Study of waste tyre granulates and polypropylene (PP) fibre as oil sorbent

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Abstract. There were various types of sorbent materials that exist in the current market that dealing with the oil spill incidents. However, because of high cost and incapable of repeated use, make it harder to combating oil spillage effectively and to suite environment friendly material. This study was done to assess waste tyre granulates and polypropylene (PP) fibre as oil sorbent in terms of its capacity, different type of oil absorbs and durability. Two different types of oil where used in this study in measuring the durability of the materials which are diesel and used engine oil. The sorbent capacity and re-usability tests were used to evaluate the practical sorption of each material. From the result it was found that waste tyre granulates had low oil practical sorption than PP fibre with almost 50% different. However, waste tyre granulates had high elasticity compared to PP fibre which enable it to be used repeatedly without losing its oil sorption capability. Therefore, both waste tyre granulates and PP fibre were combined to develop a new composite material sorbent that capable of recovering greater amounts of oil than using waste tyre granulates alone. The result shows that these composite material sorbent can be used repeatedly for at least 25 times.

1. Introduction

The term oil spill is used interchangeably with the oceanic or marine oil spill. The unintentional or deliberate release of crude liquid petroleum oil and other derived oil into the marine ecosystem is termed as an oil spill [1]. There were wide range modes of transportation in petroleum such as pipeline, tanker and train. Transporting oil from production area to another area especially offshore could impose some risks, such as accidental oil spills, which can cause severe damage to ecosystem and loss to human society. From 1970 to 2019, more that 5.86 million tonnes of crude oil was spilled into the oceans [2]. In Malaysia alone, records show there were 125 numbers of oil spill incident in The Strait of Malacca from 1976 to 1997 [3]. Oil spill disasters usually involve high number of casualties for both aquatic lives and birds [4][5]. Not only the environment will affect but also the human health especially people that involve in the crude oil industry [6]. Therefore, planning for oil spill disasters requires learning from previous events, yet it was challenging because it involves particular geographical conditions, ecological, societal around the vicinity [7].

Today, various method in containment of oil spill available, which the process of confining the oil either to prevent it from being spread or to divert the spillage to another area. Some common method of oil containment was using physical containment such as the deployment of sorbent. Sorbents are insoluble materials or mixtures of materials used to recover liquids through the mechanism of
absorption, or adsorption, or both [8], [9]. The absorbent must be at least 70 percent insoluble in excess fluid. To be useful in combating oil spills, sorbents need to be both oleophilic (oil-attracting) and hydrophobic (water-repellent). Sorbents can be divided into three basic categories: natural organic, natural inorganic, and synthetic. Natural organic sorbents were made from organic materials such as hay or sawdust. Natural inorganic sorbents consists of clay, sand or volcanic ash. While synthetic sorbents were made from man-made materials that were like plastics.

There were diverse types of materials that exist in the current market to deals with the oil spill incidents. However, because of their high cost and incapable of repeating use, make it hard to combat oil spillage effectively and keeping the procedure cost friendly. It was found that waste tyres had the potential to be used as an adsorbent candidate in crude oil clean up [8], [10]. Generally, most tyre contain several types of rubber which are natural and synthetic [11]. Naturally, the properties of rubber are not only waterproof, but also elastic. These unique characteristics deems the rubber to be more effective and more durable for combating oil spillage in marine environment. Despite enormous advantages of using waste tyre powder, the disadvantage of the waste tyre powder is it had a low oil absorbing capacity than other materials that currently exist on the market [9]. Elasticity and durability characteristic of the tyre would make possible for reused in this study. Other than recycling tyres for generating fuel or roadway material, waste tyres can also be used in removing organic waste from water [9].

