Oil Spillage Treatment Using Sorbent

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ABSTRACT:

Oil sorbents contains a wide range of organic, inorganic and synthetic products designed to remove oil in preference to water. The composition and configuration of oil sorbent are based on the material used and their intended application in the response. Synthetic sorbent material should be used in self-restraint and care should be taken to ensure that it is used to its maximum capacity to minimize subsequent waste disposal problems. Sorbents are used most effectively during the final stages of shoreline clean-up and for recovering small pools of oil that cannot be easily recovered using other clean-up techniques. Although some sorbents have been specifically made for viscous oils. For sustainable environmental disposal of used sorbents is major issue. This paper, reviews method of oil spill cleanup, factors affecting the oil spill cleanup, sorbent material and its forms, properties of oil sorbent, criteria for selecting sorbents. The need for extensive study of improving and developing viable natural absorbents in recent years is increasing due to the enormous negative environmental impact of oil spill to the surroundings and the inhabitants. Therefore proposes eco-friendly materials such as Sugarcane bagasse, sugar leaves straw, phragmitesaustralis, straw fibers, palm fruit wastes as promising oil absorbent materials. Sugarcane bagasse has been the most widely available and probably the most efficient of all these materials. Sugarcane bagasse can float on the water surface for a very long period of time to collect oil adequately. It has been found that Sugarcane bagasse sorption capacity is higher than phragmitesaustralis sorbent, sugar leaves straw.

Keyword:-

Sorbent, phragmitesaustralis, Sugarcane bagasse, sugar leaves straw.

1. INTRODUCTION:

India is developing country to become developed country we need enormous amount of energy resources. Oil is one of the important sources of energy in modern industrial world. It has to be transported from the source of production to many places across the globe through oceans and inland transport. During transportation there is a chance of oil spillage over the water body can arise from a number of different sources ranging from oil loading, unloading or pipeline operation, and from a collision or grounding of vessels carrying oil in local ports or coastal waters. They can also emerge from tankers or barges operating on inland waterways, or from exploration and production operation and tankers operating in international waters and these cause environmental pollution. Planning for an oil spill emergency helps in minimized potential danger to human health and the environment by ensuring a timely and coordinated response.

2. METHODS:

2.1. Mechanical:

Primarily use mechanical methods to remove oil spills. There are the three categories of mechanical tools used for recovery spilled oil.

a) Booms:-

It is easier to clean-up oil if it is all in one spot, so equipment called containment booms act like a barrier to keep the oil from spreading or floating away. Booms float on the surface and it consist of three parts: a 'freeboard' or part that rises above the water surface and contains the oil and prevents it from splashing over the top a 'skirt' that rides below the surface and prevents the oil from being pushed under the booms and escaping and some kind of cable or chain that connects, strengthens, and stabilizes the boom.

b) Skimmers:-

Skimmers are machines that take ups oil from surface like a vacuum cleancer.Physically separate the oil from the water so that it spills over a dam into a tank. The recovered oil has to be stored somewhere though so storage tanks or barrels have to be brought to the spill to hold the collected oil. Skimmers get blocked easily and don't work efficiently on large oil spills or when the water is highly viscous.

c) Sorbents-

These are materials which removes liquids by either absorption or adsorption. Oil will coat some materials by adsorption. This property makes removing the oil from the watersurface easier. Absorbent materials, very much like paper towels, are used to soak up oil from the water surface.

2.2. Chemical:

A chemical such as detergent breaks floating oil into small particles or drops so that the oil is no longer in a layer on the water's surface. These chemicals break a layer of oil into small droplets. These small droplets of oil then disperse or mix with the water. The use of dispersants often harms aquatic life and the dispersed oil remains in the body of water where it is toxic to aquatic life.

2.3. Physical:

Burning-

Burning of oil can actually remove up to 98% of an oil spill. The spill must be a minimum of 3mm thick and it must be relatively fresh for this method to work. Disadvantage of this method is that heavy air pollution. Therefore it is not used for oil spill cleanup.

