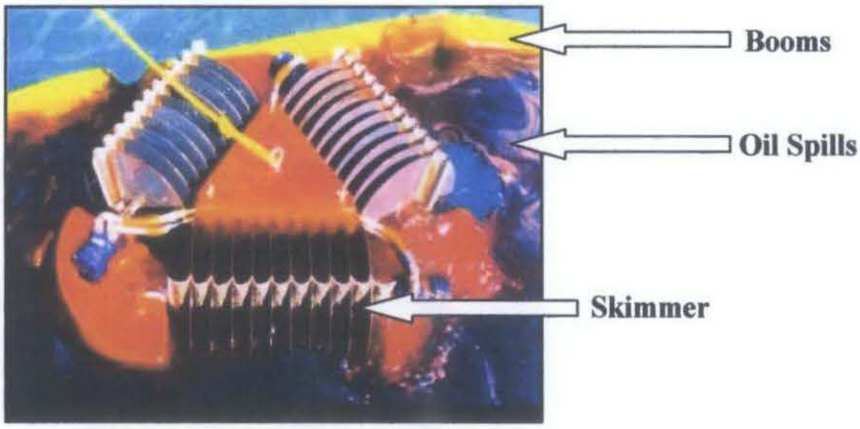

Figure 2.6: A Skimmer Collects the Oil that Retain within the Booms.

C) Absorbent

Oil sorbents material can be categorized into three major classes: inorganic mineral products, organic products and organic vegetable products. Mineral products include perlite, graphite, vermiculites, sorbent clay and diatomite. Synthetic products include polypropylene and polyurethane foam, their main disadvantage being that they degrade very slowly as compared with vegetable or natural-based products and are not naturally occurring as mineral products (Teas et al, 2001; Adebajo et al, 2003).

2.6 ECONOMICAL AND EFFICIENT METHOD – Synthetic and Natural Recyclable Absorbents

At present, most of the commercially available oil sorbents are organic synthetic products such as polypropylene and polyurethane (Teas et al, 2001; Adebajo et al, 2003; Lim and Huang, 2007). However, there are non-biodegradable and can be difficult to deal with after use due to the xenobiotic nature (Lim and Huang, 2007). The mineral products used as oil sorbents include zeolite, perlite, organoclay, silica, aerogel, and diatomite. Most of them have poor buoyancy and oil sorption capacity (Lim and Huang, 2007). Besides, they are difficult to handle on site due to granular or powder forms. The poor reusability and oil recovery are their disadvantages. The limitation of the minerals products and organic synthetic products have led to the recent interest in developing alternative materials, especially biodegradable ones such as natural-based products (Lim and Huang, 2007).

Natural-based products and residues have good oil absorbency, inexpensive and available locally. Some are waste materials and hence their reuse will result in savings in disposal free. Natural-based products have potential to sorb significantly more oil then even PP materials that are commercially used. In this study, SCB, kapok and rice husk will be tested to determine their capability as oil absorbent.

2.6.1 Sugarcane (*Saccarhum officinarum*) Bagasse

The production of sugar from sugarcane is one of the largest agriculture in Malaysia. SCB is a residue produced in large quantities by sugar industries. In general, 1 tonne of sugarcane bagasse generates 280 kg of bagasse, the fibrous by-product remaining after sugar extraction from sugarcane (Sun et al, 2004). However, the utilization of sugarcane bagasse is still limited and reserved as animal feed. It is not utilized for other better purpose. From the environmental perspective, this agriculture waste can be reused to solve oil spill problem. Furthermore, most agriculture waste is harmless to both human and the environment.

SCB is a fibrous, low density material with a very wide range of particle sizes and high moisture content (10-15%). Therefore, it is needed to be air-dried before it could be used as absorbent. SCB consists of three components namely, pith, fibre and rind mixed in different proportions. There is a considerable difference in shapes and sizes of the three components. The rather regular shape of spongy pith particles with a near unity length/width ratio can be approximated by a spherical shape. The shape of fibres with high length/width ratios can be modelled by cylinders. The large rind material roughly comprises rectangular particles with high length/width ratios. Some fibres are often adjacent to the inner wall of the rind particles (Rasul et al., 1999).

2.6.2 Kapok *(Ceiba Pentandra)*

Kapok fiber is also an agricultural product which has high oil absorbency characteristics. Kapok trees of the family *Bombacaseae* are cultivated in Sri Lanka, other parts of East Asia, Africa and Southeast Asia especially Malaysia. In Malaysia, *kekabu* is the local name for kapok. Their silky fibers clothe the seeds of the tree. The kapok fiber is fluffy, lightweight, non-allergic, non-toxic, resist to rot and odorless. It has rich oiliness and inelastic to be spun. It is conventionally used as stuffing for bedding, upholstery, life preservers and other water-safety equipment because of its excellent buoyancy and for insulation against sound and heat because of its air-filled lumen.

Kapok fibers typically comprise 64% cellulose, 13% lignin and 23% pentosan (Kobayashi et al., 1977). Besides these constituents, they also contain waxy cut in on the fiber surface which makes them water repellent not withstanding they are mainly composed of cellulose. This study systematically evaluated kapok fiber for its oil absorbency and oleophilic-hydrophobic characteristics. Comparisons between the kapok, rice husk, SCB and PP will be carried out.

2.6.3 Rice Husk *(Oryzae Sativa)*

Rice husk is a waste product of the agriculture activity in most countries in Asia and in particular Malaysia. Rice husk has posed a major problem of disposal to the rice milling industry in Malaysia and elsewhere in the world. Efforts have been made in the past 20 years to use rice husk in various way. Rice husk actually could be used to absorb oil due to its special structure-skeleton of cellular structure (Huang, 2005). Therefore, its characteristics and potential as the natural recyclable absorbent will be determined in this study.

CHAPTER 3

METHODOLOGY

3.1 RESEARCH METHODOLOGY

In this study, SCB, kapok and rice husk are used as natural recyclable absorbents to remove oils from bodies of water. This method is an ecologically and environmentally advantageous way to remove oil from water to prevent harm to natural resources and marine life. Besides, it is practical, economical and easily found in Malaysia from agricultural industry. They are categorized under the lignocellulosic material whereby this category has high sorption capacity and high uptake rate (absorption rate).

In the earlier stage of this study, the author did the literature review on oil spills, the effects of oil spills to the environment, the causes of oil spills, oil spill incidents and methods of oil spill removal. Other than that, the author also has found the important information that is related to this project which is about SCB, kapok and rice husk. For the experimental methodology, the author has referred to ASTM standards.

Before starting the experiments, some preparations are done. The author has prepared the sample of SCB, kapok, rice husk and PP. SCB was grinded into 3 sizes which are 0.5 mm, 4 mm and 6 mm. The purpose of grinding is to identify the suitable size of SCB that can absorb the most oil. After that, the microporous images of each sample have been taken using SEM and FESEM. In addition, the elements of each sample also have been identified using EDX and the results are in the form of spectrums. The spectrums show that SCB, kapok and rice husk contains calcium carbonate and silicon dioxide. These two elements played important role in the absorption process. Hence, they are suitable to be used as sorbent materials. The variables used in this study are crude oil, diesel, engine oil and used engine oil. Viscosity test and density test have been done to determine the viscosity and density of each type of oils.

The second part of this study is the experimental works. The experiments have been done to determine the relations between oil absorbency and other factors such as time of absorption and types of oil. The experiments are also aimed to prove that natural-based products are better that the synthetic absorbent that made of PP.

The final stage of this study is to analyst the data that obtained from the experiments. After that, discussion will be made based on the obtained results before come out with the conclusion. Figure 3.1 below shows a general process flow of this research method in order to meet the set objectives:

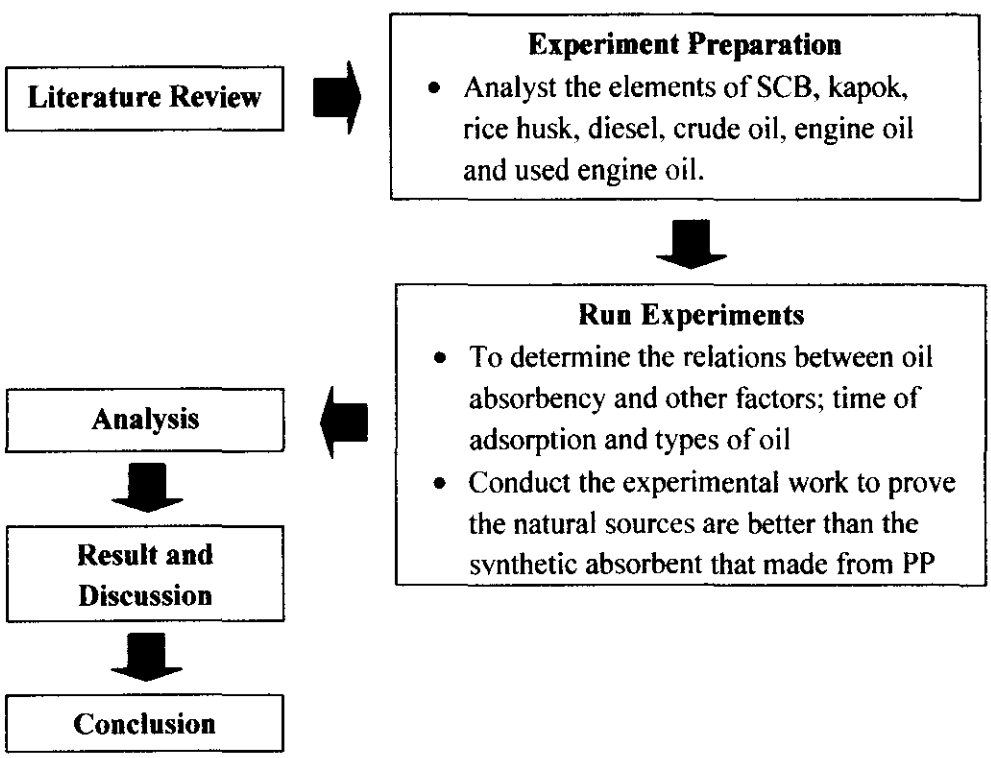

Figure 3.1: Process flow of project research methodology.

