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Remediation of water from crude oil spill using a fibrous sorbent

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HIGHLIGHTS

- Waste Tyre Cord Fiber "WTCF" was used as oil sorbent material.
- The oil sorption capacity was 15.45 g oil/g sorbent material in artificial sea water.
- The reusability of sorbent was studied for 10 cycles.
- Oil sorption capacity was reduced from 11.612 to 8.79 g oil/g.
- One g of WTCF had the ability to adsorb 107.66 g of oil.

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ABSTRACT

Remediation of oil-polluted water was studied using waste tire cord fiber WTCF as a waste fibrous sorbent. The rate of sorption, sorption capacity, oil retention, water uptake, adsorption isotherm model, and kinetic behavior were evaluated. It was found that the oil sorption capacity was equal to 15.45 g oil/g sorbent. For fixed amount of sorbent, oil sorption was increased with an increasing of the amount of oil until equilibrium state was reached. The sorbent was proven to have a high retention time; it can save 66.3% of the adsorbed oil after five minutes drainage. This property makes the material as a unique material to have such high retention time. The reusability of sorbents showed that this sorbent can have 75.7% of the sorption capacity after 10 cycles. The total amount of adsorbed oil was 107.66 g oil/g of WTCF for 10 cycles. Langmuir, Frendlich, Timken, Hurkins–Jura, Halsay, Radlich–Peterson, and Dubinin–Radushkevich adsorption isotherm models were applied to fit the adsorption remediation process. The remediation process using WTCH was following a second order rate kinetic and Radlich–Peterson adsorption isotherm model.

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1. Introduction

Sorbent materials are widely used for oil spill to remediate water from contaminated oil. The low cost vegetable fibers are environmentally friendly materials with densities close to that of synthetic polymers or even lower showed high oil sorption capacity (Wei et al., 2003). The efficiency of fibers for remediation of water from crude oil contamination is related to the surface properties of the fibers, the concentration of crude oil, the amount of fibers, and the temperature of the crude oil (Wahab, 2014). Many works had been performed for water remediation from contaminated oil. The properties of technical hydrolysis of lignin showed a low ability to release back water and low rate of reaching equilibrium but wood

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shoddy possessing higher ability and rate to reach equilibrium (Nenkova et al., 2004, 2008). Kapok fibers packed in nylon net was able to adsorb 15.5 g diesel oil/g fiber (Abejero et al., 2013).

The characteristics of the hydrolyzed and acetylated fibers were evaluated using FT-IR, CP-MAS, C-NMR, SEM, and TGA. The maximum oil sorption capacity of the hydrolyzed fiber (16.78 g/g) was slightly lower than that of the acetylated fiber (21.57 g/g), but higher than the unmodified fiber (3.94 g/g) (Zhang et al., 2014). Cotton grass fiber and cotton grass mats were compared with commercially available synthetic sorbents (Suni et al., 2004). The cotton fiber had superior sorption properties and adsorbs two to three times as much and fast as the synthetic one. Cotton grass fiber sorbs no measurable amount of water making this material as an ideal sorbent for oil from the surface of water. The law value cotton fibers for used oil removal had an excellent commercial potential as a sorbent for oil (Hussein et al., 2011). Mixed leaves residues, mixed sawdust, sisal (Agave sisalana), coir fiber, sponge-gourd and silk-floss were used as sorbent materials of crude oil (Annunciado et al., 2005a). The silk-floss fiber had very high degree of hydrophobicity and oil sorption capacity of approximately 85 g oil/g sorbent in 24 h. Organic (loose natural wool fibers (NWF), recycled wool based non-woven material (RWNM), and inorganic (sepiolite)) were used as sorbents using continuous tubular contactor (initial oil concentration of 1511 mg/dm^3) and batch tank (initial oil concentration of 5066 mg/dm^3) (Rajakovic et al., 2007, 2008). Wool-based sorbents had higher sorption capacity (5.56 g/g for NWF and 5.48 g/g for RWNM) compared to sepiolite (0.19 g/g) in batch tank. Recycled wool based nonwoven material was used as sorbent in oil spill cleanup (Maja et al., 2003, 2008). It adsorbed higher amounts of base oil SN 150 comparing to diesel or crude oil from the surface of the demineralized or artificial seawater bath and exhibited excellent buoyancy after 24 h of sorption and good reusability since the decrease in sorption capacity did not exceed 50% of the initial value after five sorption cycles in oil without water. Activated carbon powder from coconut fiber activated with ammonium chloride and carbonized at 400 °C was used for the removal of diesel and kerosene from aqueous solutions by measuring the change in chemical oxygen demand COD (Egwaikhide et al., 2007). The removal efficiency was less than 45% corresponding to 6.8 mg/l/g decreases in COD and the removal of diesel and kerosene followed a pseudo first order rate law. Different sorbents were evaluated for short, medium, and long term static sorption systems (Zubaidi et al., 2015). Waste tire rubber powder (WTRP) with two mesh sizes, polypropylene yarn (PP), flexible polyurethane foam (PUF), mixed waste textile (MWT), Teflon (PTFE), and cork C. The Oil sorption consequence of these sorbents was as follow:

