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An Eco-friendly Solution for Oil Spill Absorption

Ahmad Arquam, Minal Deshmukh† and Aadil Pathan
School of Petroleum Engineering, MIT World Peace University, Paud Road, Kothrud, Pune, 411038, India
†Corresponding author: Minal Deshmukh; minal.deshmukh@mitwpu.edu.in

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ABSTRACT

It is extremely difficult to clean up accidental oil spills in water since conventional oil sorbents absorb much more water in addition to the oil. Alternatively, cleanup techniques might lead to secondary contamination. This study examines and measures the oil absorption capacities of two hydrophobic natural fibers: water hyacinth (*Eichhornia crassipes*) and lotus (*Nelumbo nucifera*). At the laboratory scale, the absorption of engine oil, vegetable oil, and diesel oils onto various dry biomass materials, including water hyacinth and lotus with different particle sizes (BSS-44, BSS-60, BSS-100, BSS-120, BSS-160, and BSS-200), was investigated. Water hyacinth shows a higher absorption efficiency for all samples as compared to the lotus.

INTRODUCTION

The environment has been exposed to oil for years since it is a naturally occurring element (Kingston 2002). Oil production and consumption are rising day by day due to the industrial economy's fast rise. When manufactured, used, stored, or transported, oil can leak or discharge, severely damaging the environment and depleting energy supplies (Cao et al. 2016). When oil spills on the sea's surface, it goes through several processes at once, including spreading, emulsification, evaporation, dispersion, biodegradation, sinking, photo-oxidation resurfacing, and tarball creation (Al-Majed et al. 2012). So, it has an impact on marine life. The number of oil pollutants that penetrate the ecosystem of the seas is large, difficult to degrade, and greatly complicates the cleanup procedure.

Additionally, it endangers public safety and seriously harms fishing, tourism, and the aquatic environment (Suleman 2012). Consequently, controlling oil spills has been a research focus (Yu et al. 2019). On May 27, 2020 an uncontrolled oil and gas spill happened in the Baghjan village of Assam owing to failing pressure mechanisms in an oil well operated by the state-owned Oil India Limited (OIL). The water eventually caused the gas-emitting mist to condense, which in turn caused hazardous floods to occur in neighboring houses and fields, harming crops and damaging the soil. Similarly, in Nagaland, the district's Changpang and Tsorri villages were badly damaged by spills from Oil and Natural Gas Company (ONGC) drill sites, as shown in Fig. 1. More than 2,000 individuals have experienced the contamination of their farmlands, woods, and water supplies as a result of the leak.

Several techniques are used to remove oil from water surfaces where it has been spilled. This falls into one of five categories (Jarrah et al. 2018): mechanical processes. Booms are often used to encircle and control the oil spreading from water surfaces, whereas skimmers are typically used to remove liquid oil from the water's surface (Ramanathan et al. 2022, Ansari et al. 2003). This method is time-consuming and costly, necessitates many mechanical tools, and is ineffective when the oil spill is far from the beaches. Internal burning this approach, which may eliminate 600 to 1,800 barrels of oil every hour and decrease its impact on aquatic plants and animals, is one of the most affordable ways to remove oil from the water's surface (Gote et al. 2023). However, this approach has drawbacks related to spill settings and pollutes the atmosphere by producing several hazardous substances, including polycyclic aromatic hydrocarbons, sulfur dioxide, and carbon monoxide. Chemical spreaders cause oil to coalesce due to the chemical solidifiers, where it either floats on the water's top or sinks to the bottom. The surfactants reduce liquid oil's surface tension, increasing its water solubility. Both approaches are costly, unfriendly,

Fig. 1: Oil spillage in Nagaland.

and detrimental to marine environmental systems (Alaa El-Din et al. 2018). Biological procedures, specifically fungus, bacteria, algae, and yeasts, break down oil off the water's surface (Atlas & Hazen 2011). Only thin oil layers may be removed using this process; most oil sorbents must be removed using other techniques. Oil spill cleaning and recovery utilizing various sorbent materials are some of the most effective ways currently used. This technique also demonstrates the qualities of recyclability (Jarrah et al. 2018).