3.2 MATERIALS, TOOLS/EQUIPMENTS AND TEST METHODS

3.2.1 Materials

1. **Sugarcane Bagasse**

SCB that used in this study was obtained from local farmers in Perak. Firstly, the hard skin of sugarcane was separated from the sugarcane stalk to get SCB and it is then washed with water to remove dust or other foreign materials. After that, SCB is fully dried in sunlight to ensure the complete removal of moisture. Then it was grounded into 3 sizes which are 0.5 mm, 4 mm and 6 mm, as shown in Figure 3.5 – 3.7. Figure 3.2 – 3.4 show the process where the hard skin of sugarcane was separated from sugarcane stalk.

Note: During the experiments, SCB 0.5 mm is identified as failed and cannot be used to absorb oil since it flows through the mesh basket.

Figure 3.2: Sugarcane Bagasse.

Figure 3.3: Sugarcane Bagasse (SCB).

Figure 3.4: Hard Skin of Sugarcane.

Figure 3.5: SCB 0.5 mm.

Figure 3.6: SCB 4mm.

Figure 3.7: SCB 6mm.

2. Kapok

The raw kapok fibre (as shown in Figure 3.8) used in this study was obtained from nearby village in Bota, Perak. All visible lumps and impurities found in the product were manually removed before use. Then, kapok is properly stored to avoid from moisture.

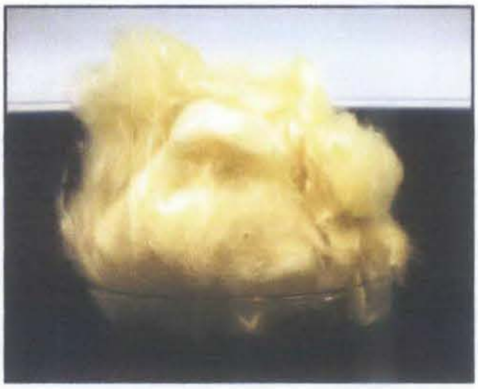

Figure 3.8: Kapok.

3. Rice Husk

Rice Husk was found in Seberang Perak, Perak which is one of the areas of paddy plantation in Malaysia. The impurity of rice husk is removed by pure water washing. Any detergent is not used to remove its impurity because probably will affects the results. Figure 3.9 below shows the rice husk.

Figure 3.9: Rice Husk.

4. Tested Oil

Four types of oils (shown in Figure 3.10 – 3.13) have been selected for this study. Diesel (PETRONAS Dynamic Diesel), crude oil (Tapis Crude), engine oil (PETRONAS Mach 5 SL 10W-30) and used engine oil were employed to investigate the oil sorption characteristic of SCB, kapok, rice husk and PP. The type and brand of used engine oil is unknown because it was taken from workshop at Sri Iskandar. These oils are chosen because of the different level of viscosity and easy to obtain.

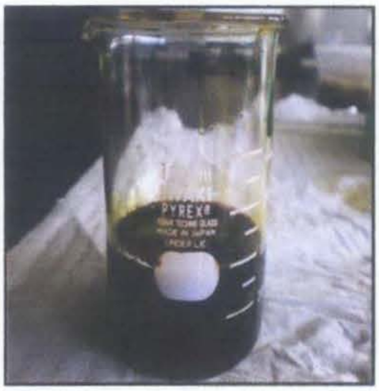

Figure 3.10: Crude Oil.

Figure 3.11: Diesel Oil.

Figure 3.12: Engine Oil.

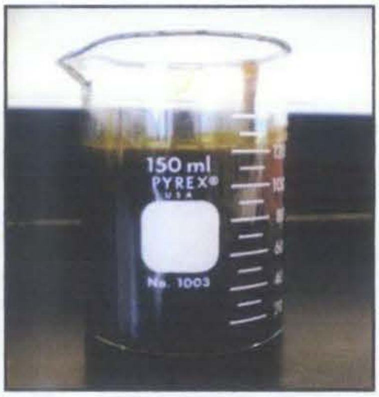

Figure 3.13: Used Engine Oil.

5. Synthetic Absorbent (PP)

The synthetic absorbent used in this study is obtained from the lab. This synthetic absorbent is made from inert polypropylene (PP) and polyester fibers. It is able to absorb oils, hydrocarbons fuels (e.g. diesel, petrol), alcohols, Toluene, Benzene, Xylenes and Esters. According to the ASTM F 726-99, before precede the water absorbency experiment, it must be cut into the size of 6 cm x 6 cm (shown in Figure 3.15) while the size of 13 cm x 13 cm (shown in Figure 3.16) is prepared for oil absorbency and optimum time test. Figure 3.14 shows the synthetic absorbent before being cut.

Figure 3.14: Synthetic absorbent, PP.

Table 3.15: PP (6 cm x 6 cm).

Figure 13.16: PP (13 cm x 13 cm).

3.2.2 Tools and Equipments

1. **4L Container**

The test cell that used in this study is 4L container as shown in Figure 13.17. It is used for all tests in this study.

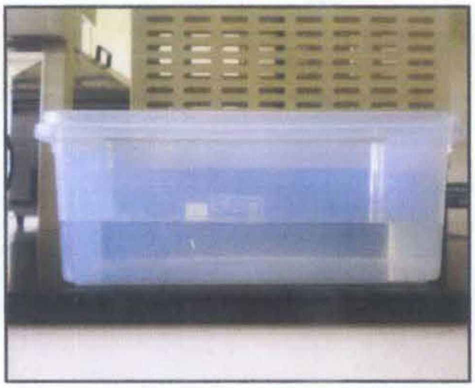

Figure 13.17: 4L container.

2. Mesh Basket

Figure 13.18 below shows the mesh basket that is used to catch absorbent samples when draining process. It is also used to accommodate the absorbent samples like SCB and rice husk when saturated during the oil absorbency test (as shown in Figure 3.19).

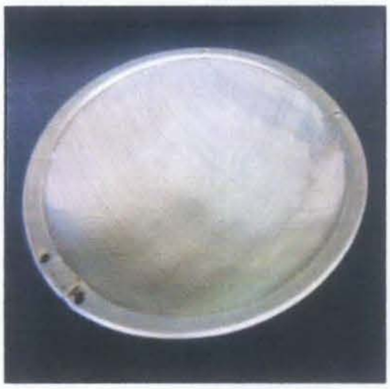

Figure 13.18: Mesh basket.

Figure 13.19: Oil Absorbency Test.

3. Shaker Table (PolyScience)

Shaker table used to shake the test cell during the experiments. The frequency of the shaker table must be set at 150 rpm with the temperature of 23 °C - 25°C (ASTM F 726-99). Figure 13.20 shows the water bath that is functioning as a shaker table. Figure 13.21 shows its above view.

Figure 3.20: Front view of the shaker table.

Figure 3.21: Above view of the shaker table.

3.2.3 Test Methods

1. **Grinding Process**

Analytical mill or grinding machine is used to ground SCB into 3 sizes which are 0.5 mm, 4 mm and 6 mm, as previously shown in Figure 3.5 – 3.7.

Figure 3.22: Analytical Mill.

2. **Oil and Grease Analyzer, OIL-20A**

OIL-20A is an apparatus for extracting oil from water with tetrachloroethylene (C_2Cl_4) and measuring an amount of infrared absorbance (absorbency by C-H expansion movement on 3.5 μ wavelength) of the extracted substances, thereby to provide digital display of oil content calculated in ppm. This method is used in optimum time test. It is used to test the oil content after being absorbed by natural-based samples as well as PP. Figure 3.24 shows the Oil and Grease Analyzer.

Figure 3.24: Oil and Grease Analyzer.

3. Surface Morphology and Micro Porous Structure Analysis

SEM (Scanning Electron Microscope) is used to analyze the surface morphology and micro porous structure of SCB. Figure 3.25 shows its image with magnification factor 50 while Figure 3.26 shows its image with 1000. From the images, pores (in red circle) at its surface can be seen clearly. The size of the pores ranges from 1.465 μm to 1.563 μm.

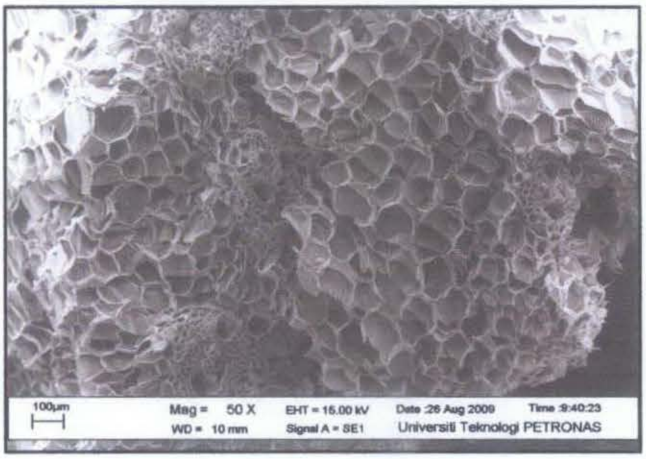

Figure 3.25: SEM Micrograph for SCB (magnification factor 50).

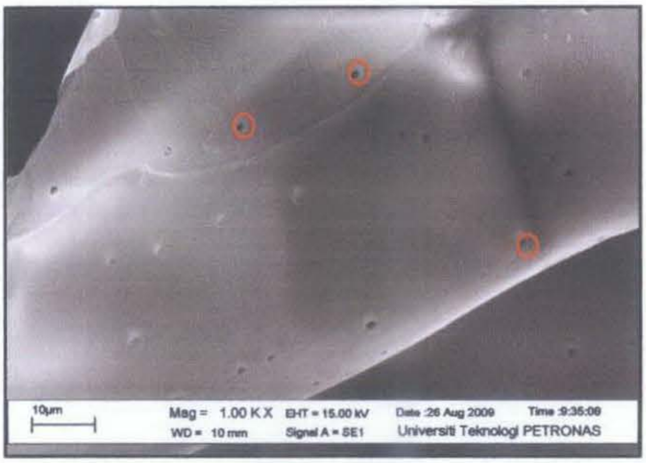

Figure 3.26: SEM Micrograph for SCB (magnification factor 1000).

