Removal of Spilled Engine Oil Using Dendro Biochar as an Adsorbent

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Abstract – Oil spills have become a severe concern in recent years due to their complexity and massive cost of cleaning. Among different cleanup methods such as mechanical, chemical, and biological, adsorption is a promising physico-chemical method for cleaning up spilled oil. Biochar is often used as an adsorbent in oil adsorption however, a waste output from dendro power plants has not been tested for the adsorption of engine oil. Hence, the purpose of this study was to determine the adsorption potential of biochar obtained from the Embilipitya dendro power plant. The experiment used varying amounts of biochar, ranging from 0.1 to 1 g, with a fixed initial oil amount (1.5 g). The maximum engine oil adsorption capacity and removal efficiency was shown by dendro biochar when the dose of biochar was 4 g/L. The removal rate slightly increased with the dosage though, the optimum adsorption capacity (1220 g/kg) when the dosage was 10 g/L. Intensities of peaks observed at ~1500 - 1640, ~2850 - 2900, and 3450 cm^{-1} of Fourier transform infrared (FTIR) spectrum for oil adsorbed biochar increased due to the formation of new bonds with hydrocarbons which indicates interactions between oil and biochar.

Keywords: Oil spill, Dendro Biochar, Adsorption

I. Introduction

Releasing petroleum hydrocarbons (PHCs) has become a serious problem worldwide, and scientific communities have focused on them. The Exxon Valdez incident, Hebei Spirit spill, Prestige spill, and the Deepwater Horizon are some examples of oil spills occurred so far which left long-term impacts on ecology, economy, public health, and wildlife [1]. Being a country adjacent to the silk route, Sri Lanka has a risk of oil spills from distressed ships. The most reason spill incident happened in Sri Lanka is X-press pearl cargo ship which caught on fire on 20th May 2021, leaving a huge ecological footprint that Sri Lanka would likely suffer for decades due to its risk [2]. Furthermore, hundreds of automobile service stations are distributed with the expansion of transportation, and the effluents from these stations may contaminate the water sources. These oily effluents may contain a variety of pollutants, such as gasoline, detergents, shampoo, and engine oils which are adjacent to water sources or wetlands.

Many cleanup techniques for oil spills have been developed for years which can be categorized into chemical, mechanical, and biological methods [3]. Among these methods, sorption-based methods have become more popular especially because of their nonflammability, chemical inertness, cost-effectiveness, and availability. In recent years, biochar was utilized broadly for remediation approaches due to its great sorption characteristics including large surface area, porous structure, hydrophobic properties, etc. Dendro biochar is a by-product of dendro power plants and is woody biochar made from *Gliricidia sepium* [4], however, no studies conducted using dendro biochar for oil removal. Hence, this might encourage researchers to look into the use of dendro biochar which is a waste byproduct of the dendro power industry to be used in oil pollution mitigation.

II. Materials And Methods

Embilipitya Biochar (EBC) originated from dendro power plant in Embilipitya, gasified at around 700 °C was collected and samples were washed several times to remove impurities and dried at 60 °C for overnight to remove absorbed water. Crushed EBC was sieved through 1 mm and 0.5 mm sieves and collected the retained particles on the 0.5 mm mesh for the study. An artificial oil spill was simulated by adding 25 ml of ultrapure water and 1.5 g (60 g/L) of engine oil into a 50 ml glass beaker and then collected by filtration onto a filter paper.

The effect of adsorbent dose on adsorption of engine oil was investigated by varying the EBC dose from 4 g/L (0.1 g) to 40 g/L (1 g) of dosage and holding the pH, oil concentration, and temperature constant at 7, 60 g/L, and 25 °C respectively. Blanks were run as controls to determine the weight of the filter paper. The filter paper was dried in an oven at 60 °C to remove adsorbed water. Mass balancing determined the adsorption capacity of engine oil. The sorption kinetics for EBC were conducted by varying the contact times from 0 to 360 min while the other conditions remained constant, including pH (7), added oil amount (1.5 g), temperature (25 °C), and dosage (10 g/L). The experimental data were analyzed using fractional power, Elovich, pseudo-first-order, and pseudo-second-order kinetic models.

