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Potential of a pyrolyzed sugarcane industry waste for spillage oil absorption

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ABSTRACT

Petroleum hydrocarbon contamination in the aquatic and terrestrial environments due to human activities is a common occurrence. This kind of environmental pollution is a serious threat to humans as well as to the ecosystems. This study investigated the development and testing of a diesel-oil absorbent produced using pyrolysis of sugarcane coir pith. The coir pith was obtained from waste sugarcane bagasse. Pyrolysis of the materials was done via a 4-hour process, and the temperatures were set at 150, 210, and 280 °C. The result of the oil sorption capacity test showed that the best oil absorption capacity of the sorbents was obtained at 280 °C pyrolysis (12.38 g g^{-1} after 120 minutes), and the least performance was obtained in control samples (2.42 g g^{-1} after 20 minutes). Oil absorption capacity increased with pyrolysis temperature and time, and the general trend was 280 °C > 210 °C > 150 °C > control. Field tests of the absorbents confirmed that the materials produced at pyrolysis temperature of 210 °C had the best performance. Those produced at 280 °C showed the worst field functioning, which may have resulted duo to conditions of the field application like water salinity. The tests confirmed that the pyrolysed products of sugarcane coir pith obtained from waste bagasse can be used to produce a good oil absorbent for oil spills, and it will serve appropriate for petroleum hydrocarbon spill remediation.

Keywords: Aquatic environment, coir pith, oil sorbent, pyrolysis, sugarcane bagasse

INTRODUCTION

Petroleum hydrocarbon contamination in the environment is mostly caused by mankind's activities (Yi *et al.*, 2016). Oil pollution reduces environmental diversity and is a great danger to ecosystem health. Additionally, it increases the fragility of ecosystems and makes ecosystems more vulnerable to stresses imposed by biotic and abiotic complexes (Kirk *et al.*, 2005; Ossai *et al.*, 2020). Environmental pollution by petroleum hydrocarbons is a common occurrence in industrial operations related to oil and gas exploration, production, storage, refinery, and transportation. Petroleum contamination risks are present in the surrounding soil, air, and aquatic environments of those operations (Parnian *et al.*, 2020; Sharif *et al.*, 2017). Petroleum-related contamination of the environment is a carcinogen factor for animals and humans, which may lead to cancer and other diseases (Sharif *et al.*, 2017). These pollutants are able to make DNA disruption and change in many life forms (Das and Chandran, 2011). In toxic concentrations, petroleum hydrocarbons are able to disrupt normal functions of the cell membranes. The adverse effects may include fluctuations in membrane fluidity, and disruption of integrity and functioning of organs. Under some circumstances, especially in aquatic ecosystems, petroleum hydrocarbons with non-bioavailable characteristics and/or hydrophobic properties turn into bioavailable molecules to many aquatic livings (Kuppusamy *et al.*, 2020).

The effects of petroleum hydrocarbons contamination are recognized in a vast majority of scientific studies (Ahmed and Fakhruddin, 2018;

Logeshwaran *et al.*, 2018). Under such situations, to avoid pollution of the environment and to rectify petroleum hydrocarbon contaminant remediation is vital for the sustainability of the ecosystems surrounding human communities (Ahmed and Fakhruddin, 2018; Kuppusamy *et al.*, 2020).

Biological, chemical, and physical characteristics explain water quality (Upadhyaya, 2020). Water quality must acquire good properties and be qualified enough to be appropriate for the ecosystem health or human requirement (Cotruvo, 2017). Petroleum contamination is a problem for the aquatic ecosystems and other ecosystems related to these polluted waters (Chen *et al.*, 2019). Skimmer devices and line-up procedures are part of a common procedure for petroleum removal in aquatic systems. Both methods are based on the difference between water and oil density (Pavlov, 2020). However, these are not efficient when floated oil thickness on the water is low. Under such conditions, oil absorbents are more efficient for water clean-up. Commercial oil absorbents are mostly produced from different raw materials including synthetic materials, cotton fibers, polymers, and agricultural wastes (Chai *et al.*, 2015; Teas *et al.*, 2001; Wang *et al.*, 2012), and these materials have a cost.

There are many regions of the world which produce sugarcane and host petroleum hydrocarbon businesses (de Matos *et al.*, 2020). Also petroleum hydrocarbon contamination in these regions such as Persian Gulf (Ranjbar Jafarabadi *et al.*, 2019), Brazil (do Ó Martins *et al.*, 2020), Ecuador (Rivera-Parra *et al.*, 2020), Malaysia (Keshavarzifard *et al.*, 2020), Egypt (Malhat *et al.*, 2019), India (Rao *et al.*, 2019), etc. Therefore, use of sugarcane culture waste or waste from sugarcane related industries might provide a cheap and plentiful raw material for an absorbent to remediate oil pollution, and it may also solve problem of agricultural waste management in these parts of world. It may also provide lead for other water pollution related risks. Khuzestan province is located in the southwest of Iran which produces about 80 percent of Iran's oil (Keyhanpour *et al.*, 2020). Additionally, this province hosted almost a hundred percent of sugarcane cultivation (110 thousand hectares) and sugar industry of Iran (Salehi *et al.*, 2020). The region produces more than one million tons of agricultural waste (Mohammadi *et al.*, 2020). With this background, this study reports development and testing of a oil-absorbent using sugarcane waste (coir pith).