2.4. Biological:

Bio remediation-

There are bacteria and fungi that naturally break down oil. This process takes large time to recover oil. it would take years for oil to be removed by microorganisms. Addition of either fertilizer or microorganisms to the water where the spill is located can speed up the breakdown process. Fertilizer can be added to the oil spill area to increase growth rate of microorganism. Addition of microorganisms increases the population that is available to degrade the oil. A drawback of adding fertilizers is that it also increases the growth of algae. When the large numbers of algae die they use up much of the oxygen so that there isn't enough oxygen in the water for animals like fish.

3. Mechanism Used For Oil Spillage:

Oil is removed by sorbent materials in two modes or mechanisms. These are: (i) adsorption and (ii) absorption. Adsorption involves the adherence of the oil to the sorbent material. The removal of oil is dependent on the viscosity of the oil. The more viscous the oil, the thicker the layer that will stick to a given material. On the other hand, absorption depend on capillary attraction; oil fills the pores within the material and goes upward into the material due to capillary force. The rate of penetration (P) is directly proportional to the radius of the capillaries (r) and inversely proportional to the viscosity of the oil.

$$P \alpha\ d/2\mu \qquad (1)$$

$$P = Kd/2\mu \qquad (2)$$

Where P = rate of penetration of oil, K = surface boundary, d = diameter of capillaries, μ = viscosity. However, Darcy's law shows flow rate phenomenon in porous materials as given in

$$u = -k/\ \mu\Delta P \qquad (3)$$

Where u is the average velocity; K the permeability of the porous materials, μ viscosity and ΔP the pressure gradient. Sorbents are materials with high affinities for oil and repellent for water.

4. SORBENT MATERIALS AND FORMS:

4.1. NATURAL ORGANIC MATERIAL:

Natural or agricultural products are widely distributed and largely used in most parts of the world for oil spill cleanup. The materials include, straw, sawdust, reeds, peat, sugar cane bagasse, dried palm fronds, etc. Most of these materials are oleophilic because of their waxy nature, they become light weight when dried, which improves their buoyancy in water, and usually oil is trapped in the mat of crisscross strands or fiber rather than absorption by capillary force. Sugarcane bagasse have high capacity to float on water surface for long period to collect oil. It has been reported that sugarcane bagasse sorption capacity is higher than commercial synthetic organic material like propylene. Similarly kapok, rice husk, banana trunk fiber, acetylation of raw cotton, cotton grass fiber are also used as an efficient oil sorbent.

4.2. INORGANIC SORBENT:

These are small size-granules generally used to sink spilled oil on the water surface. These include organic ash, glass wool, vermiculite, clay, sand, perlite, activated carbon, etc. One of the more successful inorganic manufactured materials used in the past, though expensive was ekoperl. This material is in form of fine granule therefore can absorb light oil much more than oil with high viscosity.

4.3. SYNTHETIC MATERIAL:

The most widely and satisfactory sorbent materials are synthetic polymeric materials. The properties of these materials can be varied by altering their micro-pores. Foams of polyurethane, urea formaldehyde, polyethylene, nylon, polyester materials have been used. Some of these synthetic materials tend to absorb more water in preference to oil due to their large pores. However, polyethylene fiber roving are highly hydrophobic. Despite good hydrophobic and oleophilic nature of these materials their non-biodegradable nature is a great disadvantage.

5. CRITERIA FOR SELECTING SORBENT:

The criteria for selecting sorbent material are as follows

5.1. BUOYANCY:

Sorbent to be used should have high buoyancy so that it can float water surface even after saturated with oil and water. A number of natural organic materials such as straw, rise husk, wheat straw and sawdust have high buoyancy but eventually become waterlogged and sink to the bottom of water surface. Nevertheless buoyancy can in some cases be important to find out the effectiveness of a sorbent. For example light materials may float on top of viscous oils.

