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REMOVAL OF OIL AND GREASE FROM WASTEWATER USING NATURAL ADSORBENTS

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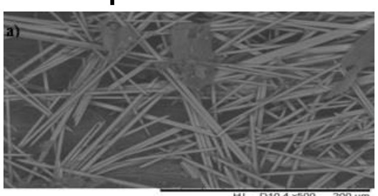
Graphical abstract



Abstract

There are several pollutants that can harm our environment. Oil and grease are one of the examples of a pollutant that can cause a severe environmental problem. The highest concentration of oil and grease inside the sewer system can cause the sewer to clog that can lead to overflow. It can affect not only to the environment but can also affecting our health. There are various methods of oil and grease removal that one of the examples is by using adsorption method. This method commonly uses activated carbon that is one of the effective adsorbents. Although effective, the cost for activated carbon is expensive thus a study was conducted by using agricultural residues as alternative adsorbents for oil and grease removal. This study objective is to determine the ability of two adsorbents, which are sugarcane bagasse and banana pith as an adsorbent in removing oil and grease from wastewater. It involved the characterization of adsorbent and the performance studies of the adsorbent. The adsorbent was characterized in term of physical and chemical characterization. Dosage and contact time are the parameter used for performance studies, to see the ability of adsorbents in removing oil and grease.

Keywords: Adsorption, adsorbent, natural adsorbent, sugarcane bagasse, banana pith

1.0 INTRODUCTION

Various pollutants are emerging in our environment. One of the pollutants that can cause an environmental problem is the present of oil and grease inside water system. High concentration of oil and grease inside sewer system can result in clogging due to the deposited oil and grease inside the sewer system. The clogging can lead to sewer overflow, which can cause water pollution such as the exposure of the pathogens [1, 2]. Many factors can contribute to the present of oil and grease inside wastewater, such as food processing industry, restaurant, farmhouse, and slaughterhouse. The enhance use of oil in development and high-demanded oil processed food (fast food industries, stalls) also the inappropriate oil discharge into the water drain either industrially or domestically usage [3]. Oil can contaminate the water in two different forms which are in the form of emulsified oil or the form of free oil [4]. Once oil wastewater introduced into aquatic environments in high concentration and become toxic to the aquatic life and damages other ecology in water bodies [5].

Assorted techniques can remove oil and grease in the wastewater, and the selection depends on the characteristic and condition of the wastewater itself. Commonly, gravitational methods, floatation, chemical and biological treatment and dissolved air flotation are the examples of conventional methods on how to treat the oily wastewater. However, these methods required highly cost and full maintenance. De-emulsification can be another choice but did not widely used due to low removal efficiency and high cost [6-8].

Various studies have been conducted in searching the best ways to remove oil in the water. The methods that are used in removing of oil include adsorption, flotation, coalescences, membrane filtration biological treatment, electrocoagulation, coagulation, and flocculation. Each of the methods has the advantages and disadvantages Among the various methods listed before, adsorption is one of the common methods use in removing pollutant. Based on the previous study, the advantages of using adsorption methods are, high oil removal efficiency, low in cost, and low in processing cost [9]. However, there are also some disadvantages in using adsorption methods; it required labor intensive and poor removal of fine emulsions [10].

The accumulation of the sorbate molecule is only at the surface, without penetrating into the adsorbent. For adsorption process to occur the selection of adsorbent is important to give a higher percentage removal. In a recent year, there were various studies on the use of natural sorbent as the adsorption materials. The use of natural organic and inorganic can give a higher adsorption, which it can adsorb between 3 to 15 and 4 to 20 times of adsorbent weight [10].

2.0 EXPERIMENTAL

This study is performed in several steps

1. Characterization of wastewater
2. Preparation of raw sugarcane bagasse (RSB) and raw banana pith (RBP) adsorbent
3. Physical and chemical characterization of RSB and RBP
4. Performance studies of RSB and RBP
5. Comparison of oil adsorptivity using RSB and RBP

2.1 Characterization of Wastewater

To determine the characteristic of the wastewater, the wastewater was characterized by several parameters. In this study, parameters tested were oil and grease concentration, pH, conductivity, and temperature.