MATERIAL AND METHODS

Oil absorbent processing

In this study, in order to make effective oil absorbent, sugarcane-coir-pith processed (Figure 1). Before treatments firstly, sugarcane bagasse de-pithed and the sugarcane-coir-pith extracted by a mechanical process (Ranjbar Jafarabadi *et al.*, 2019). Afterward, the sugarcane-coir-pith (Table 1) was processed into a pyrolysis reactor, during 4-hour anaerobic thermal treatments (Awasthi *et al.*, 2019). Thermal treatment set for three different temperatures which are 150 (sample a), 210 (sample b), and 280 °C (sample c). Air-dried sugarcane-coir-pith samples considered as the control.

Experimental setup

The petroleum material used in this study was diesel oil. At room temperature, the diesel oil

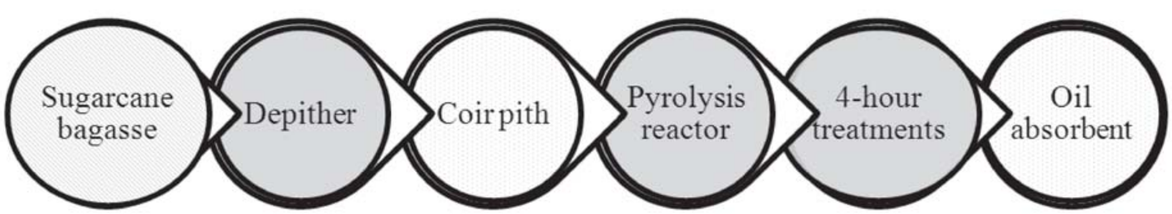

Figure 1. Treatment procedures of row materials

Table 1. Sugarcane-coir-pith analysis

Moisture content (%)	Volatile matter (%)	Fixed carbon (%)	Ash (%)	Bulk density (Kg m^{-3})	Hemi-cellulose (%)	Cellulose (%)	Lignin (%)
11.2	69.8	14.7	3.8	130	26.5	17.6	31.2

viscosity was 4.5 $mm^2 s^{-1}$ and density was about 860 kg m^{-3}. In this experiment, 100 ml water pours into a 200 ml glass beaker and also, 20 ml of diesel oil added to it. Using sorbents (sample a, b, c, d, and the control) were weighted and immersed gently into the beaker at room temperature. Therefore, after 10, 20, 60, 90, and 120 minutes ± 30s of the oil treatment, materials were collected and left to drain for 120 minutes ± 2 s in a sieve. In this experiment to determine the water sorption of the sorbents, the same experiment runs without diesel oil presence in beakers. Finally, water sorption of the sorbent materials index (WS) and oil sorption coefficient (OS) calculated by equation (1) and (2) respectively (Hoang et al., 2018):

$$WS(g.g^{-1}) = \frac{(C_{tw}-C_0)}{C_0} \quad ...(1)$$

$$OS(g.g^{-1}) = \left[\frac{(C_{td}-C_0)}{C_0}\right] - WS \quad ...(2)$$

Where C_{tw} is sorbent weight after water sorption, C_{td} shows sorbent weight after diesel oil sorption, and C_0 represents the initial dry weight of sorbets.

Statistical analysis

Identification of significant differences was performed using one-way analysis of variance (ANOVA), with $p < 0.05$ is considered significant in differences. Microsoft-Excel 2010 and IBM-SPSS Version 16 performed the statistical analyses.

Field test and evaluation

For the real field test of the treated materials, the processed sugarcane-coir-pith filled into some four-liter fluid-permeable bags and used as oil absorbent in a drilling waste management operation site, in summer 2019. The operation were in Nafte Sefid, Shushtar County, Khuzestan province, Iran (31°46′12.90″N 49°9′47.32″E), supporting an oil well drilling by National Iranian Drilling Company (NIDC). The waste management tried to reduce oil well drilling impressions on the surrounding ecosystem in the operational area of Masjed Soleyman Oil & Gas Production Company (MISOGPC), Subsidiary of National Iranian South Oil Company (NISOC). To investigate the oil absorbent performance in the mind of real users a simple questionnaire asked ten field-engineers of the site.