Apart from that, FESEM (Field Emission Scanning Electron Microscope) is also used to analyze the surface morphology and micro porous structure of SCB 0.5 mm, 4 mm, 6 mm, kapok and rice husk. FESEM produces clearer, less electrostatically distorted images with spatial resolution down to 1 nm. That is 3 to 6 times better than SEM. FESEM model used in this research is SUPRA 55 PP, brand of ZEISS.

Figure 3.27: FESEM Micrograph for SCB 0.5 mm.

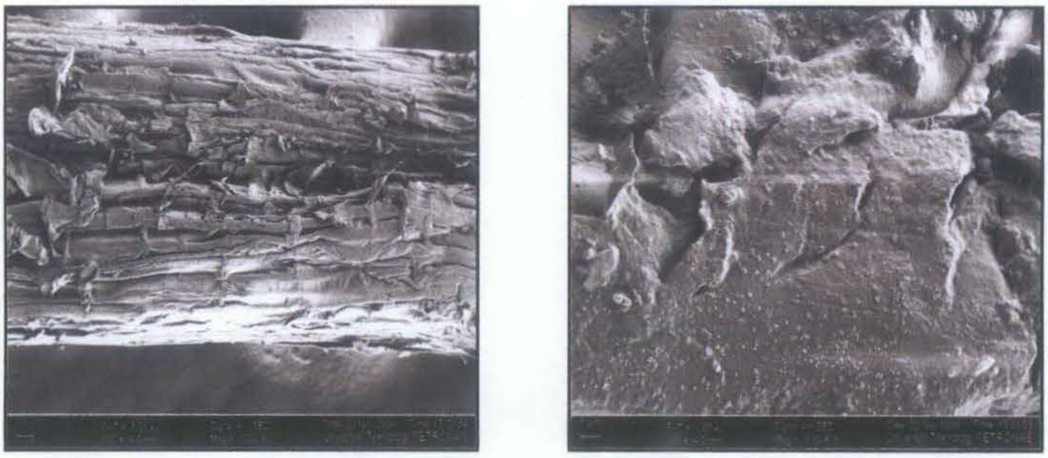

Figure 3.28: FESEM Micrograph for SCB 4 mm.

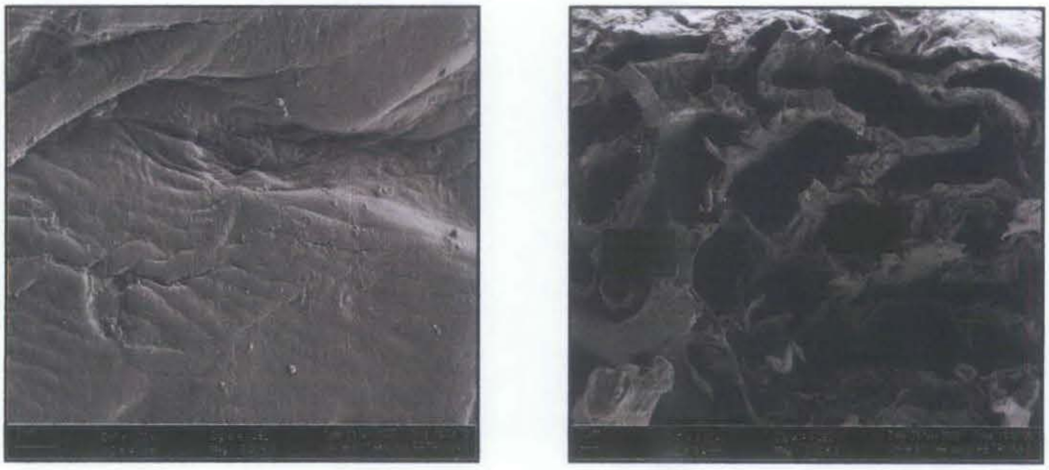

Figure 3.29: FESEM Micrograph for SCB 6 mm.

Figure 3.27, Figure 3.28 and Figure 3.29 show images for SCB 0.5 mm, 4 mm and 6 mm respectively. From the images, the roughness of the surface of SCB can be seen clearly. The pores are also clearly seen at their surfaces. Therefore, it can be said that SCB is categorised under cellulosic fibre and has the ability to absorb oil spills. The size of the pores ranges from 9.674 μm to 17.30 μm.

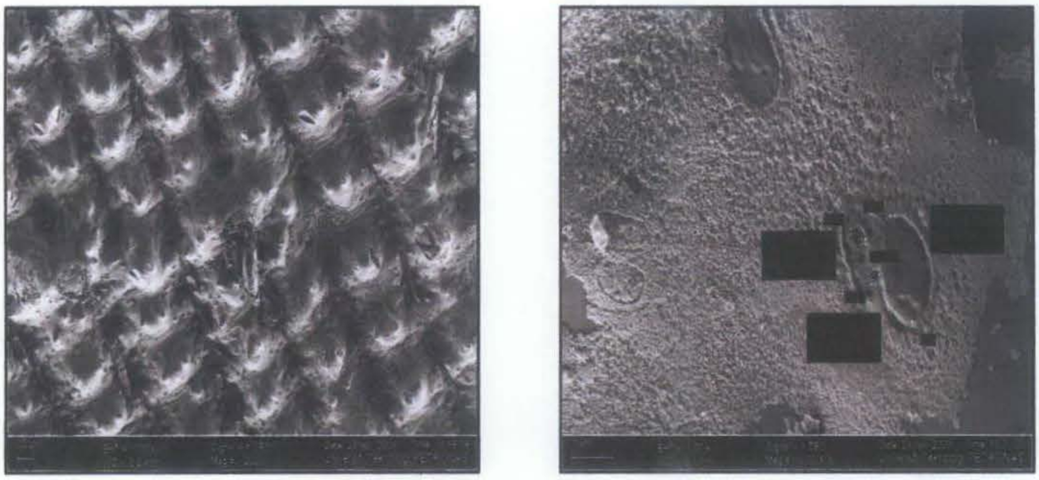

Figure 3.30: FESEM Micrograph for Rice Husk.

Figure 3.30 shows images for rice husk. The first image shows the structure-skeleton of cellular structure. Same as SCB, rice husk also has pores on its surface. This property of rice husk could be used to absorb oil. The size of the pores of rice husk ranges from 205.3 nm to 2.02 μm. It shows that, the pores size of rice husk is smaller than SCB.

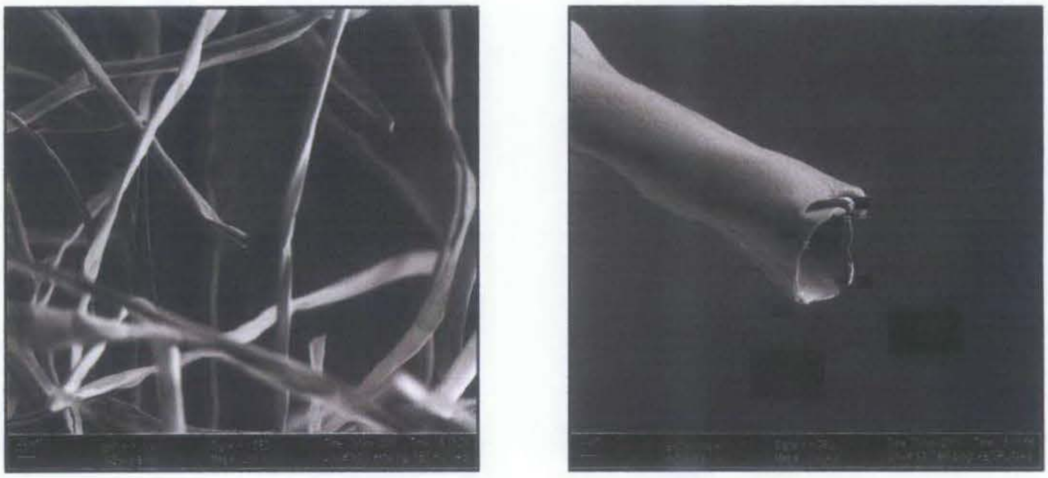

Figure 3.31: FESEM Micrograph for kapok.

Figure 3.31 shows images for fibre of kapok. The fibre has a hollow tubular structure (or lumen) with external diameter of 17.98 μm and internal diameter of 5.777 μm. This indicates that more than 50% of the fibre volume is lumen. Thus, kapok has potential to be excellent oil sorbent in its native state.

4. EDX Analysis Composition (EDX OXFORD INCA)

EDX (Energy Dispersive X-ray spectroscopy) is in combination with SEM. EDX is used to make a quantitative chemical analysis of an unknown material. X-rays generated from any particular element are characteristic of that element and as such, can be used to identify which elements are actually present under the electron probe. This is achieved by constructing an index of x-rays collected from a particular spot on the specimen surface, which is known as a spectrum. Figure 3.32, Figure 3.33 and Figure 3.34 show the spectrum for SCB, Kapok and rice husk respectively.

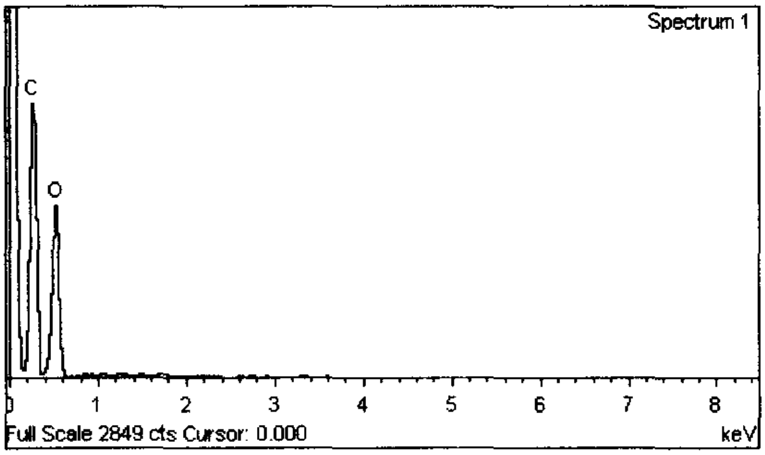

Figure 3.32: Spectrum for SCB.

