Properties of Oil Sorbent Material Produced From Kenaf Fiber

Ridwan Shamsudin, Hanisom Abdullah, and Som Cit Sinang

***Abstract*—Oil spills have tremendous effects on environment, ecology, economy, and the society as a whole. There are several techniques being used for oil spill cleanup i.e in-situ burning of oil, mechanical tools (booms and skimmers), chemical dispersants, steam flushing and also by using natural fibers as sorbents. In this research, oil sorbent material was produced from kenaf (*Hibiscus cannabinus L.*) fibers. Three sorbent materials were made from of various fiber particle sizes and tested for their oil absorbent properties. The results showed that sorbent produced from a 1.70 cm^2-sized kenaf fibers achieved the highest absorption value of 8.2327 g/g and saturation value of 0.0385 N/Mins respectively. In this study, the 1.70 cm^2-sized sorbent also demonstrated the strongest fiber bonding compared to those of 0.04 cm^2-sized and 0.80 cm^2-sized sorbents. This was confirmed by microstructure analysis conducted using a Scanning Electron Microscope (SEM). The oil sorbent materials produced in this study were found to have superior absorption value compared to other fiber-based oil sorbents such as Sisal (*Agave sisalana*), Coir (*Cocos nucifera*) and loofa sponge (*Luffa cylindrica*).**

***Index terms*—Sorbent materials, kenaf, *Hibiscus cannabinus L.*, oil spill.**

I. Introduction

Pollution resulting from oil spills poses severe environmental problems around the world. The oil spills pollution not only affects the environment with regard to its hazard but the clean up processes could be costly. In the year 1997, it was estimated that more than USD 136000/tonne spilled were spent for cleaning oil spills in the US alone [1]. The processes involved in cleaning oil spill were normally very complicated and not environmentally friendly [2]. The treatment for oil spills including chemical, mechanical and biological treatments [3]. In mechanical treatment, absorbent of synthetic or natural materials is an effective cost saving option [4].

Despite their superior absorption qualities, synthetic materials have low biodegradability. Therefore natural based absorbent material is preferred due to its non toxicity and excellent biodegradability. In recent decades, natural sorbents were produced from natural biomass such as cotton (*Gossypium hirsutium*), kapok (*Ceiba pentandra*) [4], Sisal (*Agave sisalana*), Coir (*Cocos nucifera*) and loofa sponge (*Luffa cylindrica*) [5]. This study aims to produce sorbent material from kenaf fiber and to assess its absorption capacity. Kenaf tree (*Hibiscus cannabinus L.*) is a plant that originated from Africa. The second most important natural fiber after cotton, kenaf is an environmentally friendly plant certified by the Kyoto Protocol for it is obtained from renewable and recyclable source [6]. In Malaysian context, the National Kenaf and Tobacco Board are extensively promoting the application of kenaf as feedstock in manufacturing industries [7].

The evaluation of kenaf-based sorbent properties in treating oil spills and waste water treatment are scarce in the literature. Therefore, the current study is significantly important to gain fundamental understanding about the sorption capacity and other properties of kenaf-based sorbent materials. This article reports preliminary results on the performance of sorbent material produced from kenaf fiber of different particle sizes. The properties evaluated in this study including the absorption capacity, mechanical strength and biodegradability. The results were compared with performance of other natural based sorbents reported in the literature.

II. Procedure

A. Oil Sorbent Material Made From Kenaf Fibers

In this study, kenaf fiber (MR grade) was obtained from the National Kenaf and Tobacco Board of Malaysia. The kenaf fiber was processed into three particle sizes i.e. 0.04 cm^2, 0.80 cm^2 and 1.70 cm^2. In this study, the method of producing oil sorbent materials was modified from papermaking procedures conducted in the industry [8]. The procedure involved three stages i.e. pulp extraction, pressing and drying. In the first stage, the lignin in kenaf fiber was removed to extract the kenaf pulp. This was done by boiling the kenaf fiber in sodium bicarbonate solution (20%) at 100^0C for 1 hour. It is very important to remove the lignin because it acts as glue between the fibers and the removal of the lignin will released the fibers [9]. After this step, the pulp was then filtered using a 0.04 cm^2 –sized mesh and manually pressed to remove excess water. In this study, the pore sizes of sorbent materials were not manipulated during the manual pressing stage. The pressed pulp was dried under sunlight for 24 hours to finally produce sorbent material sheets (dimension: 20.0 x 30.0 cm^2) with thickness of 0.2 cm. The aforementioned procedures were repeated in order to obtain three sorbent materials from the different kenaf particle sizes. Microstructure of the produced sorbents was observed under the Scanning Electron Microscope (Hitachi model SU8020).

