EVALUATION OF INDIGENOUS OLIGOTROPHIC PEAT AS LOW-COST SORBENT FOR ACCIDENTAL OIL SPILLS

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Abstract

Removing of oil spills from solid surfaces, sea, rivers and lakes formed as a result of accidental spillage during transport or storage is of great concern. Such ecological accidents have created a great need to find more efficient and low-cost materials for oil spill cleanup. The methods commonly used to remove oil involve the use of dispersants, skimmers, sorbents etc. The main limitations of some of these techniques are their high cost. Removal of oil by sorption has been observed to be one of the most effective techniques for removal of spilled oil under ambient conditions. In this work, indigenous oligotrophic peat was prepared using several methods and tested (according to ASTM F726-12 Standard Test Method for Sorbent Performance of Adsorbents) as a low cost sorbent in order to determine their potential for oil spill cleanup in terms of adsorption capacity, floatability and leachability. In order to cover the most common oil products causing accidental spills, for this study were used: gas, diesel and motor oil. The peat sample prepared by drying, chopping and sieving had highest adsorption capacities (expressed as g pollutant/g sorbent), depending on the contact time and pollutant properties, of 4.13 – 5.02 for gas, 5.44 - 6.81 for diesel oil and 15.13- 15.17 for motor oil. The adsorption capacity of indigenous peat sample increases along with the viscosity and density of the pollutants as follows: gas<diesel<motor oil. The adsorption performances of tested indigenous peat samples are similar to those of similar adsorbent imported materials existing on the market.

Keywords: oligotrophic peat, sorbent, oil spills

Introduction

Petroleum hydrocarbons and among them especially gasoline and diesel fuels are everyday commodities produced and used in huge quantities each day. Thus, during transport or in case of faulty manipulation or use, oil spills may occur with negative impact upon the environment, in this case remediation actions being required. Accidental oil spills are common occurrences even though most spills are usually small. A handy method to limit and remove most of the spill is by spreading a sorbent material that will facilitate a change of phase from liquid to semisolid which can be removed easily. Even though hydrophobicity and oleophilicity are primary determinants of successful sorbents, some other important factors include: recovery of oil from sorbents, retention of oil over time, amount of oil sorbed per unit weight of sorbent, reusability, biodegradability and price of the sorbent. Adsorbents can be inorganic materials (perlite, vermiculite, sorbent clay, diatomite) or organic synthetic (polyurethane foam, polypropilene) or organic natural products (peat, waste biomass coming from lignocellulosic agricultural residues or agro-industrial byproducts). The present paper studies the possibility of using indigenous peat as a cheap alternative sorbent for oil spills.

Material and method

The test material was received from the supplier as raw material. This was manually sorted, dehydrated for 4 hours at 105 ^{0}C (using a Binder drying stove) and prepared by grinding (using a planetary mill Pulverisette 6), by mincing (using a cutting mill) or by mincing and sieving, thus resulting three test products: fine grinded peat (TRP), minced peat (TRM) and minced and sieved peat (TRMS). The samples were analyzed visually and by stereomicroscope (Motic).
The products were tested as sorbent for petroleum hydrocarbons: gasoline, diesel and engine oil – all procured from a local gas station.

The Dynamic Degradation Test is designed to determine the buoyancy, hydrophobic and oleophilic properties of a sorbent sample under dynamic conditions. A sorbent sample is placed in a 4L jar which is half-filled with water. The jar is placed on its side and mounted on a shaker table, set at a frequency of 150 cycles per minute at amplitude of 3 cm for duration of 15 minutes. The contents of the jar are allowed to settle for a period of 2 minutes, after which observations pertaining to the condition of the water and the sorbent sample are recorded. If more than 10% of the sorbent is observed to sink or the water column is visibly contaminated with sorbent particles, then the sorbent is designated with a Failure and is not recommended for use on open water.

The Oil Adsorption - Short Test (15 minutes). This procedure is designed to determine a sorbent's pick-up ratio when placed in a pure test liquid under stagnant conditions. The sorbent sample is initially weighed and the value recorded. A test cell is filled with a layer of test liquid to a depth of approximately 80 mm. The sorbent sample is placed in a fine mesh basket and lowered into the test cell. After 15 minutes, the sorbent is removed from the cell and allowed to drain for 30 seconds (2 minutes for heavy oils). The sorbent is then transferred to a weighing pan and the weight recorded. All tests were conducted in triplicate.

The Oil Adsorption - Long Test (24 hours). This procedure is designed to determine a sorbent's pick-up ratio when placed in a pure test liquid under stagnant conditions. The sorbent sample is initially weighed and the value recorded. A test cell is filled with a layer of test liquid to a depth of approximately 80 mm. The sorbent sample is placed in a fine mesh basket and lowered into the test cell. After 24 hours, the sorbent is removed from the cell and allowed to drain for 30 seconds (2 minutes for heavy oils). The sorbent is then transferred to a weighing pan and the weight recorded. All tests were conducted in triplicate.