Polypropylene (PP) is a thermoplastic polymer used widely in industries [12]. PP fibre is one of the polypropylene product with low specific gravity than water which lies between 0.90 – 0.91 g/cm³ and because of this PP fibre yields the greatest volume for a given weight [13]. PP has a hydrophobic characteristic which will not absorb water in the fibre and the dimensions of PP fibre do not alter with the changing humidity or when they are wet. With high surface area and naturally oleophilic, PP fibres is an ideal absorbent candidate in combating oil spillage incidents [14], [15]. PP is ecological friendly because it is recyclable and does not pose any threats to the environment. Polypropylene can also be used in absorbing oil and be reused up to a hundred times [16]. Therefore, the objectives of this study are to determine the sorbent capacity of waste tyre granulates, PP fibre, and its composite (combination of waste tyre and pp fibre) in absorb diesel oil and used engine oil. Besides that, the study also will also focus on the durability of the materials.

2. Materials
The waste tyre granulates was prepared by weighting 100 g of waste motorcycle tyre from local shop and ground to size 2 mm by using grinder. Two 8 cm x 8 cm size mesh bags were prepared by insert 20 g of waste tyre granulates in each mesh bag. Fine mesh bags were used in order to allow all the oil passes through the bagged materials. The two mesh bags were submerged in two different types of oil diesel and engine-oil separately to simulate the oil spillage. These types of oil were chosen since it’s the common end products of crude oil.

For the PP fibre, it was cut into 1.2 cm length in order to make it easier to be fitted into a fine mesh bag. The same size of mesh bags was prepared by packaging 5 g of PP fibre in each bag. While the composite material sorbent was prepared by mixing both waste tyres granulates and PP fibre together with a specific among. A pastry rolling pin was used to press the saturated mesh bags after the sorbent test stage in order to recover all the oils from the bags and to enable the bags to be reused for the next tests.

3. Methods
There were three test run in this study which is sorbent capacity tests, re-usability test and optimum composite material.

3.1. Sorbent capacity tests.
Each sorbent bag was weight first using an electronic weight balance before submerged into 250 ml of beakers containing 100 ml of diesel oil or used engine oil. The sorbent bags were submerged until all
the sorbent bag surfaces fully in contact with the oils. After one minute, the mesh bag was taken out from the oil and hung in the air for 40 seconds in order to remove excess oil. The final weight of sorbent bags was then determined. The practical sorption was calculated by the initial weight minus the final sorbent bag after the sorption tests and divide back with the initial weight of the sorbent.

3.2. Re-usability tests
The unsaturated sorbent was weighted to determine the initial weight and been re-submerged into the beaker containing the respective oils. The practical sorption was calculated as before. The steps were repeated for another 23 times to determine its absorption capacity before the results were recorded and tabulated.

3.3. Optimum composite material
The composite material sorbent was prepared by mixing both waste tyres granulates and PP fibre before pack into the mesh bags. Firstly, 20 g of the waste tyre granulates was packed together with 1 g of PP fibres. The new composite material sorbent then underwent the sorbent capacity tests to determine its practical sorption amount. Few sorbent bags were prepared by using the same amount of waste tyre granulates with increased amount of the PP fibres by increment of 0.5 g. The maximum value of practical sorption indicates that the composition of the sorbent was ideal to be referred to as the new optimum weight of composite material. The composite material sorbent then underwent the sorbent capacity tests and re-usability tests.

4. Result and discussion

4.1. Oil sorption for waste tyre granulates
Figure 1 shows the diesel oil and used engine oil sorption per gram of waste tyre granulates. The initial diesel oil sorption shows 1.36 g per g of waste tyre granulates which also indicate its maximum practical sorption for diesel oil. As stated earlier, waste tyre in the form of granulates with size of 2 mm were used instead of using it in bulk form. This indicate that smaller absorbent size, higher the absorption ability. In average, oil sorption for diesel oil was recorded at 1.11 g per g of waste tyre granulates. Meanwhile, result of the initial used engine oil sorption was recorded at 1.39 g per g of waste tyre granulates. After the first use of the sorbent, the practical sorption has decreased. Unlike diesel oil, the used engine oil has higher viscosity and makes it easier for the sorbent to adsorb used engine oil than diesel oil [10]. Therefore, the average practical sorption for used engine oil was slightly higher compared to diesel oil as figure 1 show.
4.2. **Oil sorption for polypropylene (PP) fibre**

