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# Theoretical and experimental investigation on the removal of oil spill by selective sorbents

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ABSTRACT

In this research, oil sorption capacity of natural Peat moss and polymeric sorbents have been studied for the removal of oil spills from aquatic media. A maximum absorption capacity of 22 times its self-weight was observed for Nature sorb, in crude oil. The particle size equivalent of 100 mesh was found to have the maximum sorption capacity. Envirobond 403 provided the best oil retention capacity, with a minimum weight loss of 2.4 g/7 g of oil. Water contact angle for Nature sorb and Sphag sorb were found to be 104.33° and 73.29°, respectively. FTIR confirms physical encapsulation as the principle of absorption.


## Introduction

Water, is of utmost importance in our day-to-day lives and the motivation to preserve it is the need of the hour [1–3]. According to United Nations World Water Development Report, about 2 million tonnes of waste are discharged in the water bodies per day [4]. Also, recent studies show that around 1.5 million children die per year due to the poor quality of water [5]. It is seen that the flora and fauna dependent on the marine ecosystem also gets affected polluting the food web causing eutrophication [6,7]. The major causes for water pollution are domestic, industrial and agricultural activities and other global changes [8–10]. Also, population growth is one of the major factors as it led to industrial development and this in turn has prompted environmental pollution [11]. In the past few decades, numerous conventional methods have been proposed to resolve the contaminants present in the aquatic ecosystem [12]. As the international standards for environment protection has become more stringent, newer technologies have been developed for enhanced separation and purification [7,13,14].

Crude oil and its distillation products have a major impact on the living standards of human beings. However, the seas and coastlines are polluted as a result of anthropogenic activities, such as in the process of oil production, distribution, and utilization, including discharges during normal operations of tankers [15]. Petrochemical industries and textile are significant contributors too, contaminating the marine environment with production discharges [9,16–24]. Discharge from industrial washers is estimated to have 300–7000 mg/l of emulsified oil concentration and about 30,000 mg/l of free floating oil [25,26]. These discharges pose a risk of fire due to in situ combustion of oil and increase in volatile organic compounds (VOC), leading to photochemical smog [27,28]. Also, frequent oil-spill accidents during the oil exploration and transportation processes have been reported so far [29–31]. The numbers are prone to increase, with enormous pressure on drilling firms and oil companies, to make petroleum products easily available in the global market. These marine oil spills have a great impact on the environment and pose a major threat to the aquatic ecosystem and birds [15,32].

On the economic front too, oil spills have an adverse effect, including the loss of non-renewable energy resources and cost of production and refining. The public and industries obtain a wide range of benefits from the coastal and marine ecosystem [33–35], that are in general categorized as ecosystem services; These include supporting services, products such as fish and other food resources and cultural services such as tourism, aesthetic pleasure, etc. Hence, even a slightest disturbance in the marine ecosystem has the potential for a multi-fold impact. Such impacts of oil spill establish the pressing need for an effective clean-up method.

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Though many techniques for oil spill clean-up have been explored [36–38], each method is faced with a variety of shortcomings.

In situ burning is the immediate response to an oil spill in relatively small water bodies. In this technique, the thick oil slick is burnt on the surface of water, to prevent the marine ecosystem from being affected. It requires specialized fire-resistant booms and igniters [39]. Though it is a simple, quick technique capable of removing oil at very high rates, it has limitations in the form of viscous residues that can sink and affect the sea bed, release of potential irritants [40] and possibility of secondary fires [37]. The basic and most commonly used method of oil spill clean-up is physical separation by the use of skimmers and booms [36]. Skimmers are extensively used to separate floating oil from surface of water, while booms are used to contain the spill in a narrow region. The efficiency of skimmer however, depends on weather conditions. The U.S. Environmental Protection Agency (1999) “Understanding oil spill and oil spill response” stated that skimmers tend to recover more water than oil in rough or choppy waters. Other limitations include the process being labour and equipment intensive [36], attrition of booms under harsh sea conditions, and higher operating cost resulting from poor efficiency [41]. Another evolving method for marine oil spill clean-up is bioremediation, which involves addition of “oil-eating” microorganisms to degrade complex chemical compounds to simple molecules [42]. Though many authors consider it as a cost effective and environment friendly method for treating oil spill in comparison to other techniques [43–47], others have pointed out that bioremediation is not very effective in degradation of heavy components and polycyclic aromatic hydrocarbons (PAHs), associated with crude oil [37,48–52]. Also, this technique is limited by various abiotic factors such as fixed nitrogen content, temperature and oxygen availability [37]. Atlas and co-workers suggested the addition of fertilizers to improve fixed nitrogen concentration and thereby enhance degradation efficiency [48]. However, this increased nutrient concentration will lead to eutrophication, resulting in depleted oxygen content, indirectly affecting the degradation efficiency [46]. In addition, this technique is highly compound specific, and there is a possibility of the resultant compound being more toxic than the original compound [42]. In certain cases, dispersants or surfactants are used to reduce the interfacial tension between oil and water, and thereby aid in natural degradation of hydrocarbons in crude oil. These dispersants are proven to have maximum efficiency when used immediately after the occurrence of oil spill, before the lighter hydrocarbons escape [53]. But, these dispersants may result in finer droplets that are harmful to aquatic life [54].