The leaching test was performed to estimate the amount of adsorbed pollutant released in water in dynamic conditions. The test was realized after the long adsorption test by adding the saturated peat to a 250 ml test cell with 200 ml of water. The test cells were set on an orbital shaker (Innova 44R, New Brunswick Scientific) at 150 rpm and 25^{0}C. After 24 hours of leaching, the amount of released pollutants was evaluated

Results and discussion

The raw peat material was a non-homogenous mixture of peat fibers (76%), soil (18%), rocks (4%) and branches (2%) as shown in figure 1.

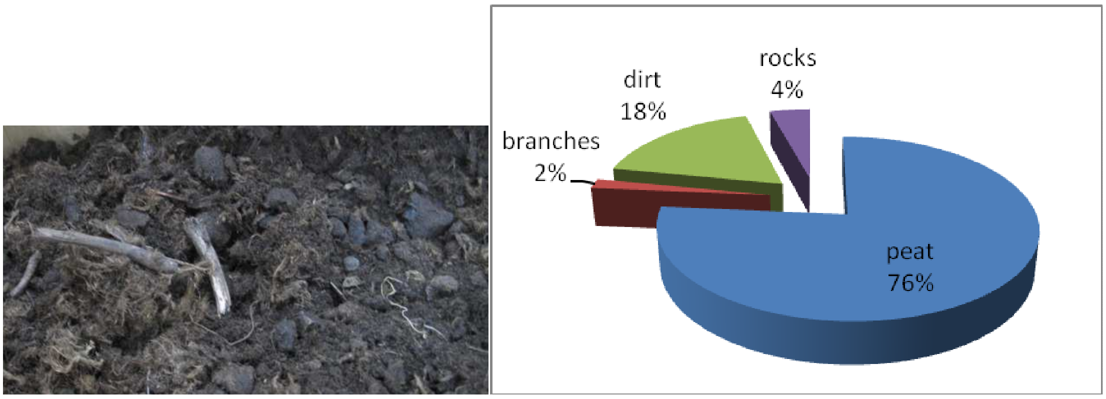

Fig.1. The composition of raw peat

After manually sorting the sample was prepared as described in the previous section, thus resulting three products to be tested (figure 2): TRP – fine peat powder, TRM – small fibers mixed with powdered peat and TRMS – small peat fibers.

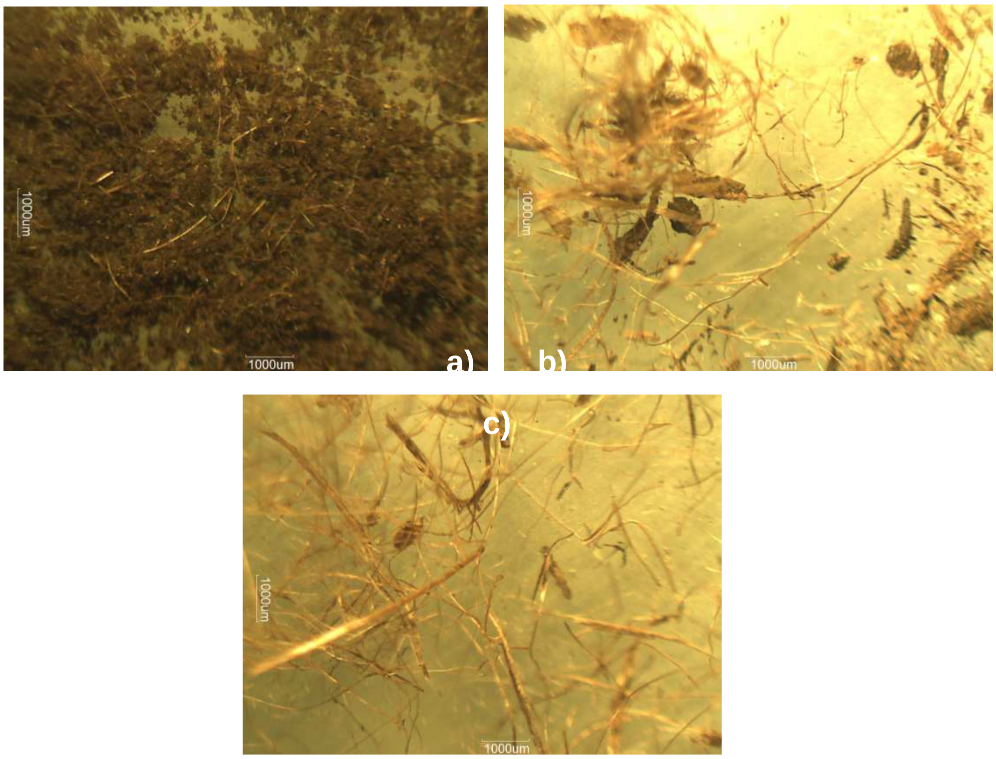

Figure 2. Stereomicroscopic images of test products: a). TRP; b). TRM and c). TRMS

The floatability test indicated that the sorbent samples prepared by mincing (both TRM and TRMS) remained at the end of the test above the water surface while the fine powdered sample TRP sank at the bottom of the test vessel thus failing the test (figure 3).