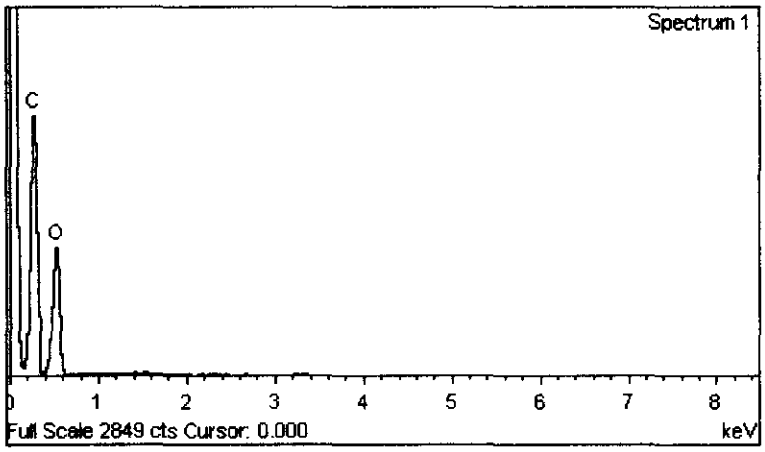

Figure 3.33: Spectrum for Kapok.

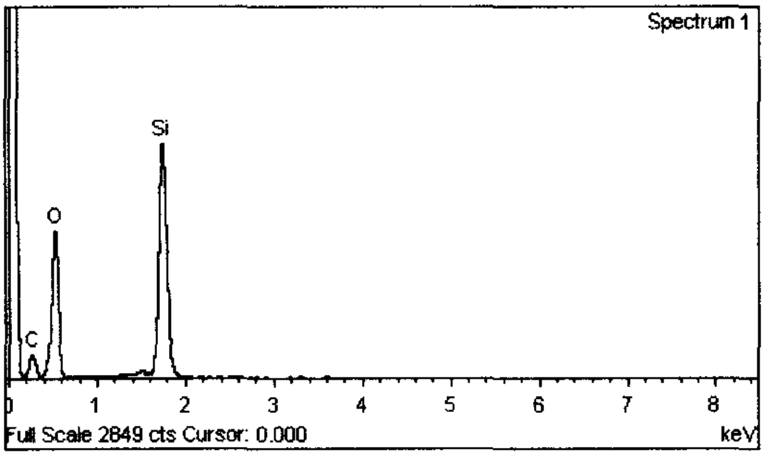

Figure 3.34: Spectrum for Rice Husk.

Table 3.1: Weight % of element for each material.

Material	**Element**	**Weight %**
SCB	C	50.92
	O	49.08
	Totals	100
Kapok	C	53.79
	O	46.21
	Totals	100
Rice Husk	C	24.01
	O	51.03
	Si	24.94
	Totals	100

Standard: C = $CaCO_3$, O = SiO_2, Si = SiO_2

Based on the spectrums in the Figure 3.33 – 3.35 and Table 3.1, it is shown that kapok has the highest percentage of weight for calcium carbonate ($CaCO_3$) which is 53.79 % followed by SCB, 50.92 % and rice husk, 24.01 %. For element silicon dioxide (SiO_2), rice husk has the highest percentage which is 51.03 % while SCB has slightly lesser than rice husk with percentage of 49.08. Kapok has the lowest percentage of weight with 46.21 %. Calcium carbonate and silicone dioxide normally found in mineral products. According to Adebajo (2003), mineral products include materials such as zeolites, silica, perlite and graphite are also widely used in oil spills control. Therefore, SCB, kapok and rice husk have high potential to be oil sorbent since they have high content of calcium carbonate and silicon dioxide.

5. Viscosity Test

Viscosity test has been done for diesel, crude oil, engine oil and used engine oil by using Brookfield LVPV-1+ Viscometer. There are a few spindles that can be used during the test. However a suitable spindle and suitable rpm must be selected in order to get the most constant results which is the accurate viscosity. The test is done in several times for each type of oil until it shows a constant value. In this test, spindle number 1 is chosen and rpm is set to 30. The value of viscosity is appeared in unit centrepoise (cP). Figure 3.35 shows the viscosity test for crude oil while Table 3.2 shows the viscosity for the oils.

Figure 3.35: Viscosity Test for Crude Oil.

Table 3.2: Viscosity for Each Type of Oil.

Types of Oil	rpm	Viscosity, cP
Diesel Oil	30	1.6
Crude Oil	30	42
Engine Oil	30	79.6
Used Engine Oil	30	62.6

Based on the Table 3.2, the lowest viscosity is the viscosity of diesel which is 1.6 cP and engine oil has the highest viscosity with 79.6 cP. Normally, used engine oil has the higher viscosity than engine oil but it is different in this case since the used engine oil was obtained from workshop and the type and brand of the used engine oil cannot be identified.

6. Density Test

Other test method is density test. Density test have been completed to the oils by using DMA 35 M Anton Baar. Table 3.3 shows the results of the test.

Table 3.3: Density for Each Types of Oil.

Types of Oil	Density at 25°C, g/cm^3
Diesel Oil	0.830
Crude Oil	0.855
Engine Oil	0.851
Used Engine Oil	0.929

3.3 EXPERIMENTAL PROCEDURE

3.3.1 Water Absorbency

From determination of ASTM F 726-99 (ASTM, 1999), this procedure is designed to test for water take up of an absorbent sample. This test is performed at room temperature. According to ASTM F 726-99, commercial absorbent like roll, film, sheet, pad, blanket and web are categorised under Type I absorbent while SCB, kapok and rice husk are categorised under Type II absorbent since the materials are unconsolidated, particulate material without sufficient form and strength to be handled with scoops and similar equipment. The procedures for determination of water absorbency are shown below:

Part A: For Type I Absorbent

1. Take 4 pieces of the oil absorbent pad with the size of 6 cm x 6 cm.
2. Weigh all the pieces and defined as W_1 in unit gram.
3. Place all the pieces in a 4L container which is half-filled with water.
4. Place the container's cover on its opening and place it on a shaker table (water bath).
5. Set amplitude of the shaker to 3 cm and its frequency to 150 rpm for a duration of 15 minutes.
6. Let the contents of the container to settle for 2 minutes.
7. Observe the condition of all the pieces and water.
8. Record the observation.

   Note: Any absorbent pieces which do not remain floating at the surface of the water are considered to have failed this test.
9. Strain the contents of the container using a mesh basket to catch all the pieces.
10. After 30 seconds drain, weigh the drained sample and record it as W_2 in unit gram.
11. Calculate the water absorbency (water pick-up ratio) by using this equation:

$$\textbf{Water absorbency} = \frac{\mathbf{W_2 - W_1}}{\mathbf{W_1}} \quad (1)$$

Part B: For Type II Absorbent

1. Weigh 4 g of SCB 6 mm and defined as W_1 in unit gram.
2. Place it in a 4L container which is half-filled with water.
3. Place the container's cover on its opening and place it on a shaker table (water bath).
4. Set amplitude of the shaker to 3 cm and its frequency to 150 rpm for a duration of 15 minutes.
5. Let the contents of the container to settle for 2 minutes.
6. Observe the condition of SCB 6 mm and water.
7. Record the observation.

   Note: If 10% or more of the absorbent material has sunk, the absorbent is considered to have failed this test.
8. Strain the contents of the container using a mesh basket to catch SCB 6 mm.
9. After 30 seconds drain, weight the drained sample and record it as W_2 in unit gram.
10. Calculate the water absorbency (water pick-up ratio) by using equation (1).
11. Repeat step 1 to step 10 for other types of absorbent: SCB 4 mm, kapok and rice husk.

3.3.2 Oil Absorbency

The procedures for determination of oil absorbency are complying with ASTM F 726-99 (ASTM, 1999). The objective of this test is to determine optimum absorbent capacity without the competing presence of water. This test is performed at room temperature. According to ASTM F 726-99, for Type I absorbent (oil absorbent pad), the test liquid layer should be of a minimum thickness of 2.5 cm if the thickness of the absorbent is under 2.5 cm. If the absorbent is thicker than 2.5cm, then a liquid layer at least as thick as the absorbent sample should used while for Type II absorbent (SCB, kapok and rice husk), the test liquid layer should be of a minimum thickness of 2.5 cm if the thickness of the absorbent sample spread over the area of the test cell is under 2.5 cm. If the absorbent is thicker than 2.5cm, then a liquid layer at least as thick as the absorbent sample should used. The overall procedures are described below:

Part A: For Type I Absorbent

1. Cut the oil absorbent pad with the size of 13 cm x 13 cm (the sample to be tested shall have a minimum weight of 4 gram).
2. Weigh the absorbent and defined as S_1 in unit gram.
3. Fill the 4L container with crude oil until the thickness is 2.5 cm.
4. Place the absorbent into the 4L container (the absorbent shall be allowed to float freely within the container).
5. Cut the plastic wrap to a certain size that can fit well the absorbent. Weigh the plastic wrap and defined as S_2 in unit gram.
6. After 15 minutes, remove the absorbent in a vertical orientation along an edge with a clip and let drain for 30 seconds.
7. Place a plastic wrap under the absorbent to catch any additional drips and immediately transfer the absorbent to the plastic wrap.
8. Weigh and record the absorbent with the plastic wrap as S_3 in unit gram.
9. Calculate the oil absorbency (oil pick-up ratio) by using this equation:

$$\textbf{Oil absorbency} = \frac{S_3 - S_2 - S_1}{S_1} \qquad \textbf{(2)}$$

10. Repeat step 1 to step 9 for other types of oil: Diesel, engine oil and used engine oil.

Part B: For Type II Absorbent

1. Weigh 4g of SCB 6 mm and defined as S_1 in unit gram.
2. Fill the 4L container with crude oil until the thickness is 2.5 cm.
3. Place the SCB 6 mm in a mesh basket.
4. Place it into the 4L container (the SCB shall be allowed to float freely).
5. Cut the plastic wrap to a certain size that can fit well the mesh basket. Weigh the plastic wrap and defined as S_2 in unit gram.
6. After 15 minutes, remove the mesh basket and let drain for 30 seconds.
7. Place a plastic wrap under the mesh basket to catch any additional drips and immediately transfer the mesh basket to the plastic wrap.
8. Weigh and record the mesh basket with the plastic wrap as S_3 in unit gram.
9. Calculate the oil absorbency (oil pick-up ratio) by using equation (2).
10. Repeat step 1 to step 9 for other types of oil: Diesel, engine oil and used engine oil.
11. Repeat step 1 to step 10 for other types of absorbent: SCB 4 mm, kapok and rice husk.

