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Adsorption Study of Bio-Degradable Natural Sorbents for Remediation of Water from Crude Oil

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Abstract. Remediation of oil polluted water was studied using two bio-degradable organic natural sorbents. These natural sorbents were flower of Arabic herbs Massofa and Youda. Short period static sorption process was performed in this work. Many parameters such as rate of sorption, sorption capacity, oil retention, water and oil uptake, and reusability were studied. Using different amount of sorbents, the average oil sorption capacity for Youda was 6.281 g of oil absorbed/g of sorbent whereas for Masoofa it was 5.415 g of oil absorbed/g of sorbent. The performance of these biodegradable sorbents was compared with other biomass sorbent materials available in the literature. It was found that Massofa and Youda were promising materials for removing oil spill from the surface of water.

Keywords: Crude oil spill, seawater, sorbent material.

1. Introduction

Every year approximate 5 million tons of petroleum oil is shipped across the oceans in shipping containers which places the marine life and the ecosystem in high risk. Oil spills can also impact marine fishes and birds and plantation. In 2010 the BP Deep Horizon rig was lit in flames leading to the death of 11 workers and released approximately 5 million barrels of oil into the Gulf of Mexico. The oil spills lasted for three months and lead to the death of a huge population of marine animals and polluted 320 km of shorelines. Many authors try to use an efficient and economical way of remediation from availably local materials. The removal of crude oil from contaminated water using powdered and granular activated carbon was investigated [1]. The removal of oil after 8 days with the addition of salt reached 99.9% and they recommended using powder activated carbon for oil spill removal. Walnut shell media was used as sorption material for oil spill [2]. The sorption capacity is equal to 0.56 g/g of mineral oil in aqueous medium and 0.30 g/g in pure mineral oil. Other work was performed using powdered activated carbon by treating coconut fiber with ammonium chloride and then carbonized at 400^{o}C [3]. The activated carbon was characterized in terms of pH, surface area, loss on ignition, moisture content and bulk density. The removal of diesel and kerosene from aqueous solutions measured by changes in the chemical oxygen demand shows that removal efficiency was less than 45% corresponding to about 6.8 mg / l / g decreases in (COD). The removal of diesel and kerosene from aqueous solution followed a pseudo first order rate equation. Thermally carbonized raw pith bagasse was used to study the sorption efficiency of oil. It was found that the sorption capacity and porosity of activated carbon depends largely on carbonization conditions, morphology and physical state of precursor, i.e. pith bagasse [4], [5]. Thermal carbonization reduces the water pick up from 12.13 g water/g fiber to 0.62 g water/g carbonized fiber. Barley straw was also used from same authors as oil sorbent [6]. Oil sorption is dependent on the type of oil; the carbonized barley straw in pad form with best conditions was tested for several factors to obtain the highest sorption capacity comparing with raw barley straw. Sorption

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properties and adequate reusability, indicating that a material based on natural fibers could be a variable alternative to commercially available synthetic materials that have poor biodegradability. Sorption capacity of carbonized fibers for different kind of oils was studied. Fibers extracted from bagasse and carbonized at 300°C for 2 hr were found to have a high performance for sorption, recovery and recycling of heavy oils, even the viscous ones. Sorption capacity showed strong dependence on the weight of sorbent and oil film thickness. Different forms of date palm kernels powder were used for remediation of oil polluted water. The carbonized date palm kernel powder activated with $ZnCl_2$ was found to be the best oil performance for oil spill treatment. He found that the oil sorption capacity was equal to 4.48 g/g [7].

The objective of current work was to develop new available locally sorbents material such as Youda and Massofa for water remediation process from oil contamination.

2. Material and Experimental Work

2.1. Materials

Crude oil from local resource was used as contaminant for water. The main physical properties of crude oil were summarized in Table 1. All the tests were performed according to ASTM standards.