$$\text{PUF} > \text{MWT} > \text{PP} > \text{C} > \text{WTRP (30 mesh)} > \text{PTFE} > \text{WTRP(1–4 mesh)}.$$

The potato peels was used to adsorb waste lubricating oil from the surface of water (Tontiwachwuthikul et al., in press).

UAE is one of the exporting oil countries in the Arabian Gulf. Most of the crude oil is passing through the Gulf to different countries. The oil spill is one of the most important environmental issues. The water remediation from the oil spill is a challenge for these Gulf countries. The waste tire plant in Sharjah/UAE generated high quantity of WTCF. This material is exported to different countries. The proposed work is to use this material for remediation of water from oil spill in the Gulf area. This material needs to be separated from rubber tire granules, cleaning from other impurities, washing with tap and distill water, drying, evaluating for water remediation from oil contamination, and comparing with other materials.

2. Material and experimental work

2.1. Materials

Waste tire cord fiber (WTCF) was provided from waste tire recycling plant in Sharjah/UAE. The waste tire recycling plant reported the following mass analysis: rubber granules = 67%, steel cord = 14%, and textile fiber (WTCF) = 19%. The waste tire cord fiber consist of 60% viscous rayon fibers, 38% polyamide fibers, and the remaining 2% being small rubber particles closely adhering to the tire cord fiber (Hupka and Mydlarczyk, 1979). The amount of reinforcing steel or synthetic fibers in rubber tires varies among manufacturers. For Western Europe, the average composition of reinforcing fibers as percentages of all material input are as follows: rayon 2.8%, nylon 1.3%, polyester 0.1%, and steel 13.1% (Guelorget et al., 1993). The waste WTCF was subjected to cleaning and washing processes with distilled water to remove any dust and rubber granules, and then drying using shelf dryer at 80 °C for one day. The electron-scanning microscopy of WTCF showed rough surfaces, which reveal porous nature (Fig. 1). Crude oil from local source was used as contaminant for water. The physical properties of crude oil are as summarized in Table 1. All these tests were performed according to the ASTM standard methods. The sulfur content was performed using energy-dispersive X-ray fluorescence bench top spectrometer SPECTRO iQ II (SPECTRO Analytical Instruments, Kleve, Germany). Salt content was performed using Petrotest SCO1 apparatus. All chemicals were used as received without any further purification.

2.2. Experimental methods

Oil sorption capacity of WTCF in water was determined by adding 40 g of oil to 400 ml artificial seawater (3.5% NaCl) as described in Choi and Cloud (1992). Different masses of dry WTCF sorbent was added to the top of the oil–water mixture, the contents were shaking using Orbital shaker incubator table top type UT-420D at a frequency of 110 cycles min^{-1} for 30 s. Short and medium term sorption tests were achieved with contact time of 15 min and 1 h respectively. It is a batch

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