3.3.3 Optimum Time of Absorbing Process

Part A:

1. Weigh 4 g of SCB 6 mm.
2. Fill a 4L container with 2L water.
3. Add 3 mL of crude oil into the container.
4. Place the SCB 6 mm in the container.
5. Observe and record the condition of SCB 6 mm once it is contacted with water.
6. Place the container's cover on its opening and place it on a shaker table (water bath).
7. Set amplitude of the shaker to 3 cm and its frequency to 150 rpm for a duration of 5 minutes.
8. Let the contents of the container to settle for 2 minutes.
9. Observe and record the condition of SCB 6 mm and water.
10. Take 50 mL of mixture (water and crude oil) and put in a small container.
11. Strain the contents of the container using a mesh basket to catch SCB 6 mm.

12. Put the SCB 6 mm in a transparent plastic bag.
13. Observe and record the colour changes of the SCB 6 mm.
14. Repeat step 1 to step 13 by changing the absorption time to 10 min, 20 min, 1 hour, 1 hour 30 min, 2 hours and 3 hours.
15. Repeat step 1 to step 14 for other types of absorbent: SCB 4 mm, kapok, rice husk and oil absorbent pad (oil absorbent pad must be cut into 4 pieces with the size of 6 cm x 6 cm).
16. Repeat step 1 to step 15 for other types of oil: Diesel, engine oil and used engine oil.

Part B: to determine the concentration of oil after absorption process

1. Transfer 50 mL of sample (from step 10 of part A) into a separating funnel.
2. Using a pipette, add 10 mL of tetrachloroethylene (C_2Cl_4) into the separating funnel.
3. Stopper the separating funnel and shake vigorously for about 1 minute. Invert the separating funnel and open the stop-close to release the pressure that has built up.
4. Repeat step 3 for another 3 times.
5. Place the funnel on the stand and leave it standing still for about 15 minutes. *Note: The contents in the funnel will separate into 2 layers. The top is the sample and the bottom layer is the C_2Cl_4 containing the extracted oil.*
6. Drain the bottom C_2Cl_4 into a 50 mL beaker.
7. Use the syringe (labelled "sample") and fill it with about 5 mL of the sample solution.
8. Insert the metal tip of the syringe to the sample inlet part (labelled "SAMPLE IN"), turn the syringe 180° clockwise to lock the syringe into the sample inlet.
9. Wait for approximate 2 minutes and note the value on the digital display.
10. Remove the sample from the measuring cell by pulling the plunger from the syringe back out.
11. Clean the measuring cell with C_2Cl_4 using the syringe (labelled "solvent") 3 times.
12. Repeat step 1 to step 11 for each sample from step 16 of part A.

CHAPTER 4

RESULTS AND DISCUSSIONS

4.1 WATER ABSORBENCY

Water absorbency is the amount of water absorbed on 1 g of absorbent. Water absorbency is determined using equation (1). Material used to be oil spill absorbent should be minimal in water absorbency. In addition, the water absorbency of material should be lesser than its oil absorbency (Bordeson, 2004). Table 4.1 shows the result of water absorbency for PP while Table 4.2 shows the result for natural-based product which are SCB, kapok and rice husk. Based on the graph in the Figure 4.1, PP has the highest water absorbency which is 14.811 g/g followed by SCB 6 mm (8.905 g/g), SCB 4 mm (8.448 g/g), rice husk (3.4425 g/g) and kapok (0.30025 g/g). During the experiment, the thickness of each PP is increased. It shows that, PP also has the ability to absorb water or more hydrophilic compared to the others. For SCB 6 mm and SCB 4 mm, only 1 to 2 % of their particles have sunk while the others are still floating freely until the end of the experiment. The colour of water has changed from clear to a bit cloudy or yellowish due to the lignin content of SCB dissolved in the water. Moreover, more than 50% of rice husk have sunk to the bottom of the container during the experiment. According to ASTM F 726-99 (ASTM, 1999) rice husk is considered failed for this experiment since the percentage of sunk is more than 10%. The colour of water also changed from clear to cloudy. It is known that the most suitable oil spill sorbent must exhibit the minimum water absorbency characteristic. Therefore, for this experiment, kapok and SCB can be considered better than PP.

Table 4.1: Result of water absorbency for Type I absorbent, PP.

Sample of PP	Weight Before (W_1), g	Weight After (W_2), g	Water Absorbency, g/g
1	0.789	10.292	12.044
2	0.634	12.742	19.098
3	0.758	10.598	12.982
4	0.700	11.283	15.119
Mean			**14.811**

Table 4.2: Result of water absorbency for Type II absorbent.

Sample	Weight Before (W_1), g	Weight After (W_2), g	Water Absorbency, g/g
SCB 6 mm	4	39.62	8.905
SCB 4 mm	4	37.79	8.448
Kapok	4	5.201	0.30025
Rice Husk	4	17.770	3.4425

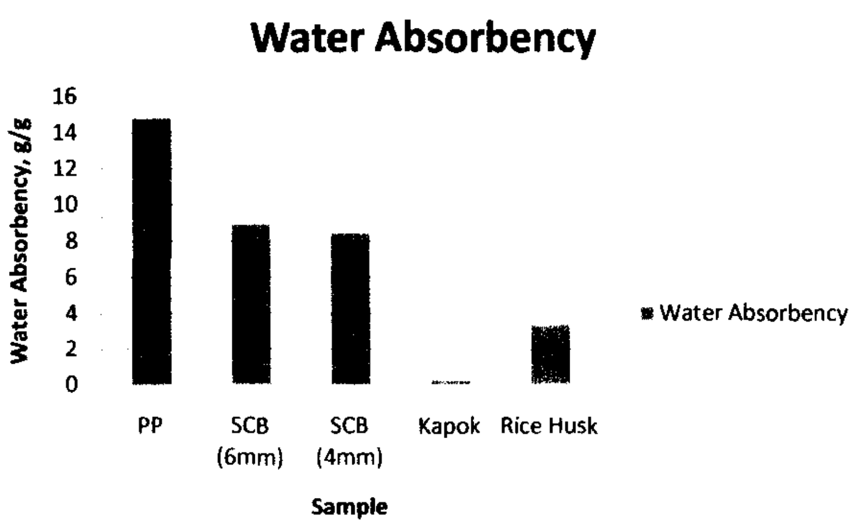

Figure 4.1: Water Absorbency Test.

4.2 OIL ABSORBENCY

Oil absorbency is the amount of oil absorbed on 1 g of absorbent. Oil absorbency of materials, which varies with types of oil, is investigated by procedures of 3.3.2. It is determined using equation (2). Table 4.3, Table 4.4, Table 4.5 and Table 4.6 show the results of oil absorbency for diesel, crude oil, engine oil and used engine oil, respectively. Based on the graph in Figure 4.2, kapok shows the highest oil absorbency for all types of oil followed by SCB, PP and rice husk. The result for SCB 6 mm and SCB 4 mm is quite similar. However, SCB 6 mm is better than SCB 4 mm since SCB 6 mm has slightly higher value than SCB 4 mm. As it is normally expected the sorption capacity of a material like SCB better has good surface roughness and area to maximize sorption.

Materials used to act as the oil spill absorbent should have oil absorbency more than 5 g/g and to be an excellent absorbent, the oil absorbency should be more than 10 g/g (Bordesorn, 2004). Therefore, when only oil absorbency is concerned, kapok, SCB 6 mm and SCB 4 mm are excellent for all types of oil. On the other hand, PP is a good absorbent for only crude oil, engine oil and used engine oil with absorbency 10.82 g/g, 18.00 g/g and 16.55 g/g, respectively. Rice husk is not recommended to be used to absorb diesel and crude oil because its oil absorbency is lower than 5 g/g. However, rice husk still has potential to be oil sorbent for engine oil and used engine oil as its oil absorbency for both types of oil is more than 5 g/g. For all absorbents, oil absorbency in engine oil is the best followed by in used engine oil, in crude oil and in diesel due to the effect of viscosity.

A good absorbent should not have only high oil absorbency, but its water absorbency should be lower that its oil absorbency. In other words, ratio of oil absorbency to water absorbency, as shown in Table 4.7, should be greater than 1. Therefore, it can be concluded that the oil absorbency is significantly different with types of absorbent.

Table 4.3: Result of oil absorbency for Diesel.

Sample	Weight Before (S_1), g	Weight of Plastic Wrap (S_2), g	Weight After (S_3), g	Oil Absorbency, g/g	> 5 g/g
PP	4	0.62	43.42	9.70	Yes
SCB 4 mm	4	0.53	46.57	10.51	Yes
SCB 6 mm	4	0.71	48.03	10.83	Yes
Kapok	4	0.55	81.95	19.35	Yes
Rice Husk	4	0.60	15	2.60	No

Table 4.4: Result of oil absorbency for Crude Oil.