Table 1: Characteristic of investigated oils

Properties	ASTM Method	Crude oil
Specific gravity@15.6 °C	ASTM D 1298	0.80846
API gravity	ASTM D 1298	43.52
Viscosity @40 °C, cst		5.749
Water content, vol. %	ASTM D 95	0.0625
Water and sediment, vol%	ASTM D 4007	0.0625
Carbon residue, wt%	ASTM D 189	0.453
Ash content, wt%	ASTM D 582	0.0558
Asphaltene content, wt%	ASTM D 3279	0.274
Salt content, ppm	ASTM D 3230	80 ppm
Sulfur content, wt%	ASTM D 4294	1.01

Two different sorbents were used. Youda also known as Eliedh is a herb. Masoofa is a plant with a wool-like appearance (Fig. 1). They are usually boiled with water before being served [8]. They just dried prior using for treatment.


(A)


(B)

Fig. 1: A) Youda and (B) Masoofa sorbents for oil spill

2.2. Remediation of Oil Polluted Water Work

The evaluation of water uptake and buoyancy of sorbent, tests in static condition were based on the method described in [9].

Water uptake and buoyancy of sorbent tests in static condition were performed. In static condition, the sorbent was placed in a beaker filled with approximately 7.5 cm deep layer of de-ionized water. After 15 minutes and 24 hrs, observations were done and the sorbent was removed from water, any sorbent, which did not remain floating on the water was considered to fail the test. The sorbents were passing the test.

The water uptake (C_{H2O}, in gg^{-1}) after 30 seconds of drainage was determined according to:

$$cH2O = \frac{mwt - mo}{mo} \quad (1)$$

where
m_{wt} mass of the wet material after 30 seconds of drainage (g)
m_o initial mass of the material (g).

0.5 -5 grams of dry sorbent was added and shacked using laboratory shaker at a frequency of 110 cycle's min^{-1} for 30 sec. The medium term static sorption tests were achieved using a contact time of 1 hour. The wet oil sorbent was removed, let to drain for 30 seconds and weighed. The amount of adsorbed oil (oil sorption capacity C, in g oil g^{-1} of sorbent mass) was calculated according to:

$$c = \frac{mf-(mo+mw)}{mo} \quad (2)$$

where
m*f* mass of the wet oil material after draining (g)
m*o initial* mass of dry material (g)
m*w* water content in the material (g).

Water content was determined by centrifuge after adding heptane as solvent for several times and squeezing the sorbent to remove all the oil and water from it, in accordance to ASTM D 4007 method for 5 minutes using Seta Oil test centrifuge. The oil sorption capacity of sorbent in only oil was measured; 1.00 g of material was placed on top of 150 ml of oil in a glass beaker. As in the previous procedure, after 15 min of sorption under shaking, the oil was drained for 30 seconds and the material was weighed. The amount of oil adsorbed is determined according to Eq. 1 and (mw) is equal to zero.

3. Results and Discussion

The water and oil uptake was measured for both sorbents. It was found that the water uptake was very low (Fig. 2) which represents a positive point of choosing these sorbents.

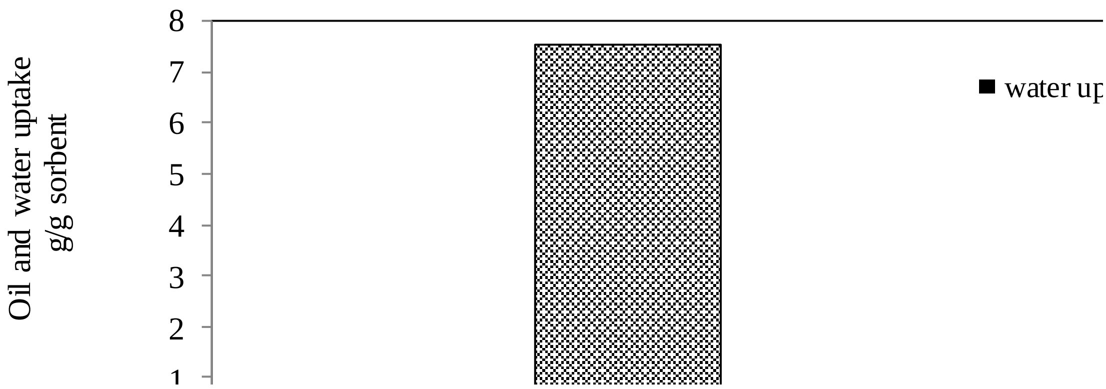

Fig. 2: The water and oil uptake for masoofa and Youda

The amount of oil sorption was increased with the amount of sorbent as shown in Fig. 3. The oil sorption capacity was measured with different amount of sorbents in g oil adsorbed per g of sorbent used for the test. This is shown in Fig. 4.

