Sorption of waste lubricant oil spills from seawater using natural hollow fibres

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Abstract. Waste lubricant oil is mostly produced by its replacement on engines machine, which is frequently discarded into the environment to seawater in particular. Calotropis gigantea and Ceiba pentandra fibres had the potential to be used as a natural oil absorbent material. This study was conducted on these fibres' oil sorption capacity in artificial seawater, using different variations in the thickness of the oil layer, contact time, mass absorbent, and temperature. The highest sorption capacity was obtained by 65.70 g/g for Calotropis gigantea, 79.71 g/g for Ceiba pentandra on fibre weight of 0.3 g, 9 mm oil film thickness, contact time 60 minutes, at room temperature. This report represents that both fibres are highly effective sorption on waste lubricant oil.

1. Introduction

Lubricant oil is a class of oils used to reduce that friction, heat, and wear between mechanical components in contact with each other [1]. Typically, lubricant oils contain 80-90% base oil (petroleum hydrocarbon) and less than 10-20% additives [2]. The spent lubricant oils are problem waste. High management cost needed for disposal of waste oil, illegal dumping of waste oil into the sea could be the regular practice by irresponsible people [3]. If waste lubricant oil is disposed of directly into the seawater, the oil will float because the oil density is lighter than seawater and quick spreading on the surface water [4], [5]. The oil layer on the surface of the water can reduce sunlight and oxygen into seawater. Sunlight can make oil molecules soluble in water and be toxic for aquatic life[2]. Poor management and careless disposal of waste lubricant oil can cause damage ecosystems, decrease water quality, decrease quality of life, damage coral reefs, and damage other ecosystems [6].

Various methods of handling waste lubricant oil in the seawater can be selected, such as in situ burning, mechanical removal, bioremediation, absorbent and dispersant chemicals adjusted to oil spill size, sea and weather conditions[7]. Oil absorbent is commonly used because it was easy to find, simple, and cost-effective[7], [8], [9]. Porous materials containing small capillaries in many surface areas are best for oil absorbent [7], [8]. The form of oil absorbents are available into pads, blankets, and pillows, and is generally made from synthetic materials such as polyester, polyethylene, polypropylene, and polyurethane[7]. These products have a high sorption capacity because of their hydrophobic and oleophilic properties but non-biodegradability[8], [9], [10].

Nowadays, natural sorbents are considered developing because of their rich source, low density, low cost and biodegradability. A high number of natural oil sorbent have been previously studied, e.g. orange peel waste[9], raw flax[11], chestnut fibres [12], kenaf fibres [13], corn stalk[14], jute fibres [15], palm fibres [16], cotton fibres [17], wheat straw[18], water hyacinth[19], and banana fibres [20]. The main characteristic of oil-absorbing materials is high sorption capacity, recovered quickly, and the absorbent
is reusable and has good buoyancy[21]. The hydrophobic and oleophilic properties would contribute to the improvement of their oil and water sorption[7], [14], [22]. The hydrophobic nature means that the ability to absorb water is low and good buoyancy implies a low density than water [23], [24].

Kapok (Ceiba pentandra fibre/CPF) and biduri (Calotropis gigantea fibre/CGF) are natural fibres with a lower density than water and good buoyancy. The low fibre density is caused by the thin fibre walls and the hollow in the middle fibre. Besides, the fibres are coated with wax which is reflected in its excellent hydrophobic and oleophilic properties[8]. These properties make CPF and CGF fibres the best candidates for natural oil-absorbing materials. The purpose of this research was to investigate the oil sorption capacity of CPF and CGF on the effect of absorbent weight, contact time and temperature.

2. Materials and methods

2.1. Materials
The material used Ceiba pentandra fibre (CPF) and Calotropis gigantea fibre (CGF) collected from local trees in West Java, Indonesia. Waste lubricant oil is taken from one of car workshop in Bandung. Artificial seawater (3% salinity by NaCl) was followed to SNI ISO 105-E02:2013: Textiles-Test for colour fastness - Part E02: Colour fastness to seawater.

2.2. Method
A certain amount of waste lubricant oil was into a 500 ml beaker containing 200 ml artificial seawater at different oil film thicknesses (9, 18, 36 mm). Different dosage fibrous material (0.3, 0.5, 0.7, 0.9, 1.1 g) was gently and evenly placed for a certain contact time (10, 20, 30, 60, 90, 120 minutes). Various temperature (30 and 50°C) occurs at oil film thickness 18 mm, a mass of absorbent 0.3 g, and contact time 30 minutes. Oil film thickness is the thickness of waste lubricant oil floating on the seawater on the breaker glass. The fibres are lifted and hung on the net for 5 minutes. The sample weight was determined and recorded. All weighing used PRECISA XB200A analytical balances with accuracy 0.0001 g. In this paper oil sorption refers to oil removal using sorbents. Sorption capacity was calculated from the following relations:

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\text{Sorption capacity (g/g)} = \frac{\text{mass of oil absorbed}}{\text{mass of absorbent}}
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3. Results and discussion

3.1. Sorption experiments
The density of waste lubricant oil was 0.8770 g/ml. The oil sorption capacity and efficiency by Ceiba pentandra fibre (CPF) and Calotropis gigantea fibre (CGF) are thoroughly examined. Several factors have been varied to study their effect on oil sorption for the waste lubricant oil using CPF and CGF. The sorption capacity of removal depends on various factors, including the type of fibres, contact time, thickness of the oil film, a mass of absorbent and temperature.

