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Absorbents for oil spills clean-up: A short review

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ABSTRACT
Due to their environmental and economical Oil spills are becoming a global concern. Oil sorbents are one of the most used methods for remediation processes of oil spills. This short review investigates the use of various sorbents for oil spill clean-up. the absorbents represent: natural sorbents, mineral sorbent, synthetic sorbent, commercial sorbent. The absorption capacities, absorption capacity, absorption rate, Buoyancy measurements, and water absorption of the above materials were evaluated. Natural sorbents have high oil absorption capacity, and high absorption rates, their results exceed those of the commercial sorbent. synthetic sorbents showed promising results specially with heavy oil. It is recommended to investigating the recyclability of the different types of sorbents

Keywords – Absorbents, Natural sorbents ,Oil spills.

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I. INTRODUCTION

Oil spills are known as a release of liquid petroleum or one of its components (like diesel) due to human activities into the environment, especially the marine environment, based on this definition oil spills are considered as environmental disasters.

The human activities that cause oil spills are categorized into three sources: oil extraction, oil transportation and oil consumption. It is estimated that more than 7 million tonnes of oil have been spilled into the environment between 1907 and 2014 due to of 140 major oil spills [1]. The latest major oil spill in the world is the deep water horizon, which took a place in the Gulf of Mexico in 2010, when over 4.9 million barrels of oil leaked into the water [2] , affecting 180,000 km2 of ocean [3], the spill happened as result of an explosion on one of the oil rigs extracting oil in the gulf water, the incident killed 17 workers and injured 17 [4].

In 1989 an oil tanker sailing near the coast in Alaska slammed a Bligh reef, realising 41,639 m3 of oil [1], in middle east the worst oil spill was gulf war oil spill in 1991, when 4-6 million barrel of oil spilled into the Arabian gulf [5].

Economic impact of oil spills includes economical losses, environmental damages, clean-up costs, research costs, and some other costs, for example Deep water horizon oil spill affected 5.5 billion-dollar industries, and 200 thousand jobs [6]. Oil spills harms the environment either directly or due to clean up processes…..petroleum, and spilled oil are poisonous which cause the death of living species, oil also reduces the birds and mammal's ability to control and maintain their body temperatures [7]. In Exxon Valdes disaster 250,000 birds were killed, and another 23,400 seabirds in deep water horizon incident [6]. Oil spills cause stress and psychological problems for the residents of the affected area, 40% of Gulf of Mexico residents reported health and psychological problems after the deep horizon accident [8]. Cleaning of oil spills is difficult, and it depends on many factors, such as type of spilled oil, weather condition and water temperature, and type of shorelines and its soil [4].

There are many methods in practice for cleaning of oil spills including; bioremediation using microorganisms [9], in-site controlled burning, mechanical methods (like using skimmers...etc.), chemical dispersants, and absorbents (either natural or synthetic products) [4]. The above-mentioned factors should be taken into account when choosing the appropriate method for clean-up, usually in practice two or more methods are combined to achieve effective results [10]. Each of these methods have their advantages and disadvantages, in site burning has safety concern and cause air pollution [4], while bioremediation is limited to small floating masses of oil [4], mechanical methods are costly and requires a lot of equipment and personnel [11], chemical dispersants is effective in use for large areas, however they are harmful to the environment, and have limited effect on thick viscous oil. This review paper discusses absorbents in detail in the coming sections.

Absorbents for oil spill clean-up.

Oil sorbents are oleophilic and hydrophobic materials, that means that they can adsorb (or absorb) oil and rebel water [4], oil sorbents are divided into two types depending on how they act [12], absorbents and adsorbents; the latter incorporates oil into the body of the material by diffusion [12], while absorbents attracts oil to its surface by a number of mechanisms like:

1- Wetting properties because of surface tension.
2- Capillary action.
3- Cohesion/adhesion.
4- Surface area. [12]

About 200 different sorbent materials are used for oil spill removal [13]¬¬, this review paper focuses on absorbents as they are the most commonly used type of sorbents to clean oil spills.

There are three main types of absorbents; organic synthetic which are the most commonly used [14], mineral inorganic, and natural organic materials [4].

Absorbents are spread over the oil slick and allowed to sorb the oil, then the absorbents are collected, and disposed or in some types squeezed and recycled into use [6], efficiency of them depends on their: density, adsorption capacity and rate, and among other factors their recyclability. [4]

Mineral inorganic absorbents such as zeolite, graphite, silica, and treated clay [12] are not commonly used because they are expensive, highly dense, non-bio-degradable, and cause harm to the marine environment [4].