From this graph, the average oil sorption capacity of Youda is equal to 6.281 gram of oil per gram of sorbent and for Masoofa is 5.415 gram of oil per gram of sorbent. The oil retention value of these sorbents was also measured. This value represents who long the sorbent can keep oil with losing the adsorbed oil. The retention time measurements showed that after 5 minutes drainage, the amount of oil that can be kept inside Youda was 4.71 g oil /g sorbent and for Masoofa were 2.55 g oil /g sorbent. These amounts represent 74.99% of the oil drained after 30 seconds while that for Masoofa represent 47.1%. This means that Youda can keep the oil for long time. This value was approximately true after 10 minutes of oil draining (Fig. 5).

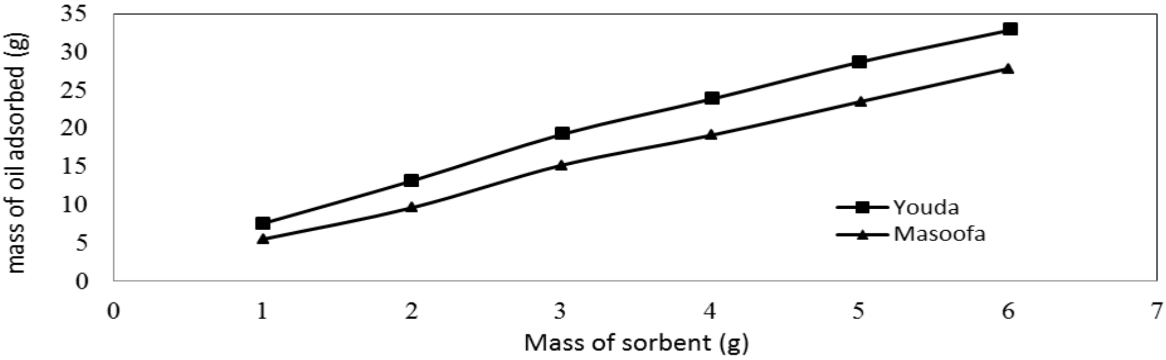

Fig. 3: Mass of oil with amount of masoofa and Youda sorbents

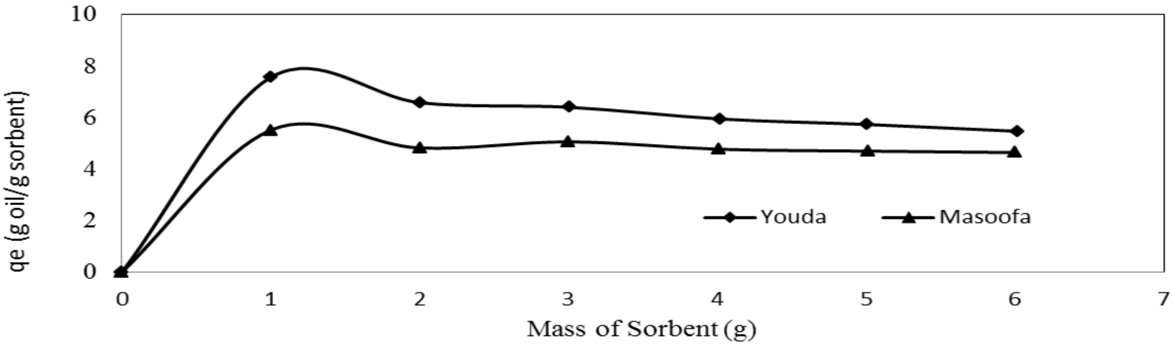

Fig. 4: Oil sorption capacity of Masoofa and Youda using different amount of sorbents