The best oil sorbents will likely have excellent hydrophobic-oleophilic properties to draw liquid oil into the fibrous structure, quick sorption kinetics to make cleanup of spills easier and prevent leakage, good buoyancy and stability in water to facilitate collection, and recyclability and biodegradation potential (Zhang et al. 2017). Many types of sorbent materials have been employed to date for the cleaning and recovery of oil spills. These sorbents either operate by adsorption or absorption. When used with less viscous oils, absorbents function similarly to sponges and absorb oil through capillary action or suction. Conversely, adsorbents are most effective for heavy, sticky oils because they have a wide surface area, high porosity, and strong chemical affinity for spilled oil. Certain sorbents may sequester oil by acting in both ways. Several methods based on sorbent materials have recently been created as potentially effective remedies for the oil leak issue (Shang et al. 2016). These sorbents may be correctly divided into synthetic polymeric materials, inorganic mineral products, and organic natural materials (Wang et al. 2012). Due to their capacity to absorb large amounts of oil, several synthetic polymers, including poly (dimethylsiloxane), polystyrene fiber, polypropylene fiber, polyester fiber, polyurethane sponge, and several carbon-based materials, have been utilized for oil spill cleanups (Zhang et al. 2017). However, synthetic materials' inability to degrade naturally is a serious problem.

Additionally, the preparation process frequently calls for lengthy, complex synthesis processes, which raises the cost of production. Applications for cleaning up oil spills using inorganic mineral materials such as zeolites, silica, vermiculite, sepiolite, and perlite have been investigated. According to studies, these materials' insufficient buoyancy and inadequate oil-absorbing capabilities render them ineffective at cleaning up oil spills (Zheng et al. 2017). Numerous fibers from plants, including cattail, nettle, cotton, milkweed, kapok, sunflower seed, and Metaplexis japonica fiber, are examples of organic natural materials (Yu et al. 2019, Viju et al. 2021, 2019). Natural cellulosic fiber-based oil sorbents have recently attracted more attention because of their beneficial qualities, including oil absorbency equivalent to synthetic sorbent materials, sustainability and environmental friendliness, and affordability. Oil may bind to cellulosic fiber surfaces through interactions with waxes and oils or be physically trapped on its surface due to its shape. The porous internal structure of the fiber's porous structure may allow the oil to become trapped there. Oil may diffuse through the fiber more easily thanks to its porous core, improving its sorption capabilities (Wang et al. 2012, Cao et al. 2016).

This research study aims to examine studies on natural fiber-based oil sorbents, summarize the status of the science, and highlight recent advancements in oil spill cleaning gear. The current work examines the sorption of organic oils onto the dry biomass water hyacinth (*Eichhornia crassipes*), a freshwater aquaphyte with the necessary buoyancy, hydrophobicity, and biodegradability for oil sorption (Jansi Rani et al. 2014). It may be found in ponds and rivers. It is regarded as the worst aquatic plant and develops and reproduces rapidly (El-Sayed 2003). The thick mats of water hyacinth float on the water's surface, obstructing navigation and causing problems with irrigation, fishing, recreation, and power production.

Additionally, these mats block sunlight from entering and lessen water aeration, which causes an oxygen shortage. They decrease biological diversity by competitively excluding submerged plants. Removing water hyacinth dumps requires expensive mechanical collection and disposal methods, creating a solid waste problem. Much study has been done on the optimum use of discarded water hyacinth. This study has aimed to explore the possibility of the aquaphyte as a low-cost option for treating oil effluents and spills.