Sample	Weight Before (S_1), g	Weight of Plastic Wrap (S_2), g	Weight After (S_3), g	Oil Absorbency, g/g	> 5 g/g
PP	4	0.55	47.83	10.82	Yes
SCB 4 mm	4	0.50	57.58	13.27	Yes
SCB 6 mm	4	0.66	58.58	13.48	Yes
Kapok	4	0.50	107.34	25.71	Yes
Rice Husk	4	0.55	15.99	2.86	No

Table 4.5: Result of oil absorbency for Engine Oil.

Sample	Weight Before (S_1), g	Weight of Plastic Wrap (S_2), g	Weight After (S_3), g	Oil Absorbency, g/g	> 5 g/g
PP	4	0.63	73.63	18.00	Yes
SCB 4 mm	4	0.55	84.35	19.95	Yes
SCB 6 mm	4	0.65	85.25	20.15	Yes
Kapok	4	0.66	246.70	60.51	Yes
Rice Husk	4	0.55	41.59	9.26	Yes

Table 4.6: Result of oil absorbency for Used Engine Oil.

Sample	Weight Before (S_1), g	Weight of Plastic Wrap (S_2), g	Weight After (S_3), g	Oil Absorbency, g/g	> 5 g/g
PP	4	0.56	70.76	16.55	Yes
SCB 4 mm	4	0.48	76.52	18.01	Yes
SCB 6 mm	4	0.58	77.86	18.32	Yes
Kapok	4	0.58	204.34	49.94	Yes
Rice Husk	4	0.50	34.86	7.59	Yes

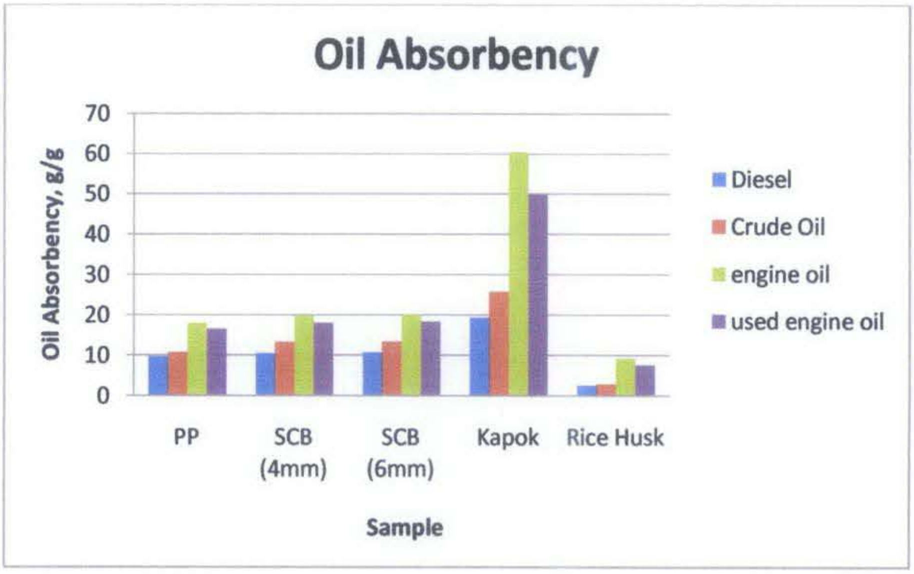

Figure 4.2: Oil Absorbency Test.

Table 4.7: Oil/Water Absorbency Ratio.

Sample	Diesel		
	Oil Abs, g/g	**Water Abs, g/g**	**Ratio**
PP	9.70	14.811	0.65
SCB 4 mm	10.51	8.905	1.18
SCB 6 mm	10.83	8.448	1.28
Kapok	19.35	0.30025	64.5
Rice Husk	2.60	3.4425	0.76
	Crude Oil		
PP	10.82	14.811	0.73
SCB 4 mm	13.27	8.905	1.49
SCB 6 mm	13.48	8.448	1.60
Kapok	25.71	0.30025	85.7
Rice Husk	2.86	3.4425	0.83
	Engine Oil		
PP	18.00	14.811	1.22
SCB 4 mm	19.95	8.905	2.24
SCB 6 mm	20.15	8.448	2.4
Kapok	60.51	0.30025	201.7
Rice Husk	9.26	3.4425	2.69
	Used Engine Oil		
PP	16.55	14.811	1.11
SCB 4 mm	18.01	8.905	2.02
SCB 6 mm	18.32	8.448	2.17
Kapok	49.94	0.30025	166.47
Rice Husk	7.59	3.4425	2.20

4.3 OPTIMUM TIME OF ABSORPTION PROCESS

The optimum time of absorption process is the time when oil is absorbed at the highest amount. Then, absorption process will start decreasing when absorbent materials reached to the saturation point. Thus, it will start to release the oil back to the water. The optimum time for each sample of absorbent is determined based on the graphs in Figure 4.6 – 4.9. Results for this test are summarized in Table 4.48 – Table 4.11. Optimum time for SCB 6 mm and SCB 4 mm is 2 hours. It means that, SCB has the ability to absorb oil in a very fast manner from 5 minutes until 2 hours of duration. After 2 hours, absorbing process started decreasing. In addition, the optimum time for kapok is 1 hour and 30 minutes and for PP, its optimum time is only 5 minutes. In 5 minutes, PP is able to absorb with high concentration compared to other samples. However, it started to release oil back to the water after 5 minutes slowly. The optimum time for rice husk is 3 hours but it absorbs with very little oil concentration which is not more than 15 ppm for all types of oil. From the results, it is found that oil absorbency of PP, kapok and SCB with the presence of water varies in the range of 80 ppm to 95 ppm for all types of oil and it is obviously seen that the most excellent absorbent is kapok since its results shows the highest result compared to SCB and PP. Moreover, oil concentration that is absorbed by SCB 6 mm and 4 mm are slightly higher than PP. It is because, when SCB is poured into the container that contains water and oil, it will be well distributed on the surface of water hence, leading to high absorption. Therefore, only a thin slick of oil is left but in the case of PP, it only can absorb until it reached to the saturation point. Figure 4.3 shows the engine oil on the surface of water before the optimum time test for SCB 6 mm and PP for 2 hours. Figure 4.4 shows SCB 6 mm that has been coated with the used engine oil. The used engine oil will be fully removed when SCB 6 mm is taken out while in Figure 4.5, there is still used engine oil after the absorption process. Thus, SCB is better than PP.

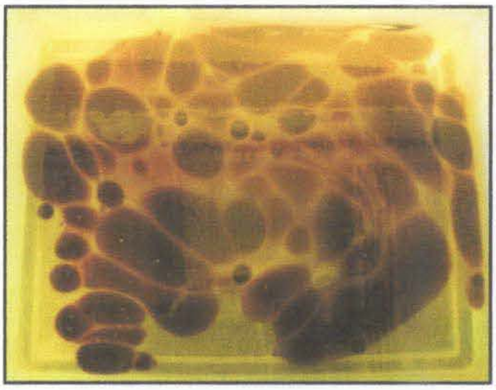

Figure 4.3: Engine Oil on the Surface of Water.

Figure 4.4: SCB 6 mm.

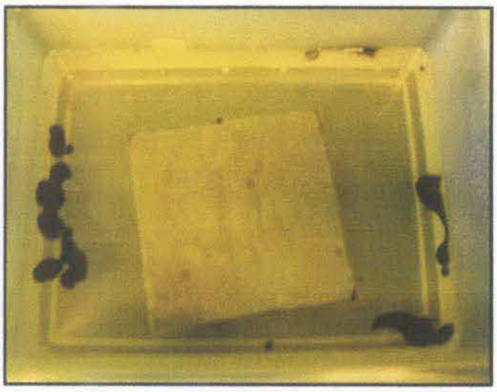

Figure 4.5: Polyproplene, PP.

Table 4.8: Oil Concentration for Diesel Oil.

Diesel Oil, initial concentration (W_0) = 90 ppm			
Sample	**Time**	**Oil Content After Absorption (W_1)**	**Oil Content that is Absorbed by Sample ($W_0 - W_1$)**
PP	5 min	4.1	85.9
	10 min	6.3	83.7
	20 min	8.1	81.9
	1 h	8.8	81.2
	1h 30 min	9.5	80.5
	2 h	9.9	80.1
	3 h	10.1	79.9

Sample	Time	Oil Content After Absorption (W_1), ppm	Oil Content that is Absorbed by Sample (W_0 - W_1), ppm
SCB 6 mm	5 min	9.3	80.7
	10 min	8.8	81.2
	20 min	7.5	82.5
	1 h	4.6	85.4
	1h 30 min	3.1	86.9
	2 h	2.7	87.3
	3 h	10.6	79.4
SCB 4 mm	5 min	9.6	80.4
	10 min	9.1	80.9
	20 min	8.3	81.7
	1 h	4.8	85.2
	1h 30 min	3.7	86.3
	2 h	2.9	87.1
	3 h	11.0	79.0
Kapok	5 min	6.5	83.5
	10 min	4.8	85.2
	20 min	4.6	85.4
	1 h	3.5	86.5
	1h 30 min	1.1	88.9
	2 h	8.25	81.75
	3 h	15.3	74.7
Rice husk	5 min	80.7	9.3
	10 min	80.7	9.3
	20 min	80.6	9.4
	1 h	80.3	9.7
	1h 30 min	80.2	9.8
	2 h	80.1	9.9
	3 h	80.1	9.9