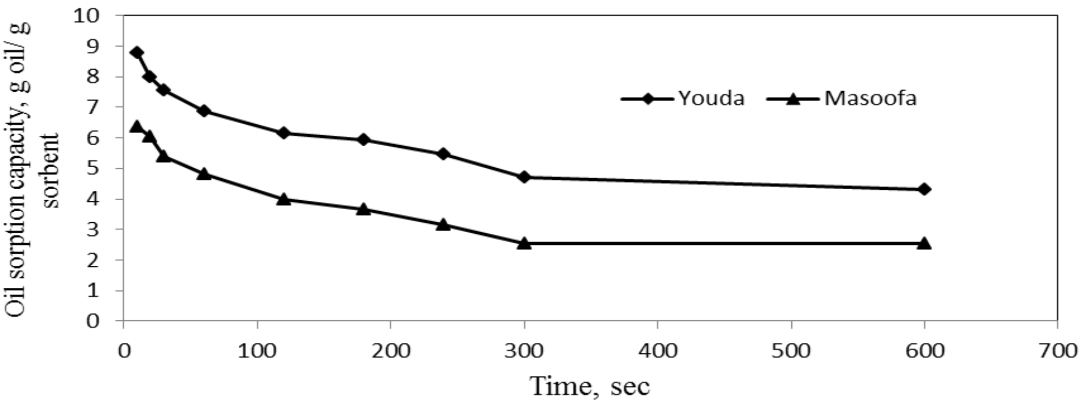

Fig. 5: Oil retention for Masoofa and Youda sorbents

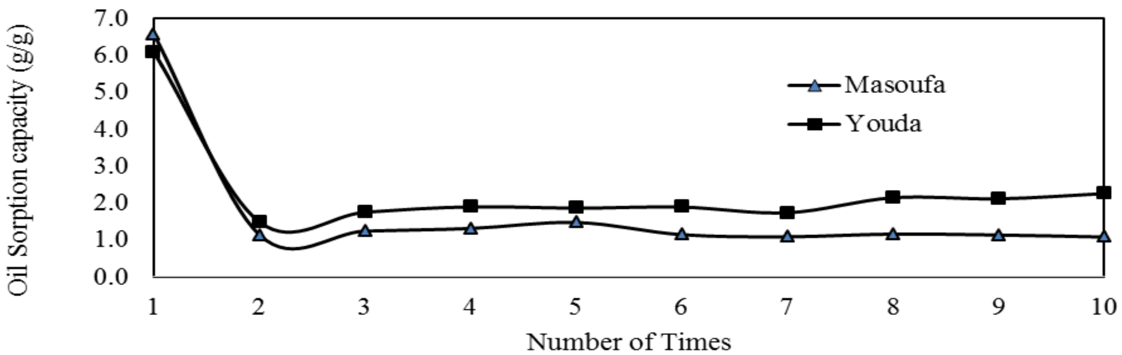

Fig. 6: Reusability of sorbents

The reusability of sorbents was studied for ten times as shown in Fig. 6. The performance of these sorbents was decreased sharply after the first use. This result was believed to be ordinary for natural materials.

3.1. Comparison of This Job with Others

The oil sorption of various fibers at different granulometry ranges is shown in Table 2.

Table 2: sorption capacity of different natural materials [10]

Fiber	>3.35 mm (g/g sorbent)	0.85-1.7 mm (g/g sorbent)
Sisal	3	6.4
Leaves Residue	1.4	2.7
Sawdust	4.1	6.4
Coir fiber	1.8	5.4
Sponge ground	1.9	4.6

The highest oil sorption capacity was achieved with Sisal and sawdust; it was equal to 6.4 g oil per gram of sorbent. The entire work results showed an oil sorption capacity of 6.281 gram of oil per gram of sorbent for Youda and 5.415 gram of oil per gram of sorbent for Masoofa which believed they are accepted values for natural materials.

4. Conclusion

Two locally available natural materials were used for remediation of water from oil spill. Youda and Masoofa were used and the oil sorption capacities were 6.281 gram of oil per gram of sorbent for Youda and 5.415 gram of oil per gram of sorbent for Masoofa which believed are quite accepted. The retention time which represents the amount of oil that the sorbent can keep the oil is quite good. More work is needed to discover more available materials for oil spill on the surface of water.

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