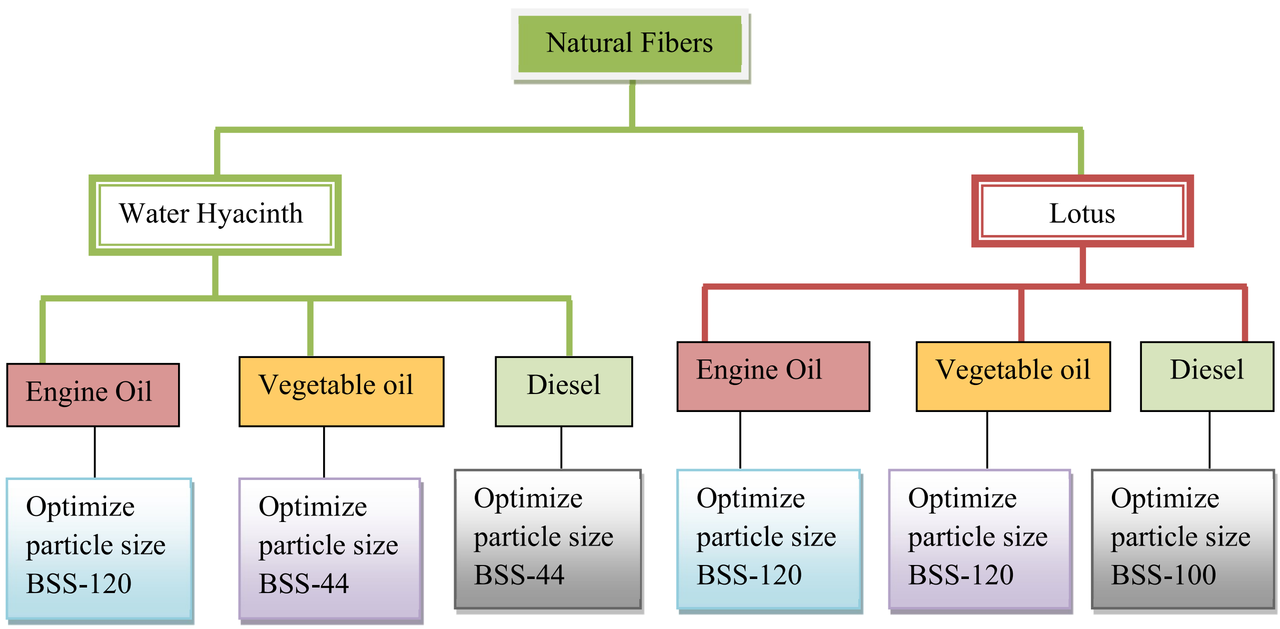
The two-level hierarchical surface structure of lotus leaves gives super hydrophobic and self-cleaning capabilities. This study examines how well water hyacinth and lotus plants can absorb oil and calculated oil separation through these natural fibers for different particle sizes (Zeiger et al. 2016).

Water Hyacinth (*Eichhornia crassipes*) Characteristics

Lignin, crystalline cellulose, and hemicellulose polymers are structural carbohydrates that make up water hyacinth (Zhang et al. 2020). Due to important functional groups on its surface, specifically carboxyl, hydroxyl, and carbonyl, water hyacinth serves as a catalyst for the adsorption of water pollutants onto plant-based adsorbents (Brown et al. 2020). Functional groups PO4, C = O, and C–H are found in the water hyacinth roots (Milke et al. 2020). Water hyacinth fibers include a sizable quantity of cellulose in the form of hemicellulose (33%), cellulose (25%), and lignin (10%). These water hyacinth characteristics encourage researchers to look into the potential use of invasive species for water restoration (Amalina et al. 2022). Using cellulose from water hyacinth to remove impurities from water has also been the subject of several research-based studies (Emam et al. 2020, Salahuddin et al. 2021). This is mostly because the cellulose backbone of this aquatic plant has several hydroxyl groups (Singh & Chandra 2019). These hydroxyl groups were chemically adjusted to make generation easier and are the main determinants of adsorption.

Lotus (*Nelumbo nucifera*) Characteristics

The large aquatic rhizomatous plant lotus (*Nelumbo nucifera*) has a creeping stem that is thin, elongated, and covered in nodal roots. With floating and floating orbicular leaves, the lotus is a perennial plant (Mukherjee et al. 2009, 1996). On a biological level, lotus possesses characteristics that set it apart from other plant species and those typical of water plants (Paudel & Panth 2015). These characteristics include flower thermoregulation, leaf ultra hydrophobicity, and seed life span. The "lotus effect" is the ultra-hydrophobicity in lotus leaves (Darmanin & Guittard 2015). The leaf's top epidermis might be protected from water by this ultra-hydrophobicity trait, preserving the stomata's ability to open



and close normally (Ensikat et al. 2011). Because of this, ultra hydrophobicity is thought to have served the lotus well in its evolutionary process. A unique thick coating of waxy papillae on the surface of the lotus leaf has been proven in studies to be responsible for this (Zhang et al. 2012, Lin et al. 2019).