2.2 Preparation of Sugarcane Bagasse (SB) and Banana Pith (BP) Adsorbent

Sugarcane bagasse were obtained from local cane stall in Shah Alam, Selangor while banana pith was taken from a small banana plant plantation in Pontian, Johor. Both of the plants residues were then washed with distilled water to remove any adhering impurities that may present at the outer layer of the plant. Both of the plants were then undergoing oven dried for at 60-70^{0}C at 24 hours until constant weight is achieved. The plants were cut to get the constant size and were labeled with raw sugarcane bagasse, RSB and raw banana pith, RBP.

2.3 Physical and chemical characterization of RSB and RBP

For this study, both RSB and RBP will undergo physical and chemical characterization. For physical characterization, the Scanning Electron Microscopy (SEM) was used to examine the surface morphology of the adsorbent. Fourier Transform Infrared (FT-IR), was used to study the functional group that may present inside RSB and RBP.

2.4 Performance studies of RSB and RBP

For performance studies, two different parameters were used to determine the performance. For time contact studies, fixed amount of sorbent and wastewater volume were used. The amount used is 5g and 500mL of wastewater. The size of adsorbent was fixed at 1.18mm for both contact time and adsorbent dosage studies. For time contact study, the contact time was varied between 15-75 minutes. As for the amount of adsorbent dosage study, the time was fixed at 60minutes and the volumes of wastewater used are at 500mL. The adsorbent dosage was varied between 1g, 3g, and 5g. The oil and grease test was conducted by using SPE methods 10300. For percentage removal calculation, Equation 1 used where C_0 and C_e are the concentration of oil and grease in the initial and equilibrium in g/L.

$$\text{Percentage removal (\%)} = \frac{C_0 - C_e}{C_0} \quad (1)$$

3.0 RESULTS AND DISCUSSION

3.1 Wastewater Characterization

Table 1 shows the outcome of the wastewater characterization. From the experimental data, the concentration of oil in wastewater is 148.79 g/l which can be considered as high.

Table 1 Wastewater Characteristic

Parameter	value
Oil and Grease	148.79 g/l
pH	6.39
Temperature	25.9^{0}C

3.2 Characterization of RSB and RBP

For physical characterization, both of the results show different surface morphology when compared with each other. Figure 1a shows that RSB had reasonable homogeneity in aggregate shape and have wall structure that gives an advantage for adsorption capability. While based on Figure 1b, RBP shows a smooth and clean figure when compared with the structure for RSB.

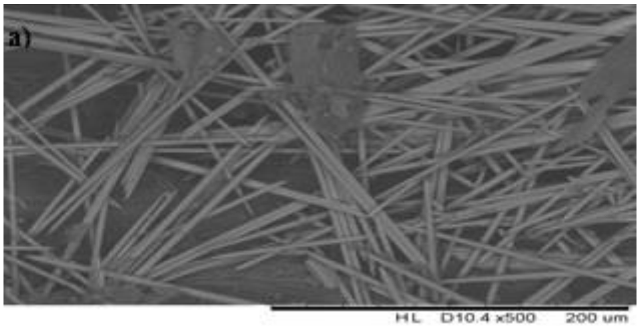


Figure 1a SEM for RBP at x500

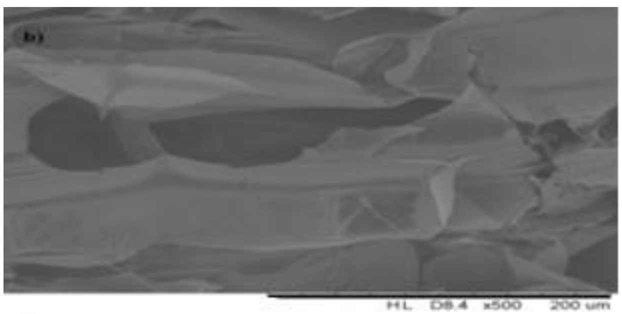


Figure 1b SEM for RSB at x500

For chemical characterization, Figure 2 shows the FT-IR spectra for both RSB and RBP before the adsorption process.