B. Absorption Capacity Test

All the sorbent materials were assessed to evaluate its

Manuscript received May 6, 2014; revised October 14, 2014.

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DOI: 10.7763/IJESD.2015.V6.655

absorption capacity. The test was conducted in a simulated condition using vehicle diesel waste oil obtained from a local workshop. In order to determined the absorption value, 100 m*l* of diesel waste oil was poured into a beaker containing 1000m*l* of water. This condition simulated oil spillage that happen to float on top of water bodies. Then, the kenaf sorbent material (~2.5g, dimension: 9.0 × 9.0 cm^2) was placed into the beaker and left to absorb the waste oil for 5 minutes. This optimum absorption duration was pre-determined. It was found that longer absorption time did not significantly affect the absorption and saturation value of the sorbents. The initial and final mass of the sample was recorded and used in the calculation of the absorption and saturation values.

The absorption value was calculated as the ratio of sorbent material to dry sorbent mass as illustrated in Equation 1 [5].

$$\text{Sorption rate} = (S_t - S_0)/S_0, \qquad (1)$$

where,

S_t - Total mass of sorbent samples (g)

S_0 – Dry sorbent mass (g)

The saturation value which indicates the maximum absorption capacity of the sorbents was calculated by using Equation 2 [10].

$$\text{Saturation point} = (W_2 - W_1)/t, \qquad (2)$$

where,

W_1 - Initial Weight of the mat sample (g)

W_2 - Weight of the mat sample after time T (g)

T – Time (min)

C. Mechanical Strength Test

Another aspect being tested was the mechanical strength of the absorbent paper. The strength of the absorbent paper was calculated based on the breaking length value [11]. This analysis assesses the maximum load that can be sustained by the sorbent materials before tearing. In this test, strips of paper sized (dimension 2.0 × 17.0 cm^2) was hanged at a point and loaded with weights until the strip breaks according to the guidelines described previously [11]. The breaking length of the paper was calculated by using equation 3.

$$\text{Breaking length} = mb/(W \times \text{Basis Weight}) \qquad (3)$$

where,

mb - Total mass to break strip of absorbent paper (g)

W - Width at break (m)

Basis weight - Sheet mass/Sheet area (g/m^2)

D. Biodegradability Test

To simulate the biodegradability of sorbent materials after cleanup process in natural condition, the used sorbent materials produced in this study were left in the outdoor for 80 days. The period taken for the sorbent materials to biodegrade into less than 0.1 cm^2 sized-pieces was recorded.

III. Results and Discussion

A. Microstructure of the Sorbent Materials

Oil sorbent materials have been produced from three different sizes of kenaf fiber which were 0.04 cm^2, 0.80 cm^2 and 1.70 cm^2. Obviously, the difference of particle size affects the microstructure intermingling of fibers in the sorbent materials as observed in the SEM images (Fig. 1).

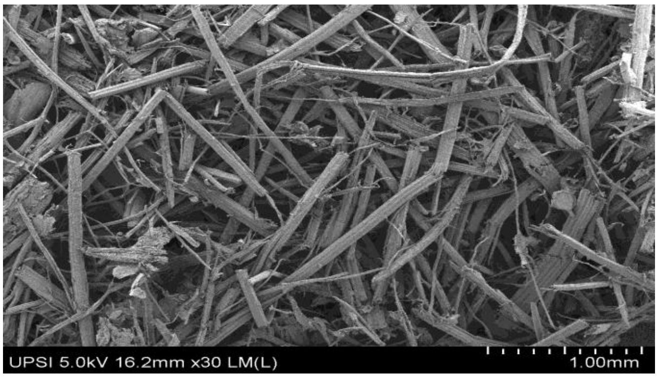

Fig. 1a. Image under scanning electron microscope: Absorbent paper from kenaf sized-0.04 cm^2.