From figure 2, the initial diesel oil sorption was recorded at 3.04 g per g of PP fibre which also indicated the maximum practical sorption for diesel oil. Although PP fibres has rapid oil sorption rate and a large sorption capacity, it lacked of elasticity, resulting in rapid decrease of oil sorption after the first use [14]. For the second tests onwards, the oil sorption remained at only 50% of the initial sorption capacity. In average, oil sorption was recorded at 1.52 g per g of PP fibre.

![Figure 2. Practical sorption for PP fibre.](image)

On the other hand, the initial sorption capacity for used engine oil was recorded at 3.90 g per g of PP fibre but decreased rapidly after the first test. From then on, the oil sorption remained at only 55% of the initial sorption capacity. Due to used engine oil was more viscous than diesel oil, the average practical sorption for used engine oil was slightly higher compared to diesel oil.

4.3. **Optimum weight of composite material**

![Figure 3. Practical sorption for composite of waste tyre granulates and PP fibre.](image)

For the first mesh bag, 20 g of waste tyre granulates were added with 1 g of PP fibre. As show figure 3, the practical sorption of the composite material for this mesh bag when used in diesel oil was at 1.56. As the weight of the PP fibre increased 0.5 g incrementally, the composite practical sorption was also increased. However, as the weight of PP fibre is beyond 3.0 g, the practical sorption of the composite material has started to decrease. Therefore, it can be said that, the optimum weight of PP fibre to be mix with waste tyre granulates and used for diesel oil sorption was observed to be at 3.0 g.
This amount was selected to prepare the composite material for all subsequent diesel oil sorption studies.

For used engine oil, as the weight of the PP fibre increases, the composite practical sorption also increased. However, as the weight of PP fibre is beyond 3.5 g, the practical sorption of the composite material remained at 1.84. The optimum weight of PP fibre was observed to be at 3.5 g to be mix with 20 g of waste tyre granulates. This ratio was chosen to prepare the composite material for all subsequent used engine oil sorption studies.

4.4. Comparison of sorbent capability for different material

Based on figure 4, it shows that the sorption for composite material is 1.56 and 2.04 for diesel and used engine oil respectively. On the other hand, result show that the oil sorption capacity has reduced significantly after the first use. This might be due to the PP fibre has lacked elasticity, resulting in a rapid decrease of oil sorption after the first used. For the second tests onwards, the oil sorption remained at only 82% of the initial sorption capacity with an average of 1.28 g per g of composite material.

Same with the engine oil sorption the sorption capacity decreased rapidly after the first test but remained at only 73% from the initial sorption capacity. This was due to used engine oil is more viscous than diesel oil and the average practical sorption for used engine oil was slightly higher compared to diesel oil.

5. Conclusion

From the results obtained, it shows that both waste tyre granulates, and PP fibre have different sorbent capacity but PP fibre had more sorbent capacity as compare to waste tyre granulates. Although PP fibre have higher initial sorbent capacity, it can sustain for the first used only and not recommend to be reused because lack of elasticity ability. On the other hand, waste tyre granulates have good elasticity to maintain its practical sorption quality without a significant reduction after 25 times of reuse. Although the practical sorption was high for PP fibre, lack of elasticity causing the oil practical sorption to rapidly decrease to about 50% for diesel oil and 55% for used engine oil from its initial capacity.

Combination of waste tyre granulates and PP fibre as new composite material had improved the elasticity of the material as compare using PP fibre alone where it was able to maintain its practical sorption without any significant reduction after 25 times of reuse. Hence, the composite material holds advantageous with better oil sorption and better add-on values.
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