Effect of Kapok Fibers/Recycled Rayon Wastes on Motor Oil Sorption Capacity

Panadda Kongsricharoen, Darathip Pejprom, Chaowalit Senanurakwarkul, and Sutha Khaodhiar

Abstract—In this study the application of kapok as oil sorbent was investigated. The oil sorbent was prepared by mixing kapok with rayon fiber and viscose mixtures, the waste generated from the viscose fiber rayon manufacturing process. Motor oil was used in the oil sorption study. The results indicated that the sorbent, prepared from 100% by wt of kapok fibers, 14% by wt of viscose mixtures and 50 grams sodium sulfate, has the highest sorption capacity for motor oil. The sorbents were tested for short test (15 minutes) and long test (24 hours) according to ASTM (F726-06) standard. The sorption capacity was 28.10 and 29.29 g of motor oil/g of sorbent, respectively. After the 6th cycle of reuse, the sorption capacity decreased to 44%. Comparison between the prepared sorbent and PP oil sorbent showed that the prepared sorbent performance was better than commercially available PP.

Keywords—cellulose sponge, kapok fiber, oil sorbent, polypropylene, rayon fiber

I. INTRODUCTION

Recently, the production of Viscose Rayon Fiber (VRF) has expanded rapidly due to increasing demands in the world market. These fibers are used in various applications, e.g., apparel, home textiles, dress materials, wipes, personal hygiene and medical usages. However, the VRF manufacturing process produces a lot of waste, including VRF, viscose mixtures, and sodium sulfate. For instance, a production of 151,000 tons of VRF, will produce approximately 500 tons of VRF waste, 300 tons of viscose and 50 tons of sodium sulfate [1],[2]. These wastes are disposed of by landfill, which requires a large area and high cost.

Oil spill is a problem which frequently occurs and has a negative impact on the physical and biological environments. Oil spill accidents can occur from both human mistakes (e.g., surveying, manufacture and carrying) and natural disasters (e.g., earthquakes and hurricanes), and they can contaminate ground and natural water bodies [3]. There are many methods for oil spill removal, but one of the most widely used methods is sorption by sorbents. In addition, the uses of biomass sorbents, e.g., bagasse, coconut husk or kapok fiber, for oil spill remediation have been of interest to many researchers as they are less expensive and more biodegradable than synthetic sorbents [4],[5].

Kapok (Ceiba pentandra (L.) Gaertn.) is an agricultural product which has a high tube structure with large lumen. The kapok fiber is fluffy, lightweight and non-toxic [6]-[8]. It is composed of 64% cellulose and 13% lignin. Beside these constituents, it also contains waxy material on the fiber surface which makes its exhibit water repellent properties [9].

The main objective of this research is to study the oil sorption capacity of sorbents prepared from kapok fibers, rayon fibers and viscose mixtures. All analyses were conducted according to the American Society for Testing and Materials (ASTM) [10]. The capacity of the prepared sorbent was compared with the commercial PP oil sorbent.

II. MATERIALS AND METHODS

A. Sorbent materials and oil

The kapok fibers used in this study were purchased from a general market in Thailand. Rayon fibers, viscose mixtures and sodium sulfate were received from Thai Rayon Public Co., Ltd. The kapok fibers and rayon fibers were air dried, and all dust and lumps were removed.

The PP oil sorbent was obtained from Phol Dhanya Public Co., Ltd. The properties of the PP oil sorbent are summarized in Table I.