MATERIALS AND METHODS

Research has been carried out using two different hydrophobic natural fibers, namely Water hyacinth, and Lotus, with three different types of oils, including engine oil, vegetable oil, and diesel. For each oil sample, six different particle sizes of water hyacinth and lotus were taken to remove oil from the water.

Materials

The study examined two distinct natural fibers, water hyacinth, and lotus fiber. The two eco-friendly hydrophobic materials, lotus and water hyacinth, have been used for oil spill removal. Lotus flowers have been taken from Swargate, Pune. Locally grown water hyacinth was collected from Khadakwasla Lake in Pune. For water hyacinth and lotus, BSS-44, BSS-60, BSS-100, BSS-120, BSS-160, and BSS-200 particle sizes were screened out. Castrol engine oil, vegetable oil, and diesel are used in this research study.

Methods

Water hyacinth and lotus have been dried with the help of a hot air oven for 72 hours at 55 ^{0}C. Dried water hyacinth and lotus materials have been crushed into fine particles with the help of a lab-scale grinder (spice & herb grinder). With the help of different sieves, BSS-44, BSS-60, BSS-100, BSS-120, BSS-160, and BSS-200, crushed powder of water hyacinth and lotus were screened into different particle sizes.

Sample solution of engine oil, vegetable oil, and diesel with water has been made on a volumetric ratio of 1:1.

Fig. 2: Experimental setup-1.

Fig. 3: Experimental setup-2.

Fig. 4: Water Hyacinth treatment samples for engine oil.

Fig. 5: Lotus treatment samples for engine oil.

Buchner funnel of diameter 100mm has been taken for the filtration process with different natural fiber particle sizes of 1.5 g. The 30 mL of oil and water was passed through

Fig. 6: Water hyacinth treatment samples for vegetable oil and diesel.

Fig. 7: Lotus treatment samples for vegetable oil and diesel.

different particle sizes of water hyacinth and lotus for 24 hours through the Buchner funnel. Fig. 2 and Fig. 3 show the experimental setup of oil spill removal through water hyacinth and lotus with different particle sizes. Fig. 4, Fig. 5, Fig. 6, and Fig. 7 show the separation of oil and water for different particle sizes of water hyacinth and lotus.

RESULTS AND DISCUSSION

The absorbent material must reject water and absorb oil to produce effective oil spill cleaning on the water through selective oil absorption materials (Zeiger et al. 2016). The lotus and water hyacinth floating plants completely satisfy this requirement. Due to the design of their surface and the presence of wax on their surface, they are extremely hydrophobic and retain an air layer when submerged in water (Jansi Rani et al. 2014). Due to their super hydrophobic and super oleophilic qualities, water hyacinth and lotus quickly and selectively absorb oil from water. We calculated the water hyacinth and lotus plants' absorption rates. Initially, we used Castrol engine oil to assess the sorption capacity of water hyacinth (1.5 gm) with six different particle sizes. Graphs show the results, which show that water hyacinth has a better capacity to absorb oil than lotus. For 1 ton liter of oil removal, 4 kg of water hyacinth is required. On the other hand, approximately 5 kg of lotus is required to remove 1 ton liter of oil from water.

In Fig. 8, water hyacinth gives a higher oil absorption efficiency of 92% for particle size of BSS-120 compared to other particle sizes of water hyacinth. As shown in Fig. 8, the optimized particle size for removing the oil spill from the water hyacinth is BSS-120.