Polyurethane and polypropylene synthetic absorbents have high adsorption capacity because they are easily recyclable, their capacity can reach up to 220 gram of oil per gram of sorbent over 100 cycles [4], these sorbents are available under different marketing names. Unfortunately, they are not bio- degradable, and expensive when compared to natural organic sorbents.

Organic agricultural sorbents are abundant, cheap, environment friendly, and some of them have high oil capacity (sometimes higher than those of synthetic sorbents) and have a low density which make them buoyant over water surface.

On other hand, natural sorbents have limited recyclability, and they require a lot of manpower.

The papers to be studied cover the different types of absorbents, with at least one absorbent of each type, cotton grass [14], treated peat moss [13], and silk floss [15] are representing natural sorbents, treated calcium aluminium silicate sludge as mineral sorbent[16], and exfoliated graphite as synthetic sorbent[17], compared to commercial polypropylene sorbent [14].

II. MATERIALS AND METHODS

Procedures for preparing oil samples and sorbent samples was different between the papers. Weighted amount of oil was added to 100 ml of water [14] [13], or 80 ml of water [15], in case of the heavy oil and because of its high viscosity oil was added to 450 ml of water contained within a hot bath [17]. 0.6 gram of oil was added to 750 ml of water in order to test sludge absorptivity [16]. Properties for the different oils used are mentioned in table 1.

Natural sorbents except silk floss was compressed into mats while heating [14][15][13]. The sludge used in the experiment was collected dried, and then grounded to 63 micrometre or less [16], exfoliated graphite was commercially available in two forms EG-1 and EG-2 [17]. Table 2 shows the density for the sorbents in review.

The investigated parameters to measure the effectiveness of oil sorbent includes: absorption rate, absorption capacity, buoyancy, and water absorption.

Table no 1: Specifications of oil used in the experiments

Oil Type	Density (kg/m^3)	Viscosity
Petrol (Exxon Mobil 95 ER) [14]	0.75	-
Diesel oil (ExxonMobil winter grade, DITC-34) [14]	0.84	2.0 cSt (40 °C)
Crude heavy oil off shore wells of rio de Janeiro-Brazil [15]	0.9	34 cp (20 °C)
Gulf Suez mixture crude oil [16]	0.8544	31 cp (37.8 °C)
Grade [17]	0.864	0.4 kg/ms
Grade [17]	0.89	0.27 kg/ms
Grade [17]	0.949	0.35 kg/ms

Table no 2: Densities of the sorbents.

Sorbent	Density (kg/m^3)
Cotton Grass	10-42 [14]
Treated Carbonized peat moss	-
Silk Floss	< 0.620 [15]
Treated calcium aluminium silicate sludge	0.718 [16]
Exfoliated graphite (Grade A oil and crude oil)	6 [17]

Absorption Capacity and absorption rate

The tests for measuring adsorption capacity and rate has been done by putting some sorbent on the mesh steel, and making contact with oil on the surface of the water while the scale take the weight recording every second, after one hour the sorbent material was removed and weighted to measure how much oil was absorbed [14]. Another method relayed on distributing the sorbent on the surface of oil, and keeping it for 6-96 hours, after that the sorbent is dewatered and carbon tetrachloride was used to extract oil from the sorbent and measure absorption rate using gravimetric method [13].

Silk floss has been tested by adding 0.1 gram to the prepared oil-water beaker, after 2, 20, 40, 60, and 1440 min the material has been removed, filtered, and weighted, sorption capacity was calculated by using the equation:

sorption capacity= (total mass of sorbed sample - mass of sorbent)/mass of sorbent, the rate has been calculated depending on these measurements at different times [15].

In heavy oil sorption, oil will float on the surface of the water after mixing, then exfoliated graphite is added, then the colour of heavy oil will disappear, by increasing the ration of graphite/oil, maximum sorption could be calculated [17], meanwhile time of sorption was recorded to calculate rate [17].

For testing sludge absorption capacity, a known weight of sludge has been added to the oil beaker surface, and then removed manually after specified time, the remaining beaker content has been weighted to determine uptake efficiency [16].

Buoyancy measurements

All of the sorbents tested are buoyant on water surface all the time because of their low density except peat moss [13], and sludge, so tests were conducted to measure their buoyancy.