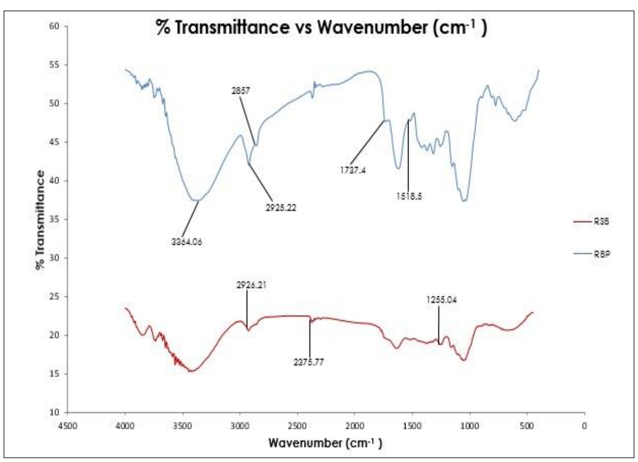


Figure 2 FT-IR Transmittance vs. Wavenumber chart for RSB and RBP

From FT-IR observation, sugar cane bagasse mainly contains a hydroxyl group (-OH), carbon-hydrogen bonding (C-H), carbon-oxygen double bonding (C=O), aromatic rings (C-H), carbon-oxygen bonding (C-O) and carbon-oxygen-hydrogen bonding (C-OH). Some of this bonding still can react with other compound and shows that sugarcane bagasse has the capability for adsorption. Plant wax is commonly present in the plant; the plant wax usually consists of n-alkanes, alcohols, and carbonyl group [11]. Another study also stated that plants wall consists of alkanes, ketones, alcohols and esters [12]. Based on the observation from Figure 2, for RBP the functional groups that are present inside RBP are alcohols, alkanes, carbonyl, and aromatics.

3.3 Effect of Contact Time

For performance studies, two parameters were used to determine the ability of RSB and RBP as and adsorbent. The two parameters are contacted time and adsorbent dosage. For contact time, the performance or the ability of the adsorbent to adsorb the oil and grease at the desirable time was studied. The time contact study is to find the desirable time for the highest of oil removal for the performance study experiment.

Based on the previous study, two phases occurred during adsorption [4]. The phases are a primary rapid phase and a slow phase. The primary rapid phase can be seen from Figure 3 where the percentage removal increases with the increase of contact time. After a certain period, the percentage removal starts to slow down which can be seen from the graph where RBP show a slightly different percentage removal at different contact time. For RSB, the percentage removal shows an increasing pattern where the highest removal is at 56%. For RBP, the highest percentage removal is at 97%.

It was found that as the contact time was longer, the rate of oil and grease removal also increase. This was due to in the beginning, the present of active sites in the structure of bagasse. So, as the contact time increased, the active sites on the adsorbent were filled with oil molecule. However, with the increase of contact time, the adsorption sites start to reduce due to oil molecules begin to fill the adsorption site. This is when a second phase start, the slow phase adsorption where adsorption still occurs but at slow adsorption.

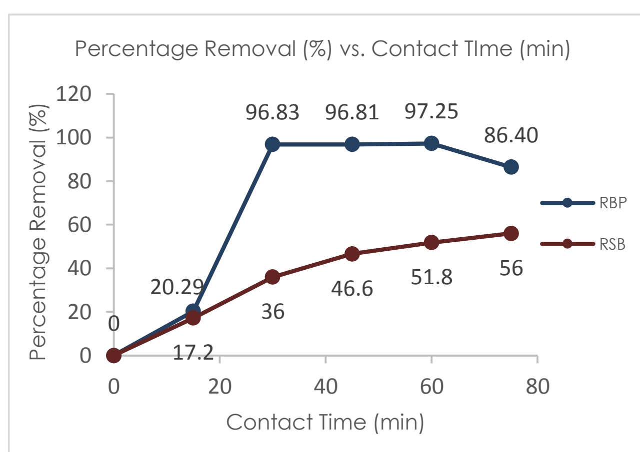


Figure 3 Effect of contact time on the percentage of oil removal

3.4 Effect of Adsorbent Dosage

From Figure 4, the percentage removal shows rapid changes with the increasing of adsorbent dosage. For adsorbent dosage study, the percentage removal of RSB shows at higher removal at 63% removal using 5g of adsorbent. The trend from Figure 4 shows that the percentage removal increases with the increasing amount of adsorbent dosage. For RBP, the highest removal rate is at 97% with the amount of dosage at 5g.

Percentage removal increases with the quantity of adsorbent can be explained by the availability of adsorption binding site. It is believed with the increase of adsorbent dosage, the availability of adsorption is increased. Thus, the adsorption efficiency increases [13]. Another study also shows the increase in adsorbent dosage; the active surface area is also increased, so the sorption at the adsorbent site increases [10].