5.2. SATURATION:

Sorbent to be used cannot become saturated easily. Even a small slick may quickly submerge a sorbent boom and oil may be released from the sorbent to the oil spilled water resource that it was intended to protect. Saturated, sorbents cannot recover further oil from the water and should be removed as quickly as possible to avoid any subsequent drain. The level of saturation can be difficult to find out; it should require cutting the boom and opening it. Incomplete saturation is mainly observed with viscous oils where booms may be recovered and thrown mistakenly, leaving the inner layers unused. Such unnecessary wastage can be eliminated by using sorbent boom with a small diameter, reducing the volume of unused material in the center of the boom, while at the same time we have to maintain its effectiveness, or by using oil snares.

5.3. OIL RETENTION:

Sorbent material should have high oil retention capacity and it should not be release oil into water when we take out the sorbent from contaminated water. It one of the important criteria while selecting adsorbent material. Some materials rapidly adsorb oil but, unless retrieved in good time, the sorbent may subsequently release oil due to the effects of wind, waves and currents. Oil retention can be a particular problem when using sorbents with low inherent strength, in particular those constructed from organic materials. Snares can become quickly saturated with oil, primarily due to their large surface area. Nevertheless they may release oil when they are lifted from the water surface. The rate of release is directly proportional to the viscosity of the oil, with lighter, less viscous oils dripping off more rapidly.

5.4. STRENGTH AND DURABILITY:

Sorbent should have high strength and more durable so that we can use it be again and again. It is one of the important factor while choosing the sorbent material for oil sorption. Sorbent booms may start to degrade and fall apart within a matter of hours as a result of environmental effects, such as wave action or abrasion on rocks. The strength of some sorbent booms, particularly those composed of enclosed loose material, is dependent on the durability of the retaining netting material, which may break open in adverse environmental conditions. Once damaged, the contents of these booms will be easily lost and may become a secondary source of water pollution.

5.5. COST:

The cost of sorbent material should be low and it should be easily available in all over the world. Organic and inorganic materials are comparatively economical than synthetic or artificial products. However, this low unit cost will require a trade off to be made to take into the consideration while selecting the sorbent material. The additional costs of disposal of higher volumes of material should also be taken into account when selecting the most appropriate product.

6. Adsorption Experiments:

To determine the sorption capacity, the tests were conducted in a batch system according to the following standard procedures:

1. ASTM F 726-99 for sorption experiments (F 726-99);
2. ASTM D 1141-98 to produce saline water (D 1141-98).

Sorption experiments were carried out in dry and wet systems using phragmitesaustralis, sugarcane leaves straw, and sugarcane bagasse nevertheless, only sugarcane bagasse was used for removing oil from the oil layer system because it showed a higher oil sorption capacity as compared to the others in dry system. A dry system contained only crude oil while there were two phases of oil and water, in a way that the oil formed a layer on water in an oil layer system.For dry system 50ml of crude oil was filled into a 250ml beaker and then a specific amount of sorbent was added to a crude oil. These test were performed in static system without agitation. For crude oil layer sorption, 100ml artificial sea water was poured into 250ml beaker. Crude oil was added to the beaker to form an oil layer with the specified thickness. Then the sorbent was spread over the surface. After certain time sorbent was removed with net which was hanged over the beaker for 5min to allow the crude oil to drain into the beaker. Each experiments was performed twice and sorption capacity was calculated using following equation:

$$\text{Oil sorption capacity} = \frac{weight\ of\ adsorbed\ oil}{weight\ of\ sorbent} \quad (1)$$

Weight of adsorbed oil = weight of initial crude oil – weight of remained oil (2)

Weight of remained oil = weight of oil layer + weight of dissolved components (3)

7. Results:

The oil sorbed and retained inside porous media can be split into three parts including (1) the oil part retained by weak capillary forces which is released under gravitational forces during several minutes (ii) the oil part retained by capillary forces, which is not released under gravitational field, and (iii) the oil part retained by strong capillary forces and adsorptive forces which is not released under gravitational and centrifugal field. In the present work after oil sorption process sorbent was hanged over the beaker for at least 5 min so that the oil part retained by weak capillary forces was extracted. In this time, the decrease in the retention capacity is very noticeable. This can be explained by the fact that a part of liquid is weakly retained into macro pores by weak capillary forces and therefore is easily drained.