For peat moss, 0.1 -5 g sample were added to 100 ml pure water beaker, and then weight was taken every 12 hours (up to 36 hours) until the sample sunk into water. Sludge has lower density compared to water, so it floats, but after a long retention time of sorption [13], some of it tends to sunk, so using it with saline water (like sea water) increases its buoyancy, hence increases its uptake capacity [16].

Water absorption

The dry test has been used to measure water absorption, where sorbent was added to oil without water, and oil absorption was measured and then subtracted from oil absorption capacity to get water up-take rate [14] [15].

Another way to calculate water absorption deepens on extracting oil from the sorbent and then using the following equation [13]:

$$W = (M1 - M)/ M * 100\% \quad \ldots\ldots(1)$$

where W is water absorption percentage;
M1 is a weight of the sample taken out from water, in g;
M is a weight of the sample prior to be put into water, in grams

III. RESULTS AND DISCUSSION

Maximum absorption capacity results for tested sorbents are showed in table 3. Graph 1 shows up-take rate for the different sorbents, it is noticed that graphite and silk floss reach their maximum oil absorption in very short time, cotton grass takes a longer time to reach its maximum capacity.

Table no 3 : Maximum Absorption capacity for sorbents.

Sorbent	Maximum absorption capacity (g oil/g sorbent)
Cotton Grass	12 [14]
Treated Carbonized peat moss	14.2-15.7 [13]
Silk Floss	84.9 [15]
Treated calcium aluminium silicate sludge	2.6 [16]
Exfoliated graphite (Grade A oil and crude oil)	86 [17]
Commercial polypropylene	5.5 [14]

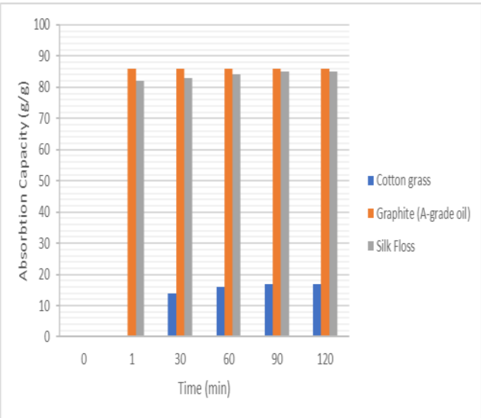

Figure no 1: Sorption rate for number of the tested sorbents

Buoyancy results shows that all of the tested materials are buoyant over water surface even after reaching their maximum absorption, except treated peat moss which 1.77% of it sediment after 96 hours, and 56.4% sediment after 170 hours [13]. Water absorption results are showed it table 4, which indicates that all of these sorbents have low water up-take rate relative to its oil absorption capacity.

Table no 4: Maximum Absorption capacity for sorbents.

Sorbent	Water Absorption (g of water/g of sorbent)
Cotton Grass	Almost Zero [14]
Treated Carbonized peat moss	1.3-1.5 [13]
Silk Floss	2.2-5 [15]
Treated calcium aluminium silicate sludge	-
Exfoliated graphite (Grade A oil and crude oil)	Almost Zero [17]

IV. CONCLUSION

Cotton grass and silk floss showed excellent results they have high oil absorption capacity, and high absorption rates, their results exceed those of the commercial polypropylene sorbent, also they have low water up-take capacity, but their low density make them hard to storage.

Peat moss is an excellent sorbent, however it is main disadvantage is that it does not float over water surfaces all the time, the issue makes it hard to use in oceans cleaning. Treated calcium aluminium silicate sludge have lower oil capacity compared to commercial sorbents, it also requires a lot of processing before it could be used as sorbent, and because of it mineral nature it could cause harm to the environment. Exfoliated graphite showed excellent results when used with heavy oils, and it has the advantage that it could be recycled easily and used again, but it is fragile and low dense [17].

As exfoliated graphite showed the most promising results, it is recommended to further investigate it, and to study more carbon-based materials especially the ones which come from natural fibrous materials, like trees.

Another recommendation would be investigating the recyclability of treated exfoliated graphite so it can be used for many times, in addition to that solving its fragility issue by different methods could be further studied. One of the main factors that affected graphite performance it is porosity (it is surface area), treating it thermally or chemically could result in increasing its performance. The test could be done using saline water from sea or ocean; to achieve better simulation of sea conditions.

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