RESULTS AND DISCUSSION

The absorbents successfully examined in both laboratory and field, also removed oil properly in the condition of this experiment. The effect of different thermal treatments on the sugarcane-coir-pith oil absorption capacity is briefly illustrated in Table 2. In Table 2, the sorbents reduced diesel oil of the water, properly. Under the conditions of this study, with an increase in the temperature of the pyrolysis, the oil absorption capacity of the sorbent materials conformity was also increased. On the other hand, in the same rising trend, oil absorption capacity was exceeded by time. Overall, the lowest oil absorption capacity of the sorbent materials was 2.42 g g^{-1}, the air-dried sample, occurred 20 minutes after the beginning of the treatment. The highest oil absorption capacity of the sorbents was 12.38 g g^{-1}. Moreover, it was belonged to 4-hour pyrolysis of sugarcane-coir-pith at 280 °C. This highest outcome was present after 120 minutes at the beginning of the treatment. Other research reported oil absorption capacity for paraffin oil about 10.8 g g^{-1}, which the sorbent was biochar of popped rice pyrolysis at 300 °C (Huang *et al.*, 2020).

The pyrolysis has three main stages 1) pre-pyrolysis (at temperatures about 110-200 °C) 2) main-pyrolysis (at temperatures from 200-500 °C) and formation of carbonaceous soil products (temperatures above 500 °C). An increase in pyrolysis temperature results in the surface area expands, the higher degree of carbonized fractions, rising of pH, and volatile matter increasing. Despite that, higher temperature decreases the content of

Table 2. Oil absorption capacity (g g^{-1})

Time (min)	Control (air dried samples)	150 °C	210 °C	280 °C
20	2.42 ^{d}	3.17 ^{c}	5.32 ^{b}	6.11 ^{a}
60	2.96 ^{d}	3.69 ^{c}	6.42 ^{b}	8.55 ^{a}
90	3.44 ^{d}	4.21 ^{c}	7.65 ^{b}	11.26 ^{a}
120	3.71 ^{d}	4.78 ^{c}	8.89 ^{b}	12.38 ^{a}

Different letters in the same row indicate a significant difference at $P < 0.05$, $n = 3$.

Figure 2. Application of the absorbents, Nafte Sefid, Shushtar County, Khuzestan province, Iran, 2019

Table 3. Oil absorbent performance in the filed

Number	Question	Absorbent score			
		Control	150 °C	210 °C	280 °C
1	Was the absorbent easy to use?	8.5	8.5	8.5	8
2	Was it enough floated and not submerged?	8.5	9	9	7.5
3	Was the absorbent removes petroleum enough?	5	5.5	8	4.5
4	Did high saline water have no bad effect on the absorbent?	8	8.5	8.5	5
5	Do you consider the absorbent performance appropriate?	6	6	9	4

surface functional groups and reduces cation exchange capacity (CEC) consequently (Tomczyk *et al.*, 2020). Specific surface area is dependent on feedstock type of materials processed by pyrolysis (S. Wang et al., 2015),also it has an important role in oil absorption (Cheng *et al.*, 2017; Yang *et al.*, 2020). In this experiment, oil absorbent was processed through pyrolysis treatment. Furthermore, under the condition of this experiment, oil absorption capacity increased by the temperature of the pyrolysis process, and the trend was 280 °C > 210 °C > 150 °C > air-dried samples. So, this trend should be caused by an increase in specific surface area due to higher pyrolysis temperature. The same behavior of pyrolysis temperature reported for tetracycline adsorption (Nguyen *et al.*, 2019), phenol adsorption (Lua, 2020), and oil absorption capacity for paraffin oil (Huang *et al.*, 2020).

Oil absorbent makes use in real conditions to solve the environmental problem of petroleum hydrocarbons. In this study to know the field performance of the absorbents, they were filled into four-liter fluid-permeable bags and applied in a drilling waste management operation, that run into Nafte Sefid, Shushtar County, Khuzestan province, Iran. The operation faced oil-contaminated water and Figure 1 shows the application of the absorbents. Table 4 shows a field investigation of the oil absorbent's performance. Score numbers are field-engineers average scoring to each item.

In this experiment, as shown in Table 3, the best results belonged to absorbent, which processed at a temperature of 210 °C, but technician and field engineers were not satisfied with the 280 °C ones. Due to more water absorption and more compact shape of this absorbent, in high saline water (TDS around 12000 to 141000, some data mention in (Parnian *et al.*, 2020)), salt crystallizes in the absorbent and reduces the operational performance. In this case, salinity was varied during the operation. Sometimes it reaches a saturated point depending on drilling fluids salinity variation and the amount of the mixture of it to other drilling rig effluents (Parnian *et al.*, 2020). Questionnaire test for field investigation of the oil absorbents performance showed no considerable difference for coir pith which processed at a temperature of 150 °C and the control.

CONCLUSION

The performance of the absorbent was good, and effectively removes oil from the water. The best oil absorption capacity of the sorbents produced in 280 °C pyrolysis (12.38 g g^{-1}after 120 minutes) and minimum performance observed in control samples

(2.42 $g.g^{-1}$ after 20 minutes). Under the condition of the present study, oil absorption capacity was increased by pyrolysis temperature and time, and the general trend was 280 °C > 210 °C > 150 °C >control. The best field performance related to pyrolysis temperature of 210 °C but 280 °C showed the lowest field performance. In conclusion, the oil absorbent was efficient and appropriate to remove petroleum from aquatic medium.

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