Figure 1 shows the effect of contact time on crude oil sorption in the dry system for three different sorbents of similar particle size. It shows that sugarcane bagasse has the maximum oil sorption capacity which is about 8 gm/gm. phragmitesaustralis has a medium average sorption capacity of 5.5gm/gm. The minimum oil sorption capacity belongs to sugar leaves straw which is about 4.5 gm/gm. Sugarcane bagasse has a higher oil capacity compared to the other sorbents due to its higher porosity and lower density. It also indicates that most of the oil is adsorbed at the early stage of the process and afterward, a small amount of oil will be adsorbed.

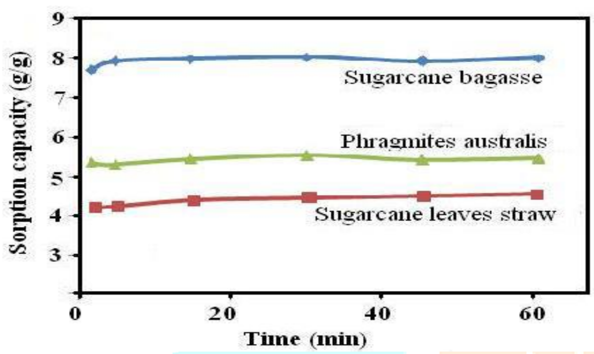


Figure 1 Effect of contact time on oil sorption in the dry system for the three sorbents

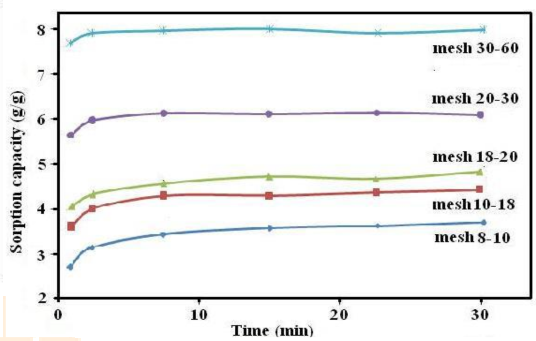
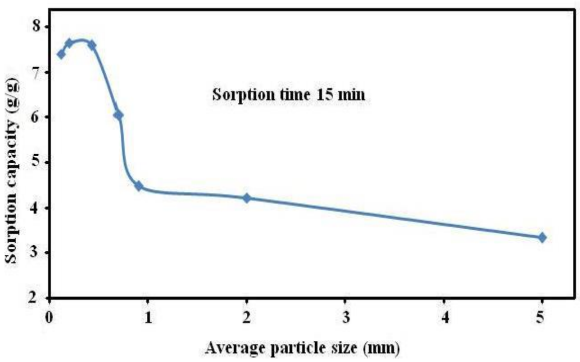


Figure 2 Effect of contact time and particle size on oil sorption by bagasse

Figure 2 indicates that the effect of sorption time on crude oil sorption capacity in the dry system for bagasse with different particle sizes.Figure 3 indicates that the sorption capacity of bagasse with different particle sizes increases with time. The time required to reach the maximum sorption capacity depends on the particle size. The time required for the maximum sorption is more for the large size particle. The smallest particle size (mesh 30-60) requires only less time, whereas it takes much longer for the largest particle size (mesh 8-10) to reach the maximum sorption. In large size particles the time of oil diffusion into particles becomes an important factor and it takes bagasse particles a more time to become saturated with oil however, this time is much shorter for small particles.