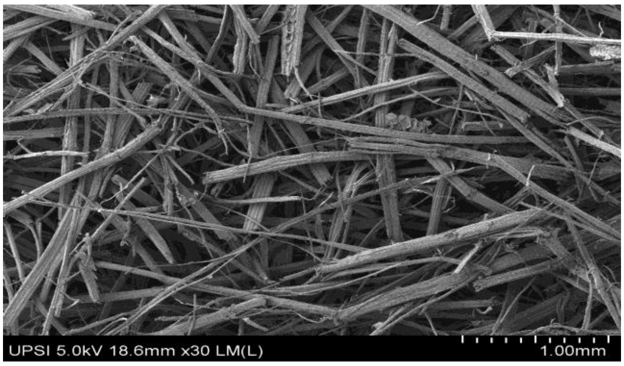

Fig. 1b. Image under scanning electron microscope: Absorbent paper from kenaf sized-0.80 cm^2

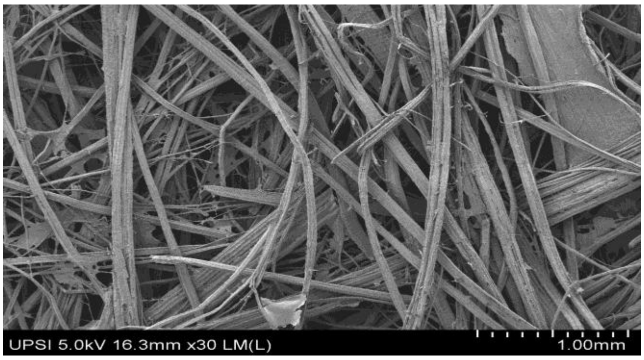

Fig. 1c. Image under scanning electron microscope: Absorbent paper from kenaf sized-1.70 cm^2.

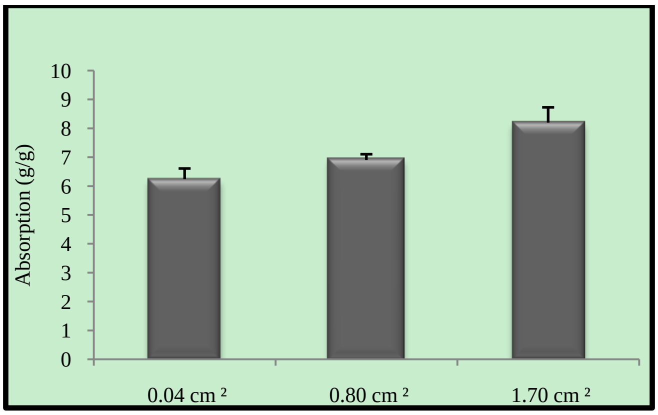

Fig. 2. Oil absorption value of three different absorbent paper made from kenaf fibers size 0.04, 0.80 and 1.70 cm^2.

Based on images in Fig. 1, clearly the sorbent material produced from 1.70 cm^2-sized fibers (Fig. 1c) appears formed a better microstructure network compared to the other two sorbent materials. The least network formation is observed in 0.04 cm^2-sized (Fig. 1a). Obviously, the length of the fibers is one of the factors that can affect the network formation on the surface of the sheets. This is due to the mechanical entanglement [12]. Next, Fig. 2 and Fig. 3 illustrate the value of oil absorption and oil saturation of the sorbent materials respectively.

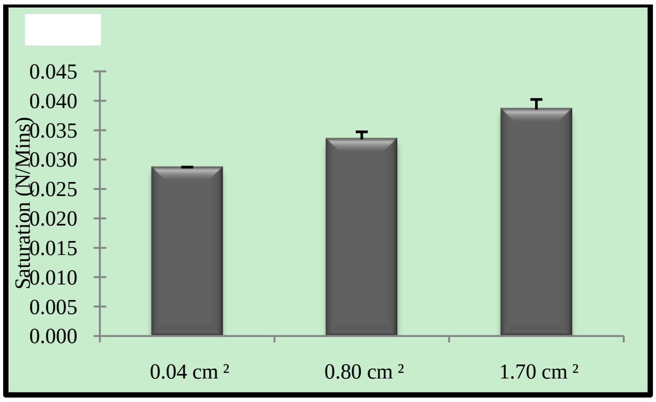

Fig. 3. Oil saturation value of three different absorbent papers made from kenaf fibers.