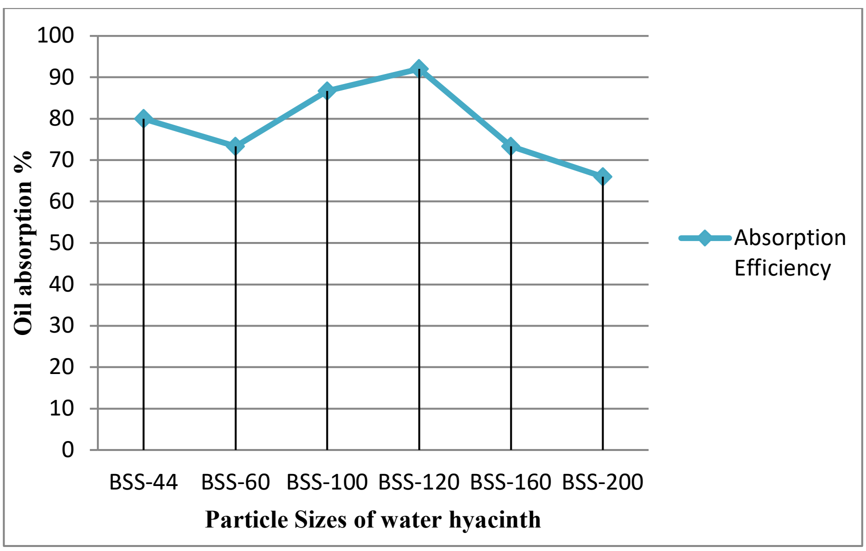


Fig. 8: Oil absorption efficiency of water hyacinth for engine oil.

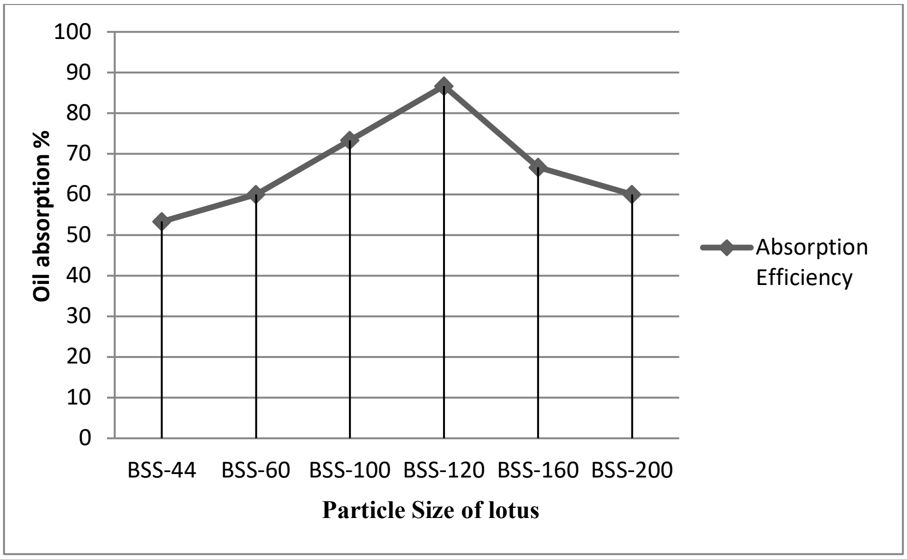


Fig. 9: Oil absorption efficiency of lotus for engine oil.

As shown in Fig. 9, the particle size of BSS-120 lotus provides a higher efficiency of 86.67%. From BSS-44 to BSS-120, absorption efficiency increases; after that, the efficiency decreases for BSS-160 and BSS-120.

In Fig. 10, water hyacinth gives a higher oil absorption efficiency of 86.66% for vegetable oil for particle size of BSS-44 compared to other particle sizes of water hyacinth. The optimized particle size for removal of an oil spill for water hyacinth is BSS-44 in a vegetable oil solution. After BSS-44, the absorption efficiency decreases for other particle sizes.

As shown in Fig. 11, for particle size of BSS-120, lotus gives a higher efficiency of 70% for vegetable oil. From BSS-44 to BSS-120, absorption efficiency increases. After that, the efficiency decreases for BSS-160 and BSS-120. The optimized particle size for removal of oil spill for lotus is BSS-120 in a vegetable oil solution.

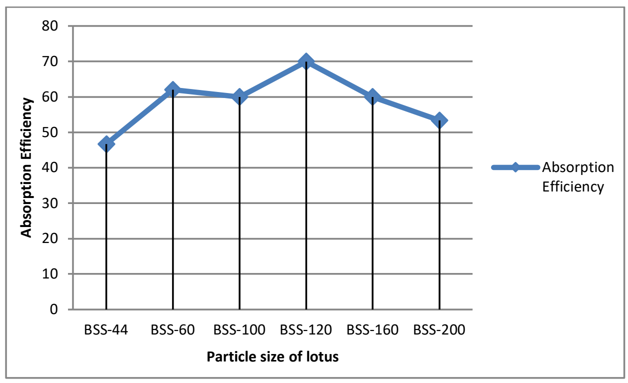


Fig. 11: Oil absorption efficiency of lotus for vegetable oil.