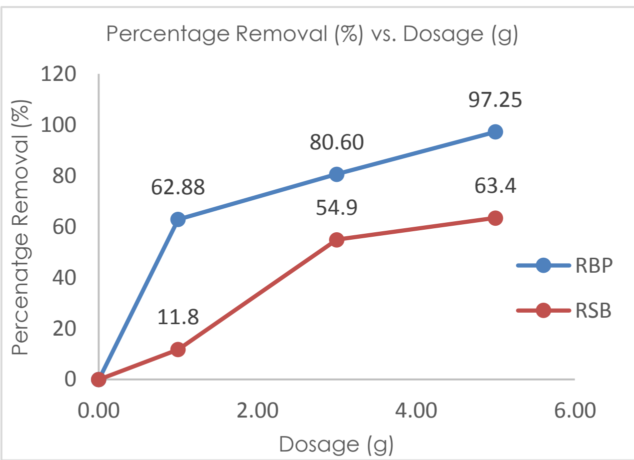


Figure 4 Effect of dosage on adsorption of oil

3.5 Adsorption Isotherm Study

The relationship between the amounts of adsorbed by a unit weight of solid sorbent and the amount of solute remaining in the solution at equilibrium can be described by the sorption isotherm [14]. For describing short-term and mono-component adsorption by biosorbents, both Langmuir and Freundlich isotherm models have showed the best [15, 16].The linear form of Langmuir isotherm is given in equation 2 while the linear form of Freundlich is given in the equation 3.

$$\frac{C_e}{q_e} = \frac{C_e}{Q_o} + \frac{1}{Q_{o}b} \quad (2)$$

$$\log q_e = \log K_f + \frac{1}{n}\log C_e \quad (3)$$

C_e is the equilibrium concentration and q_e is the amount adsorbed at equilibrium. While Q_o and b are constant for Langmuir adsorption isotherm, and K_f and n are constant for Freundlich adsorption isotherm. Figure 5-8 shows the Langmuir and Freundlich adsorption for both RBP and RSB. From the plotted graph, the linear equation from the chart are derived, and the value of R^2 were obtained to determine which adsorption isotherm is more favorable for banana pith adsorption. Table 2 show the value of R^2 and the constant for both Langmuir and Freundlich for RBP and RSB.