Proximate analysis was conducted for EBC to observe the moisture, volatile, ash, and resident matter. Fourier transform infrared (FTIR) analysis was done to identify the functional groups present in the EBC as well as the change in the material composition of the pristine EBC and the EBC after the oil was adsorbed.

III. Results And Discussion

Adsorption capacities were determined for the dosages (4, 10, 16, 24, 32, 40 g/L) of EBC as aforementioned, and the highest adsorption capacity (2465 g/kg) was observed when the dosage was 4 g/L (0.1 g). The best degree of removal efficiency with its adsorption capacity (1220 g/kg) was obtained when the mass of the adsorbent was 0.25 g (10 g/L) (Table 1). When the dosage exceeded 10 g/L, even though the removal rate of engine oil started to slightly increase, adsorption capacities started to decrease, as was previously reported [5].

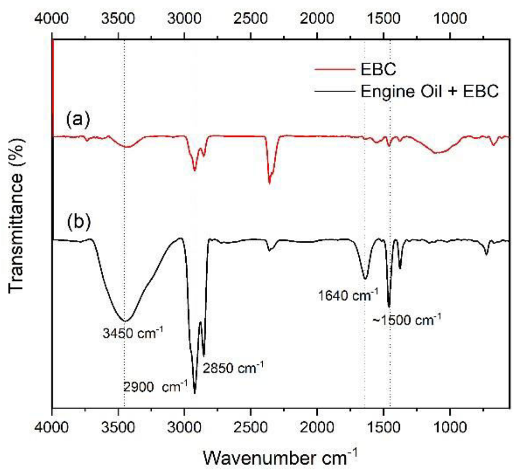
$$q_e = \frac{m_e}{m_0} \quad (1)$$

$$R\% = \frac{m_e}{m_{oil}} \times 100 \quad (2)$$

The adsorption capacity, q_e (1) and removal efficiency, $R\%$ (2) were calculated using the above equations, where m_0, m_e , m_{oil} are initial EBC amount (g) and adsorbed oil amount (g) and initial oil amount (g) respectively.

Table 1. Adsorption capacity and removal efficiency data for EBC dosages

Dosage (g/L)	Adsorption Capacity (g/kg)	Removal Efficiency (%)
4	2465	16.66
10	1220	20.44
16	752	20.30
24	555	22.48
32	465	24.66
40	376	25.14



The moisture content (7.84%), volatile matter (39.74%), ash content (10.24%), and resident matter (42.18%) of EBC were measured as proximate analysis. The FTIR spectra of pristine EBC and oil adsorbed EBC are illustrated (Figure 1). The appearance of a strong, broad peak at 3450 cm^{-1} corresponds to the stretching vibration of an O-H bond and a sharp, narrow peak at ~1500-1640 cm^{-1} corresponds to the sp2 C=C stretching vibration of an unsaturated ketone [(O=CR)−Cα=Cβ -R] functional group present additionally in oil adsorbed EBC other than pristine EBC. Spectra of oil-absorbed EBC display some sp3 C−H stretching for -CH2 (~2900−2850 cm^{-1}). According to Figure 1, the increase of intensity of the peaks in (b) confirms the adsorption of organic components including C and H, which are commonly present in the hydrocarbons (engine oil).

The sorption kinetics of EBC with engine oil was found to be fast. It was observed that oil uptake reached equilibrium in less than 60 min. Kinetic data well fitted with the Elovich kinetic model at 25 °C with high (>0.99) correlation coefficients.

IV. Conclusions

Biochar derived from dendro power plants was successfully used as a promising adsorbent for the removal of engine oil from oil-contaminated water. As per the sorption experiments carried out for adsorbent dosage, the dosage of biochar has shown a great influence on the adsorption performance of dendro biochar which shows the optimum removal efficiency when the adsorbent dosage was 10 g/L. Therefore, dendro biochar can be considered a cost-effective and efficient material that shows great potential to uptake oil pollutants from water.

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