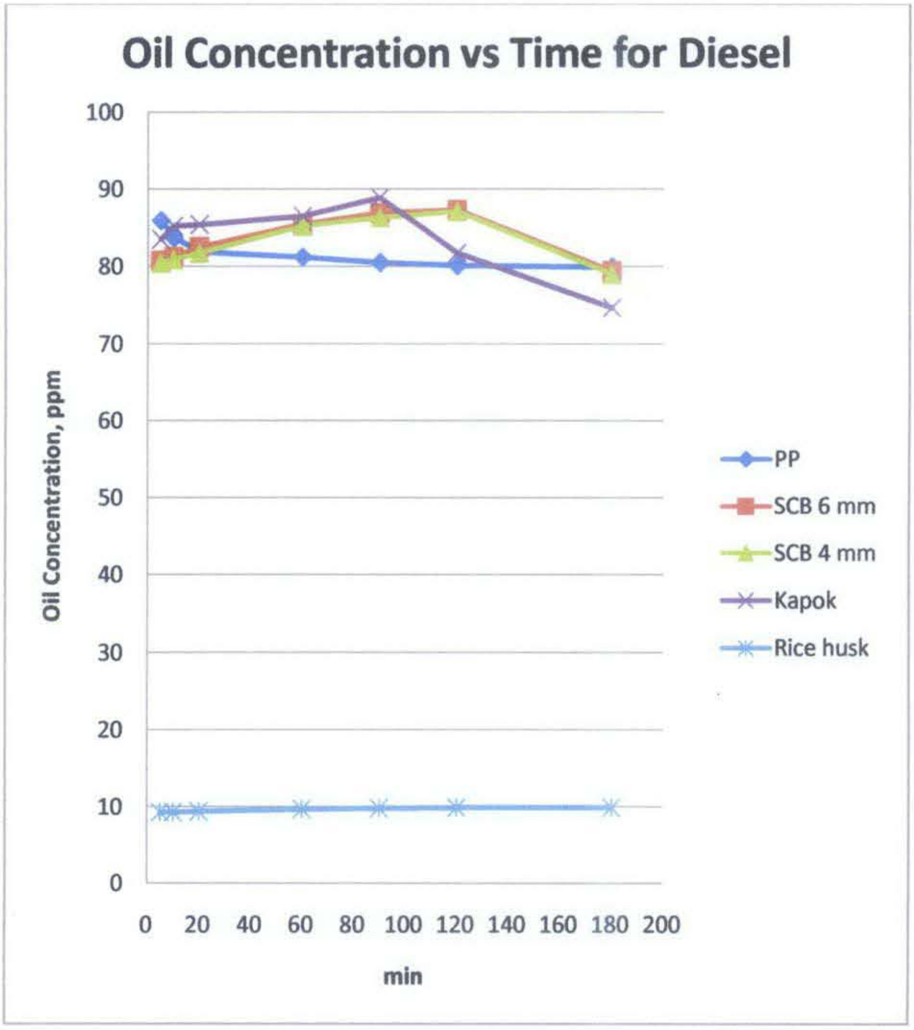

Figure 4.6: Oil Concentration vs Time for Diesel.

Table 4.9: Oil Concentration for Crude Oil.

Crude Oil, initial concentration (W_0) = 135 ppm			
Sample	**Time**	**Oil Content After Absorption (W_1)**	**Oil Content that is Absorb by Sample (W_0 - W_1)**
PP	5 min	49.7	85.3
	10 min	51.7	83.3
	20 min	53.4	81.6
	1 h	54.5	80.5
	1h 30 min	55.1	79.9
	2 h	55.6	79.4
	3 h	56.9	78.1

Sample	Time	Oil Content After Absorption (W_1), ppm	Oil Content that is Absorb by Sample (W_0 - W_1), ppm
SCB 6 mm	5 min	53.5	81.5
	10 min	52.7	82.3
	20 min	52.2	82.8
	1 h	48.1	86.9
	1h 30 min	46.6	88.4
	2 h	45.9	89.1
	3 h	56.5	78.5
SCB 4 mm	5 min	54.4	80.6
	10 min	53.6	81.4
	20 min	53.1	81.9
	1 h	49.8	85.2
	1h 30 min	48.5	86.5
	2 h	47.7	87.3
	3 h	58.1	76.9
Kapok	5 min	50.7	84.3
	10 min	48.1	86.9
	20 min	47.9	87.1
	1 h	47.2	87.8
	1h 30 min	43.6	91.4
	2 h	52.4	82.6
	3 h	58.8	76.2
Rice husk	5 min	124.1	10.9
	10 min	123.9	11.1
	20 min	123.5	11.5
	1 h	123.1	11.9
	1h 30 min	122.7	12.3
	2 h	122.7	12.3
	3 h	122.6	12.4

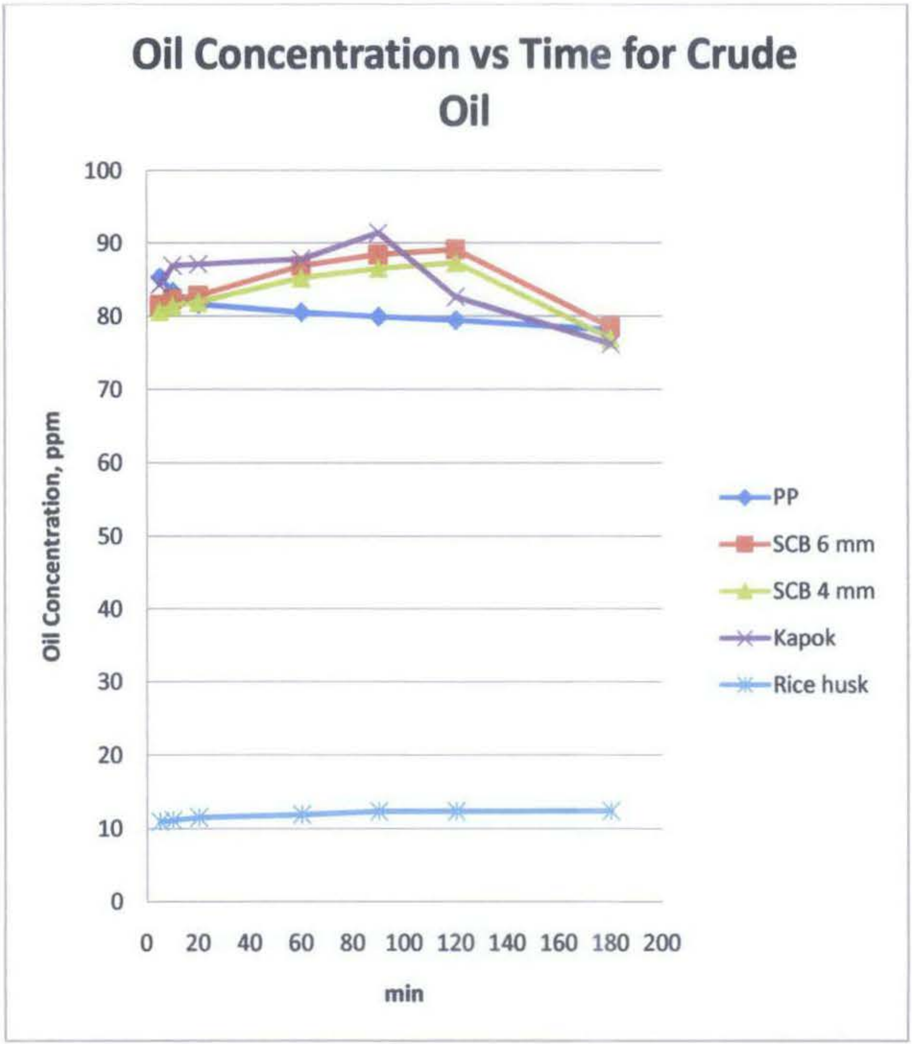

Figure 4.7: Oil Concentration vs Time for Crude Oil.

Table 4.10: Oil Concentration for Engine Oil.

Engine Oil, initial concentration (W_0) = 169.9 ppm			
Sample	**Time**	**Oil Content After Absorption (W_1)**	**Oil Content that is Absorb by Sample (W_0 - W_1)**
PP	5 min	81.2	88.7
	10 min	82.6	87.3
	20 min	83.0	86.9
	1 h	83.4	86.5
	1h 30 min	85.0	84.9
	2 h	85.6	84.3
	3 h	87.2	82.7

Sample	Time	Oil Content After Absorption (W_1), ppm	Oil Content that is Absorb by Sample (W_0 - W_1), ppm
SCB 6 mm	5 min	86.8	83.1
	10 min	86.0	83.9
	20 min	85.1	84.8
	1 h	82.4	87.5
	1h 30 min	81.0	88.9
	2 h	76.8	93.1
	3 h	82.5	87.4
SCB 4 mm	5 min	87.7	82.2
	10 min	87.1	82.8
	20 min	86.4	83.5
	1 h	83.1	86.8
	1h 30 min	82.5	87.4
	2 h	77.0	92.9
	3 h	83.7	86.2
Kapok	5 min	82.7	87.2
	10 min	82.2	87.7
	20 min	81.6	88.3
	1 h	79.2	90.7
	1h 30 min	74.8	95.1
	2 h	77.2	92.7
	3 h	80.1	89.8
Rice husk	5 min	157.2	12.7
	10 min	156.4	13.5
	20 min	156.1	13.8
	1 h	155.8	14.1
	1h 30 min	155.6	14.3
	2 h	155.6	14.3
	3 h	155.3	14.6