3.1.1. Effect of oil film thickness. Fig. 1 shows the sorption capacity of CPF and CGF versus oil film thickness (9-36 mm) using 0.3 g absorbent at a constant time (10 minutes). The oil sorption capacity of CPF and CGF increases by adding the oil film thickness. The highest oil sorption capacity in CPF is 79.22 g/g and in CGF is 50.63 g/g at 36 mm oil film thickness. The increase in oil thickness from 9 mm to 36 mm, relatively increased oil uptake by 12.78% for CPF and 1.85% for CGF. These results are under the previous study that oil sorption capacity influenced by adding initial oil feed. The oil sorption capacity depends on the amount of oil that enters the space/pore fibre. The addition of oil will cause the sorption capacity of oil increases, which is limited by equilibrium [11] [16].
3.1.2. Effect of contact time. Fig.2 shows the sorption capacity of CGF and CPF versus contact time. The different contact time ranged from 10 to 120 min on 18 mm oil film thickness. The oil sorption capacity CPF and CGF increased with time and reached the highest value of 79.12 g oil/g absorbent for CPF and 65.70 g/g for CGF at 60 minutes. The oil sorption mechanism is fast at the initial oil sorption period due to the oleophilic contact and the capillary force of surface, which increase the oil sorption on the fibre surface until the equilibrium state is reached. After the equilibrium state in 60 minutes, the oil sorption capacity became slow to reduce at contact time 90 and 120 minutes. It occurs because of the fullness of the sorption active sites of fibres [11]. These results are following the previous study that the contact time influence to oil sorption capacity. Two phenomena occur that begin with an increase in oil sorption capacity, reach an equilibrium state, and experience a decrease in sorption capacity[11].

3.1.3. Effect of mass absorbent. Fig.3 shows the sorption capacity of CGF and CPF versus mass absorbent. The different absorbent weight ranged from 0.3 to 1.1 g on 60 min contact time and oil film thickness 18 mm. In Figure 3, increasing absorbent weight on CGF and CPF decreases oil sorption. The sorption capacity of CGF and CPF gradually reduced from an absorbent weight of 0.3 to 0.7 g, however, at a weight of 0.9 and 1.1 g there was no significant change. At an absorbent weight of 0.7 g, indicates that the sorption has reached an equilibrium state. CGF achieved the highest sorption capacity with a weight of 0.3 g, namely 65.70 g / g and at a CPF of 79.31 g/g. The lowest sorption occurred at the absorbent weight of 0.7 g, CGF of 44.12 g / g and CPF of 61.51 g / g. Increasing the absorbent weight from 0.3 to 1.1 g at CGF decreased by 31.77% and 19.18% for CPF. Weight gain leads to fibre reduced porous aggregation area, which aids sorption. As a result, the number the oil absorbed in mass units decreases, furthermore sorption capacity is diminished [11].
3.1.4. Effect of temperature. Fig. 4 shows the sorption capacity of CGF and CPF versus temperature (30 and 50°C), with oil film thickness 18 mm and mass absorbent 0.3 g. Temperature can affect oil viscosity and sorption capacity, so the temperature is an essential factor in oil sorption by absorbent material [11]. The sorption capacity of CGF and CPF changes when temperature changes. When the temperature of seawater and waste lubricant oil increases from 30 to 50°C, the sorption capacity of CGF decreases from 58.78 to 47.48 g/g and the oil sorption CPF steady on 73 g/g. These results are following the previous study that the temperature effect to oil sorption capacity. In flax fibre research, increasing the temperature from 30 to 45°C decreased the oil's viscosity, which causes the solubility of oil in water. Besides, an increase in temperature causes the fibre's hydrophobic nature to weaken so that the oil sorption capacity decreases [11].
4. Conclusions
Calotropis gigantea and Ceiba pentandra fibre can be used as a natural oil absorber because they have high oil sorption. CGF reached the highest sorption of 65.70 g/g at an absorbent weight of 0.3 g, oil film thickness 18 mm and contact time 60 minutes. CPF produced the highest sorption capacity of 79.71 g/g at an absorbent weight of 0.3 g, oil film thickness 18 mm and contact time 60 minutes. The differences in oil film thickness, contact time, absorbent weight and temperature affect the sorption capacity of CGF and CPF.

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