Figure 3 illustrates the effect of bagasse particle size on oil sorption capacity at a constant sorption time of 15 minutes. It shows that decreasing the average particle size increases the oil sorption capacity and the maximum is reached at an average particle size of 0.2 mm. when we decreases the average particle size which reduces the oil sorption capacity.



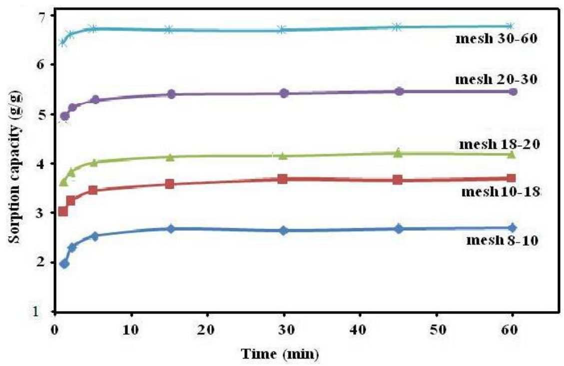


Figure 3 Effect of particle size on the oil Figure 4 Effects of particle size and sorption sorption at a sorption time of 15 minutes.timeon the oil sorption for a crude oil layer

A decrease in bagasse particle size has a higher effect on oil sorption capacity for smaller particles. This can beascribeto the fibrous form of the sorbent, which causes the particles with different fiber lengths and equal diameter to pass through the sieve. This results in the formation of heterogeneous and non-uniform particles in large sieves and the number of larger particles in the unit of mass is low due to higher bulk density therefore the interfacial area (area/volume) becomes smaller. The rise in oil sorption capacity by lowering the average particle size from 5 mm to 0.2 mm may be attributed to an increase in interfacial area. For particles smaller than 1 mm, the effect of decreasing size is higher because particles are more homogenous in this size range and the number of particles rises more considerably.

Figure 4 indicates that the effect of sorption time on oil sorption at different sorbent particle sizes for a crude oil layer on the surface of artificial sea water. Seven (7) grams of crude oil was added to 150 ml water to form an oil layer with an approximate thickness of 2.4 mm and then 1 gram sorbent was spread over the oil surface.

8. Conclusions:

The oil sorption capacity of phragmitesaustralis, sugarcane leaves straw, and sugarcane bagasse in the dry system was studied and sugarcane bagasse was then used in various particle sizes to remove a crude oil layer dispersed over artificial seawater. The following conclusions can be made from the above results obtained:

1- The maximum oil sorption capacity of phragmitesaustralis for the dry system was equal to 4.4gm/gm.

2- The maximum oil sorption capacity of sugarcane leaves straw for the dry system was 5.5 gm/gm.

3- The maximum oil sorption capacity of raw bagasse for the dry system was obtained to be 8 gm/gm.

4- The bagasse can be used effectively to remove crude oil in crude oil layer pollution from sea.

5- Particle size effect was also estimated and it was shown that the adsorption capacity improved with decreasing particle size due to increasing the surface area.

6- The maximum oil sorption capacity of raw bagasse for crude oil layer was equal to 6.6 gm/gm. optimal sorption time was observed at about 5 minutes.

It is evident that oil spill is harmful to the environment therefore, the need for cost-effective and environmental friendly sorbents for oil spill clean-up is imperative. Sugarcane bagasse have more sorbent capacity than phragmitesaustralis. but, these materials are not readily available to every part of the world. Therefore the use of Sugarcane bagasse, straw fiber,phragmitesaustralis, palm fruit fibers, raffia palm fiber, palm fruit wastes, kenaf as natural sorbent has been proposed for oil spill clean-up in the tropical region, especially because of their boundless abundance and Sugarcane bagasse is most efficient than above proposed sorbent.

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