<table>
<thead>
<tr>
<th>Type</th>
<th>Size</th>
<th>Material</th>
<th>Application</th>
<th>Sorption capacity (g of oil/g of sorbent)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sock</td>
<td>3 Inches × 8 Feet</td>
<td>100% polypropylene</td>
<td>Oil/Petroleum</td>
<td>9.072</td>
</tr>
</tbody>
</table>

Motor oil (SAE 20W 50) obtained from PTT Public Co., Ltd. was used as the experimental oil. Motor oil is classified as a medium oil type according to ASTM (F726-06) standard. Its density was 323 centipoise as reported by the manufacturer.
B. Preparation of sorbents

For each type of prepared sorbent, 100:0, 50:50, and 0:100 (%wt) kapok fibers: rayon fibers with 100:0, 34:66, 20:80 and 14:86 (%wt) viscose mixtures: water, were thoroughly mixed. After that, 0 or 50 grams of sodium sulfate were added to the mixture and blended for 30 seconds. Then the mixture was transferred to the beaker, and 10 % (v/v) of sulfuric acid was added. The mixture was allowed to stand for approximately 30 minutes until it was completely sponged. The sorbent was then removed from the beaker, washed with hot water (98 °C) to remove sodium sulfate, washed with water to remove any soluble constituents and dried at 60 °C for 18 hours [11],[12].

C. Dynamic degradation test

The experiment was divided into two parts. The first part was a water take-up study to determine the oleophillic properties of a sorbent under dynamic conditions. Different sorbents were weighed at approximately 5 grams, then placed in a 4-liter jar that half-filled with water. The jar was sealed and shaken at 150 rpm for 15 minutes. After that, the condition of the sorbent and water was observed. If 10% or more of the sorbent had sunk, then the sorbent was considered to have failed this test. The contents in the jar were strained through a mesh basket to catch the sorbents, and weighted after a 30-second drain period. The water sorption capacity (g of water/g of sorbent) was calculated, as in (1).

Water sorption capacity = \( \frac{S_w}{S_o} \)                                

(1)

Where \( S_o \) is initial dry sorbent weight, \( S_w \) is weight of sorbent samples at end of water test, and \( S_{wl} \), \( S_{w} - S_{o} \) is net water sorbed.

The second part was an observation test to study sorbent behavior when motor oil was added under dynamic conditions. The jar was half-filled with fresh water and 3 millilitres of motor oil was added. The sorbent was added to the jar. The jar was sealed and shaken at 150 rpm for 15 minutes. Observations included but were not limited to the physical appearance of the sorbent. Similar experiments were performed for the PP oil sorbent.

D. Oil sorption test

This study determined the effect of mixture ratio on sorption capacity. Approximately 5 grams of different sorbents were weighed. The test cell had a diameter of 20 centimeters and depth of 10 centimeters. The cell was filled with 2.5 centimeters of motor oil in thickness. The sorbent was placed in the basket, and placed into the cell. After 15 minutes for the short test, 24 hours for the long test, the basket was removed and the sorbent was allowed to drain for 30 seconds. The sorbent was caught and immediately transferred to a zipper bag, and weighed. The oil sorption capacity (g of oil/g of sorbent) was calculated, as in (2).

Oil sorption capacity = \( \frac{S_o}{S_w} \)

(2)

Where \( S_o \) is the initial dry sorbent weight, \( S_w \) is the weight of sorbent samples at the end of the oil test, and \( S_{ot} \), \( S_{o} - S_{t} \) is net oil sorbed. Similar experiments were performed for the PP oil sorbent.

E. Reuse test

This study evaluated the reusability of a sorbent after a series of oil sorption/desorption. The procedure was similar to the short test. Filtration was used by light fabric. The oil was squeezed out of the sorbent. The sorption/desorption cycle was repeated until oil sorption capacity was less than 50% of the sorbed oil compared to the first cycle. Similar experiments were performed for the PP oil sorbent.

III. RESULTS AND DISCUSSIONS

A. Dynamic degradation capacity

Fig.1a shows that for each amount of kapok fibers, the water sorption capacity was not different. The water sorption capacity did not depend on the kapok fibers because the fiber has hydrophobic characteristics.

![Graph](attachment:graph.png)

Fig. 1 (a) Effect of kapok fibers: rayon fibers ratio (% wt) and viscose mixtures: water ratio (% wt) on water sorption capacity (g of water/g of sorbent). (b) effect of kapok fibers: rayon fibers ratio (% wt) and viscose mixtures: water ratio (% wt) on water sorption capacity (g of water/g of sorbent) with sodium sulfate addition.