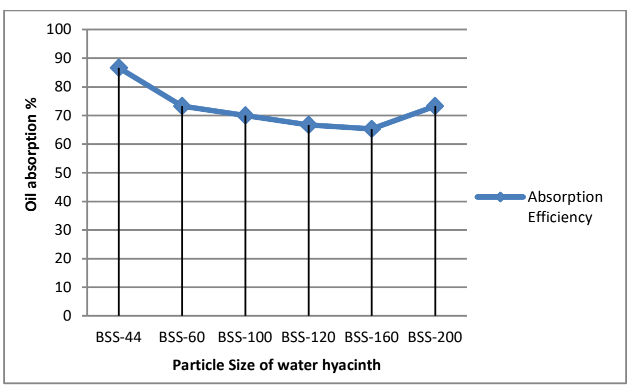


Fig. 10: Oil absorption efficiency of water hyacinth for vegetable oil.

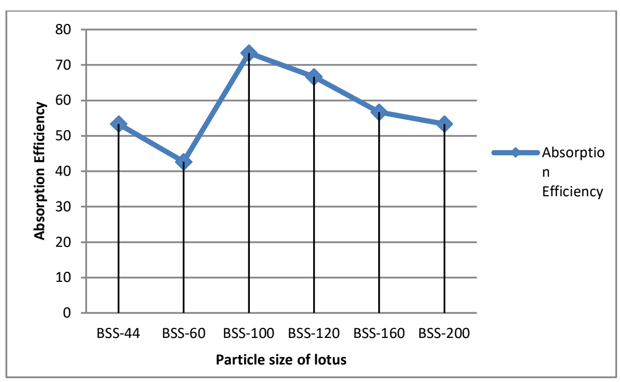


Fig. 12: Oil absorption efficiency of water hyacinth for diesel.

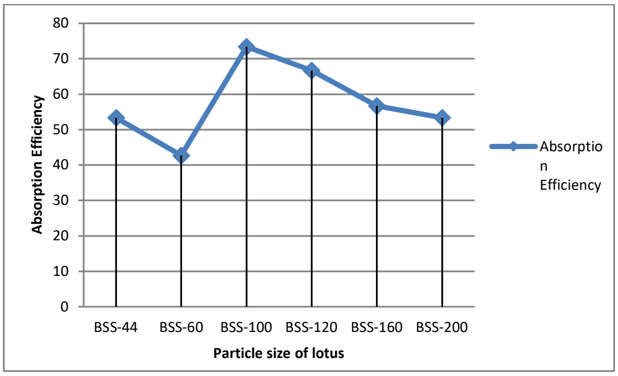


Fig. 13: Oil absorption efficiency of lotus for diesel.

As per Fig. 12, particle size of BSS-44 shows higher oil absorption efficiency, with 80% for water hyacinth for diesel solution. BSS 44 optimizes the particle size of water hyacinth for diesel solution. The graph shows that absorption efficiency decreases for other particle sizes.

In Fig. 13 for diesel solution, the lotus particle size of BSS-100 gives a higher oil absorption efficiency of 73.33%. The optimized particle size to separate diesel and water for lotus is BSS-100.

CONCLUSION

The findings of this investigation demonstrated that biomass water hyacinth has a better ability to absorb oil than lotus. Water hyacinth is a potential replacement for conventional synthetic oil absorbents used to recover oil in the absence or presence of water due to the bio material's high absorption capacity, high degree of hydrophobicity, and low water absorption. The material is cheap and easily available in tropical areas. Hence, based on the research, it can be concluded that biomass water hyacinth is a low-cost yet effective oil absorbent.

Future Scope

Another hydrophobic natural fiber could be used for oil spill removal based on their different particle size. A simulation study of the present work will help to choose the efficient absorbent for oil spill removal.

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ORCID DETAILS OF THE AUTHORS

Minal Deshmukh: https://orcid.org/0000-0002-6534-5005
Aadil Pathan: https://orcid.org/0000-0002-9974-8881