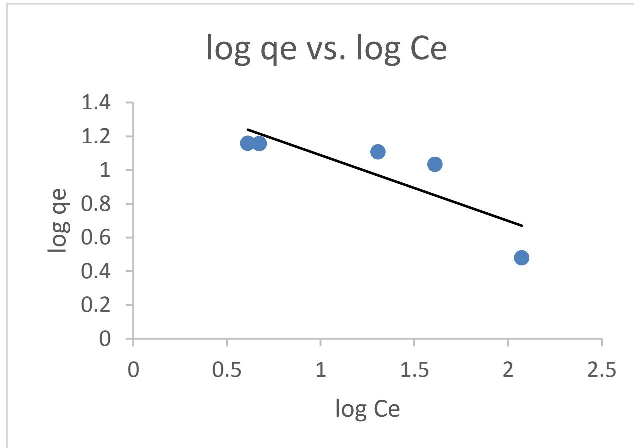


Figure 5 Langmuir isotherm plots for RBP

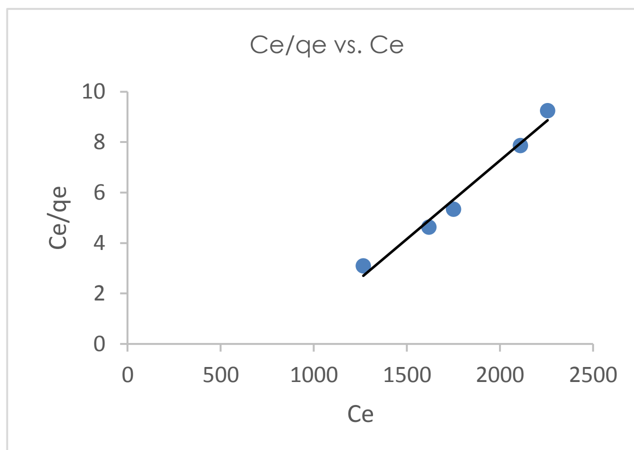


Figure 6 Langmuir isotherm plot for RSB

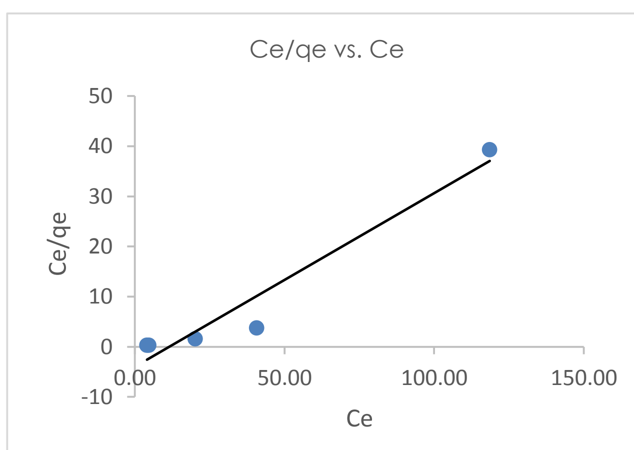


Figure 7 Freundlich isotherm plot for RBP

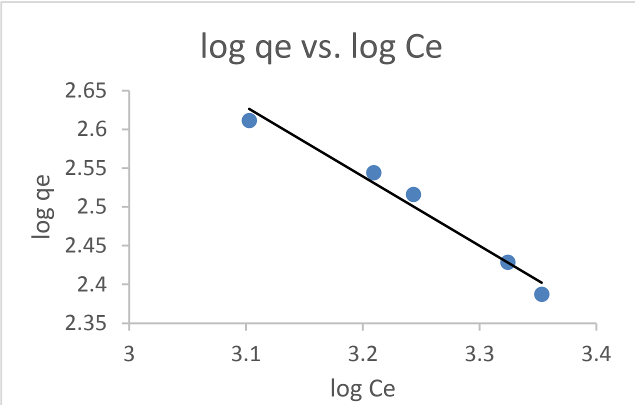


Figure 8 Freundlich isotherm plot for RSB

Table 2 Langmuir And Freundlich Adsorption Isotherm

Adsorbent	Langmuir constant		
	Q_0	b	R^2
RBP	2.8885	-0.0866	0.9456
RSB	161.2903	$-1.1950\text{X}10^{-3}$	0.9785
	Freundlich constant		
	K_f	$1/n$	R^2
RBP	30.0054	-0.3895	0.7045
RSB	2.5×10^5	-0.8935	0.9736

Table 2 showed summarization of R^2 value of Freundlich and Langmuir Isotherm for using RSB and RBP. R^2 value for RSB of Langmuir and Freundlich isotherm were greater than 0.9. However, from isotherm models plotting, RSB showed higher R^2 values in Langmuir isotherm plot. By comparing R^2 value from both isotherm models, RSB was more suitable and fit with Langmuir isotherm model.

However, for RBP, the value of R^2, from the table show Langmuir isotherm is greater than 0.9 when compared with Freundlich isotherm. Hence, the best-fitted isotherm for RBP is Langmuir isotherm. Langmuir isotherm indicates that the adsorption process occurs in a monolayer on the homogenous surface of the sorbent [10]. However, based on previous study the Langmuir and Freundlich isotherm can be used if all the conditions are obeying the isotherm rule [10]. But since the oil and grease system is a bit complex, due to the present of multiple organic components the use of this isotherm might be difficult.

4.0 CONCLUSION

As conclusion from this research study, both physical and chemical characterization shows that RSB and RBP have the capability to act as adsorbent materials for the removal of oil. RSB showed the best performance with 63.4% and 56.0% removal when adsorbent weight used was 5g and 75 minutes in contact time respectively. While, RBP both show 97% removal when adsorbent weight used was at 5g and 60 minutes. For both of the isotherm studies, both adsorbents show that the best-fitted isotherm is Langmuir isotherm.

5.0 RECOMMENDATION

Some recommendations could be done for this research study: RSB and RBP can be treated with a chemical to see if the changes in surface morphology can increase the percentage removal of oil from wastewater. Varies contact time and sorbent dosage to find the optimum condition to discover the best performance for RSB and RBP. Besides that, the isotherm studies using different isotherm model could be conducted to find the best-fitted isotherm for sugarcane bagasse and banana pith.

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