However, for each amount of viscose mixture, the water sorption capacity increased with a decreasing amount of viscose mixture. The highest water sorption capacity was
obtained from 100:0 (% wt) kapok fibers: rayon fibers with 14:86 (% wt) viscose mixtures: water and 100:0 (% wt) kapok fibers: rayon fibers, 14:86 (% wt) viscose mixtures: water with 50 grams of sodium sulfate. The water sorption capacities were 9.22 and 40.65 g of water/g of sorbent, respectively.

The water sorption capacity in Fig. 1b was greater than 1a. This is due to the addition of sodium sulfate, which increases the water sorption capacity of the sorbent. The water sorption capacity of the prepared sorbents was higher than the PP oil sorbent (1.52 g of water/g of sorbent), because the natural kapok fiber did not need chemical pretreatment [6]. The addition of sulfuric acid may decrease the functionality of water sorption. All of 0:100 (% wt) and a few kapok 50:50 (% wt) fibers: rayon fiber samples did not pass the dynamic degradation test. The samples sunk because of the good water sorption capacity of rayon fibers.

B. Oil sorption capacity

Fig. 2a and 2b show that for each amount of kapok fiber, the oil sorption capacity increased with a decreasing amount of viscose mixture because the viscosity of viscose mixtures controls the size of sorbent pores, i.e. the higher the viscosity resulted in a smaller pore [11]. For each amount of viscose mixture, the oil sorption capacity increased with an increasing amount of kapok fibers. The highest oil sorption capacity was obtained from 100:0 (% wt) kapok fibers: rayon fibers with 14:86 (% wt) viscose mixtures: water. The oil sorption capacities were 9.98 and 10.19 g of motor oil/g of sorbent, respectively. Fig. 2a shows that the oil sorption capacity was similar to Fig. 2b. The result suggests that the maximum performance of the sorbent could be used for only a short time (15 minutes).

The results in Fig. 2c and 2d reveal that the highest oil sorption capacity was obtained from 100:0 (% wt) kapok fibers: rayon fibers, 14:86 (% wt) viscose mixtures: water and 50 grams of sodium sulfate. The oil sorption capacities were
28.10 and 29.29 g of motor oil/g of sorbent, respectively.

All of the 100:0 (% wt) viscose mixtures: water, the motor oil sorption did not differ with increasing amounts of kapok fibers, because of the viscosity of the viscose mixtures. For 0:100 (% wt) kapok fibers: rayon fiber with 14:86, 20:80 and 34:66 (% wt) viscose mixtures: water, the motor oil sorption was similar because of the good water sorption of rayon fiber. However, the addition of sodium sulfate made the oil sorption capacity increase because the sodium sulfate controlled the coagulation of the pore walls, which made the sorbent of the capillary surface larger [11].

Comparison between the prepared sorbent, which obtained the highest oil sorption capacity and PP oil sorbent shows that the oil sorption capacity followed the following order: prepared sorbent with sodium sulfate > PP oil sorbent > prepared sorbent without sodium sulfate, as illustrated in Fig. 2.

C. Reusability of sorbents

Fig. 3 shows that oil sorption capacity decreased during repeated use. After the 6th cycle of reuse, the performance of the prepared sorbent and PP oil sorbent decreased to 44 and 41%, respectively. The result suggests that the prepared sorbent can be reused several times for motor oil cleanup.

IV. CONCLUSIONS

The main objective of this research was to study the oil sorption capacity of kapok fibers - VRF waste sorbents. The mixture of 100:0(% wt) kapok fibers: rayon fibers, 14:86 (% wt) viscose mixtures: water with 50 grams of sodium sulfate was the most effective approach for oil sorption. This ratio obtained the highest sorption capacity for motor oil (29.29 g of motor oil/g of sorbent), which had a higher performance than the PP oil sorbent used. The sorbent can be reused several times for oil cleanup.

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REFERENCES


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