One of the most effective methods to combat oil spills is by using oleophilic, hydrophobic sorbents. These sorbents absorb oil more than the self-weight and transform it to solid or semi-solid state for easy disposal or re-use. This is an attractive method owing to the possibility of complete removal and reuse of oil. Literature review shows that a variety of sorbents have been previously explored, and these sorbents can be broadly categorized into inorganic mineral sorbents, synthetic organic sorbents, natural organic sorbents mainly from agricultural sources, and the very promising magnetic nanocomposites [55–85], Pham and company have reported the synthesis of cost effective super-hydrophobic sponges by silanization of commercially available melamine sponges, through a process of solution-immersion [55]. It had a water contact angle of 151.0° and a capacity to absorb 82–163 times its own weight of oil and other organic solvents, depending on the polarity and density of the oil. Several others have worked on similar inorganic sorbents. But these sorbents are found to have numerous shortcomings; they may cause contamination of sea bed, and leakage of oil, owing to low retention capacity [55]. Also,

**Table 1**
Properties of peat moss.

| Physical state | Solid |
|---|---|
| Moisture content (kg of water/kg of sorbent) | 0.1 |
| Colour | Brown |
| Appearance | Fibrous particles |
| Specific gravity (water = 1) | 0.90 |
| pH | 4.6 |
| Auto ignition temperature | 260 °C |

**Table 2**
Properties of Envirobond 403.

| Physical state | Solid |
|---|---|
| Moisture content (kg of water/kg of sorbent) | 0.0 |
| Colour | White |
| Appearance | Powder form |
| Specific gravity (water = 1) | 0.91 |
| pH | 8.31 |
| Auto ignition temperature | 352 °C |

**Table 3**
Density of the oils measured using gravimetric method.

| Medium | Density of media in kg/m$^3$ at 15 °C |
|---|---|
| Crude oil | 887 |
| Engine oil | 882 |
| Lube oil | 880 |
| Diesel | 820 |
| Petrol | 710 |

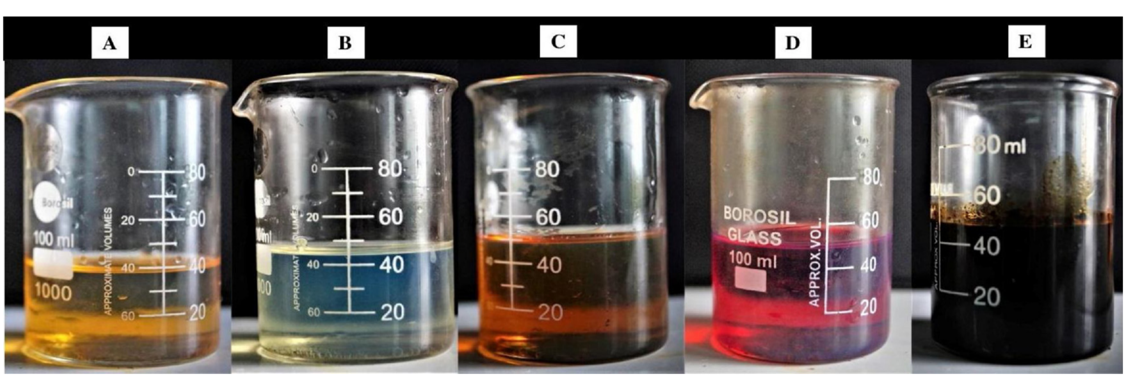


**Fig. 1.** Oils used for absorption and kinetic studies; A – petrol, B – diesel, C – lube oil, D – engine oil with Sudan IV dye for differentiation and E – crude oil. (Oil samples were stored at 4 °C and brought to room temperature before performing experiments).