In Fig. 2, sorbent made from kenaf fibers sized-1.70 cm^2 shows the highest absorption value that is 8.20 g/g followed by kenaf fibers sized-0.80 cm^2 (6.90 g/g) and kenaf fibers sized-0.04 cm^2 (6.24 g/g).The absorption ratio of sorbent sized-1.70 cm^2 to sorbent sized-0.04 cm^2 is 1:1.31. The results highlight that sorbent made from larger particle size have higher ability to absorb more oil. This value is directly correlated to the saturation value. Consequently, sorbent sheet produced from kenaf fibers 1.70 cm^{2-} sized also shows the highest saturation value of 0.039 N/Min.

The results are compared to values obtained from other natural based sorbent materials in previous studies. It was found that, the oil sorption capacity of sorbent materials produced from kenaf sized-0.04 cm^2 and 0.8 cm^2 were comparable to Sisal (6.4 g/g). Most importantly, in this study kenaf-sized 1.70 cm^2 produced sorption material that has superior oil sorption capacity than Sisal (6.4 g/g), Coir (5.4 g/g) and loofa sponge (4.6 g/g) [5]. A one-way ANOVA test (SPSS Version 21) was conducted to evaluate the significance of difference for all data in this study. It was found that the significant value is 0.002 for absorption value and 0.001 for saturation value respectively which are lower than $\alpha = 0.05$ therefore the absorption and saturation values in this study are significant.

Mechanical strength is another aspect that plays a significant role in an oil absorbent material. Oil spills often occurred in open environment where clean-up process and material was subjected to exposure in rough weather conditions. Therefore sorbent materials with high mechanical strength and durability are preferred in order to withstand the circumstances throughout the various stages of clean-up process. Mechanical strength of sorbent materials produced in this study is shown in Table I.

Sorbent made from kenaf sized-1.70 cm^2 also shows the highest breaking length characteristics compared to those of 0.04 cm^2-sized and sized-0.80 cm^2. This is because the bonding of fiber in 1.70 cm^2-particle size sorbent sheet formed the best structure networking as evidenced in the micrograph images (Fig. 1. a-c). To note, the breaking length of plain paper is 982.27 m. It was reported that the length of the fiber is one of the important factors that determined the strength of kenaf fiber due to its tear and tensile properties [13]. Another reports mentioned that the fiber strength reduce with the shortening of the fiber length [14]. Besides, the longer fiber also has an ability to bend and twist that can make stronger bond [15].

The mechanical strength of the initial sorbent material in turn affected its biodegradability. In Table II, used sorbent sheet originally produced from kenaf-sized 1.70 cm^2 was found to take the longest period (68 days to degrade to less than 0.1 cm^2 pieces) compared to the other two sorbent sheets. The data in Table II show that kenaf particle's length and strength is positively correlated to the used sorbent biodegradability period. Although, the longest time taken for the sorbent to degrade was almost 10 weeks, the biodegradability is still superior compared to conventional plastic sorbent materials such as polypropylene which can take decades to self degrade [16].

TABLE I: MECHANICAL STRENGTH OF THE ABSORBENT PAPER

Aspect	Total mass to break strip (g)	*Breaking length (m)
Kenaf sized-0.04 cm^2	34.47	3.10
Kenaf sized-0.80 cm^2	175.66	24.33
Kenaf sized-1.70 cm^2	251.10	51.71
Plain paper	1485.00	982.27

*Significant value (ANOVA) = 0.000 < α = 0.05

TABLE II: BIODEGRADABILITY PERIOD

Aspect	Time (Days)
Kenaf sized-0.04 cm^2	26
Kenaf sized-0.80 cm^2	42
Kenaf sized-1.70 cm^2	68

From the results, it can be concluded that the most suitable size to make the oil sorbent material is from kenaf fiber of 1.70 cm^2-sized due to its good networking matrix formation, the highest absorption capacity and mechanical strength.

ACKNOWLEDGMENT

The authors would like to thank the national kenaf and tobacco board of Malaysia for supplying the kenaf biomass and staff in chemistry department faculty of science and mathematics, Sultan Idris Education University for their technical assistance.

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