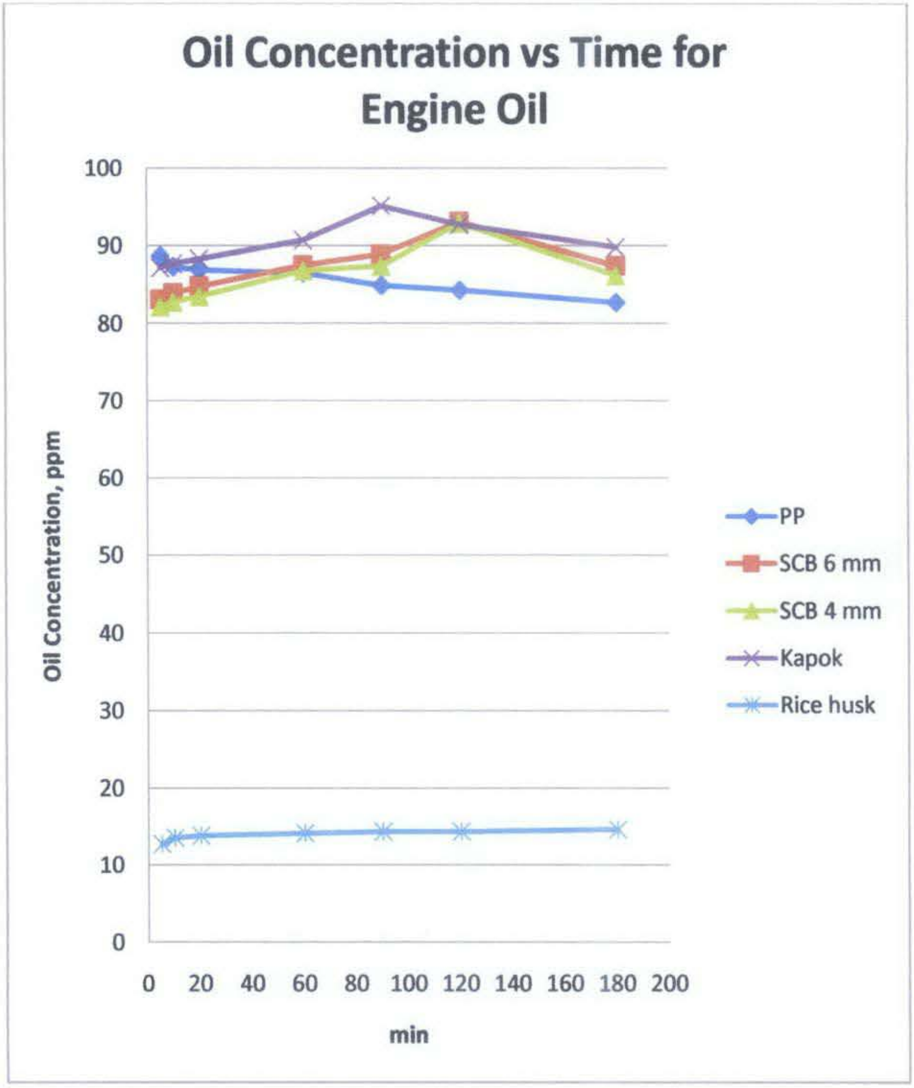

Figure 4.8: Oil Concentration vs Time for Engine Oil.

Table 4.11: Oil Concentration for Used Engine Oil.

Used Engine Oil, initial concentration (W_0) = 159.5 ppm			
Sample	**Time**	**Oil Content After Absorption (W_1)**	**Oil Content that is Absorb by Sample (W_0 - W_1)**
PP	5 min	72.8	86.7
	10 min	73.2	86.3
	20 min	73.7	85.8
	1 h	74.4	85.1
	1h 30 min	75.8	83.7
	2 h	76.3	83.2
	3 h	78.1	81.4

Sample	Time	Oil Content After Absorption (W_1), ppm	Oil Content that is Absorb by Sample (W_0 - W_1), ppm
SCB 6 mm	5 min	77.4	82.1
	10 min	76.8	82.7
	20 min	76.1	83.4
	1 h	73.3	86.2
	1h 30 min	72.4	87.1
	2 h	66.9	92.6
	3 h	72.6	86.9
SCB 4 mm	5 min	77.6	81.9
	10 min	77.1	82.4
	20 min	76.4	83.1
	1 h	73.7	85.8
	1h 30 min	72.8	86.7
	2 h	67.2	92.3
	3 h	73.9	85.6
Kapok	5 min	72.8	86.7
	10 min	72.6	86.9
	20 min	72.0	87.5
	1 h	71.2	88.3
	1h 30 min	67.7	91.8
	2 h	69.1	90.4
	3 h	70.4	89.1
Rice husk	5 min	148.2	11.3
	10 min	147.7	11.8
	20 min	146.9	12.6
	1 h	146.1	13.4
	1h 30 min	145.8	13.7
	2 h	145.8	13.7
	3 h	145.4	14.1

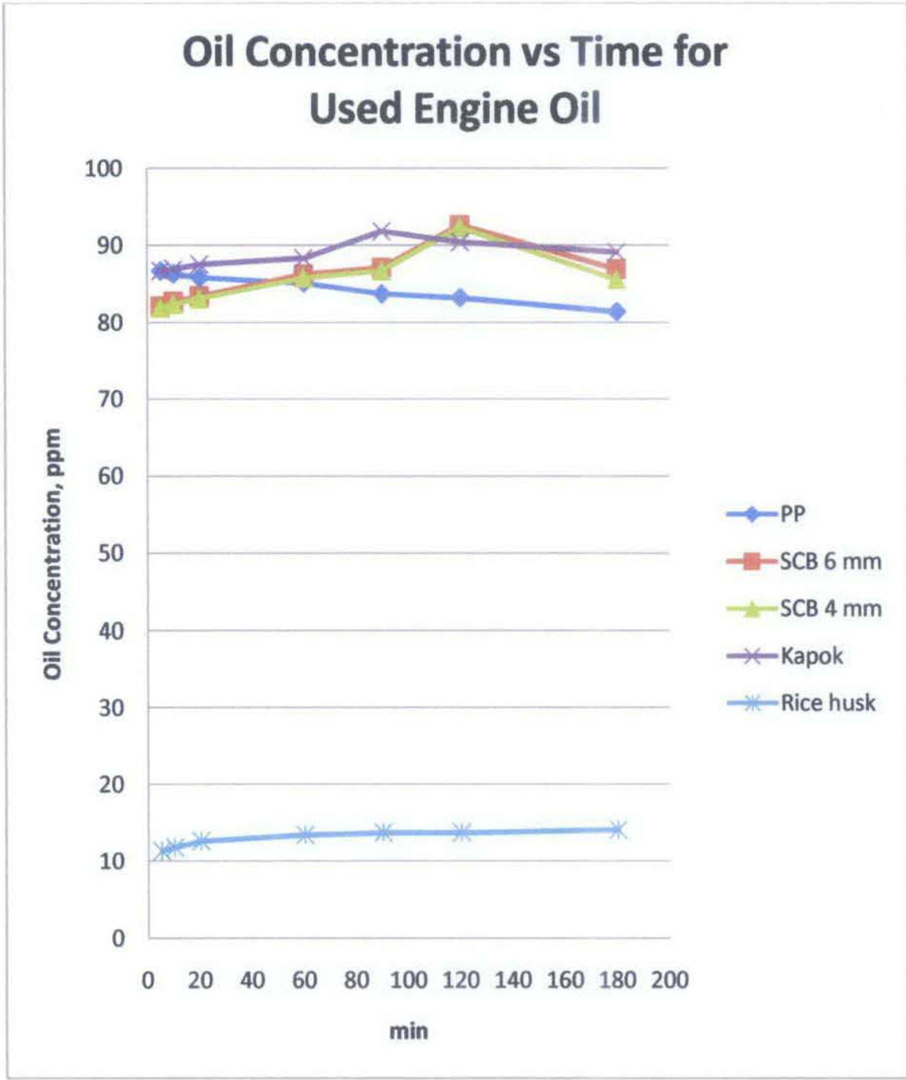

Figure 4.9: Oil Concentration vs Time for Used Engine Oil.

CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

5.1 CONCLUSIONS

Regarding to the result from water absorbency test, kapok shows the lowest water pickup while PP has the highest water pickup. Therefore, kapok is hydrophobic and PP is hydrophilic. Rice husk is failed for this test since more than 50% of them have sunk to the bottom of the container. In addition, the result for SCB 6 mm (8.9 g/g) is slightly higher than SCB 4 mm (8.4 g/g) due to the greater surface roughness and area of sorption activity.

Another characteristic to be a good absorbent, the oil absorbency of materials must more than 5 g/g or more than 10 g/g to be an excellent absorbent. In this case, kapok, SCB 6 mm and SCB 4 mm can be said as excellent absorbents for all types of oil since their results are more than 10 g/g. PP is not enough to be an excellent absorbent because its oil absorbency for diesel (9.7 g/g) and crude oil (10.82 g/g) is lesser than its water absorbency (14.811 g/g) even though its oil absorbency is more than 10 g/g for engine oil and used engine oil. It is because, according to the Bordesorn in 2004, suitable oil sorbent must have oil absorbency higher than water absorbency. Rice husk has lowest oil absorbency for all types of oil even its oil absorbency is below than 5 g/g for diesel and crude oil. However, it still has potential to be oil sorbent for engine oil and used engine oil due to the oil absorbency is greater than 5 g/g. The optimum time for PP, kapok, SCB and rice husk are 5 minutes, 1 hour and 30 minutes, 2 hours and 3 hours respectively.

Moreover, SCB causes changing in color of water. Water color changes to be more yellowish due to lignin content in materials. However, if these materials are necessary to be used in oil spill removal, effect of color changing may be negligible when compared to the damage from spilled oil.

Therefore, it can be concluded, natural-based products (kapok and SCB) are better than PP in terms of the biodegradability, water pickup ability and oil pickup ability. Other than that, PP is costly with the price is around RM 70 to RM 80 while SCB is free because it is waste from sugar production. Kapok is also cheaper and easily found in villages.

5.2 RECOMMENDATIONS

1) During the experiments, it is recommended to cover the test cell when running the test cell on the shaking apparatus in order to avoid the materials inside the test cell from spilling out.
2) As a precaution, it is highly reminded to be aware while dealing with tested oils since they are flammable. All the procedures in the lab must be followed to avoid any incident during carry out the experiments.
3) Shaker table (water bath) must be set not more than 25 °C because tested oil will vaporize if the temperature is higher hence, the result will be inaccurate.
4) SCB and kapok is strongly recommended to be used as oil spill absorbent due to the highest in both oil absorbency and oil/water absorbency ratio. For ease of application, they need to be enclosed in the form of flat sheet.

5.3 PUBLICATIONS SECTION

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2) Norizan Ali, Mohanad El-Harbawi, Ayman Abu Jabal and Chun-Yang Yin. Comparison of characteristics and oil sorption effectiveness of Kapok fiber,

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