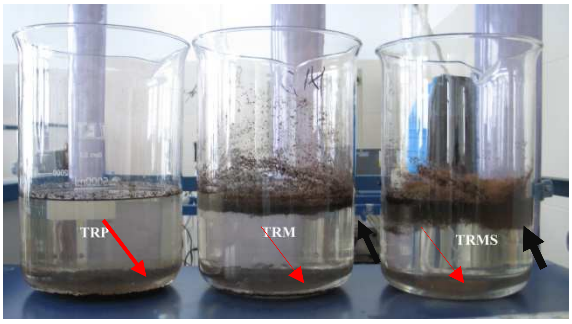

Figure 3. Floatability test – comparative

Evaluation of the adsorption capacity

The experimental results obtained in case of the peat sample prepared by mincing for short and long term adsorption tests are presented in table 1. There are also presented the results from the leachability test of the sample.

Table 1. Evaluation of the TRM sample adsorption rate

		Gasoline			**Diesel**			**Engine oil**		
	Draining time	S1	S 2	S3	S 1	S2	S 3	S1	S2	S 3
15 minutes adsorption – short test										
Adsorption rate (g pollutant/g sorbent)	30 sec	2,45	2,60	2,61	6,98	5,68	5,58	-	-	-
	2 min	-	-	-	-	-	-	6,19	7,13	6,41
Average adsorption rate (g pollutant/g sorbent)	30 sec	**2,56**			**6,08**			-		
	2 min	-			-			**6,58**		
24 h adsorption – long test										
Adsorption rate (g pollutant/g sorbent)	30 sec	3,16	2,77	2,93	7,40	5,80	6,05	-	-	-
	2 min	-	-	-	-	-	-	6,98	9,56	10,1
Average adsorption rate (g pollutant/g sorbent)	30 sec	**2,95**			**6,41**			-		
	2 min	-			-			**8,89**		
Released pollutant after 24 h of leaching	ml	0,5			1			0,5		

The adsorption capacity of the minced peat sample varied between 2,5 and 6,5 g of pollutant/g of sorbent for short term test and between 2,95 and 8,89 g of pollutant/g of sorbent for long term test. It seems that the sorbent has reached the maximum adsorption capacity in 15 minutes only in case of diesel (adsorption capacity varied with less than 10 %). In case of the adsorption test on engine oil, the adsorption capacity after 24 h is with approximately 30 % more than for short term test.
Following the leaching test, the amount of released free phase was very small (between 0,5 and 1 ml) while the leachate had a clear and clean aspect (figure 4). Moreover, the saturated sorbent floats above the water, being easy to be separated and collected – valuable property for practical application.

Figure 4. The clear aspect of leachate (24h) and floatability of oil saturated sorbent

The experimental results obtained in case of the peat sample prepared by mincing and sieving – TRMS, for short and long term adsorption tests are presented in table 2. There are also presented the results from the leachability test of the sample.

Table 2. Evaluation of the TRMS sample adsorption rate

		Gasoline			**Diesel**			**Engine oil**		
	Draining time	S1	S 2	S3	S 1	S2	S 3	S1	S2	S 3
15 minutes adsorption – short test										
Adsorption rate (g pollutant/g sorbent)	30 sec	5,49	4,79	4,77	6,37	6,52	7,54	-	-	-
	2 min	-	-	-	-	-	-	15,1	15,5	14,7
Average adsorption rate (g pollutant/g sorbent)	30 sec	**5,02**			**6,81**			-		
	2 min	-			-			**15,13**		
24 h adsorption – long test										
Adsorption rate (g pollutant/g sorbent)	30 sec	4,26	4,07	4,07	5,00	5,49	5,82	-	-	-
	2 min	-	-	-	-	-	-	15,8	15,24	14,4
Average adsorption rate (g pollutant/g sorbent)	30 sec	**4,13**			**5,44**			-		
	2 min	-			-			**15,17**		
Released pollutant after 24 h of leaching	ml	1			1			0,5		

The results showed that the adsorption capacity of the minced and sieved peat sample varied depending on pollutant properties between 5,02 and 15,13 (g pollutant/g sorbent) after the short test and between 4,13 and 15,17 (g pollutant/g sorbent) after the long term test. It seems that the sorbent reached the maximum adsorption capacity within 15 minutes of contact as no significant change was registered after 24 h.

Comparatively analyzing the results obtained for the two successfully tested peat samples (figure 5), it can be emphasized that by sieving all the impurities were removed, and thus remaining a fine and homogenous network of peat fibers that successfully adsorbed the pollutant – figure 6.

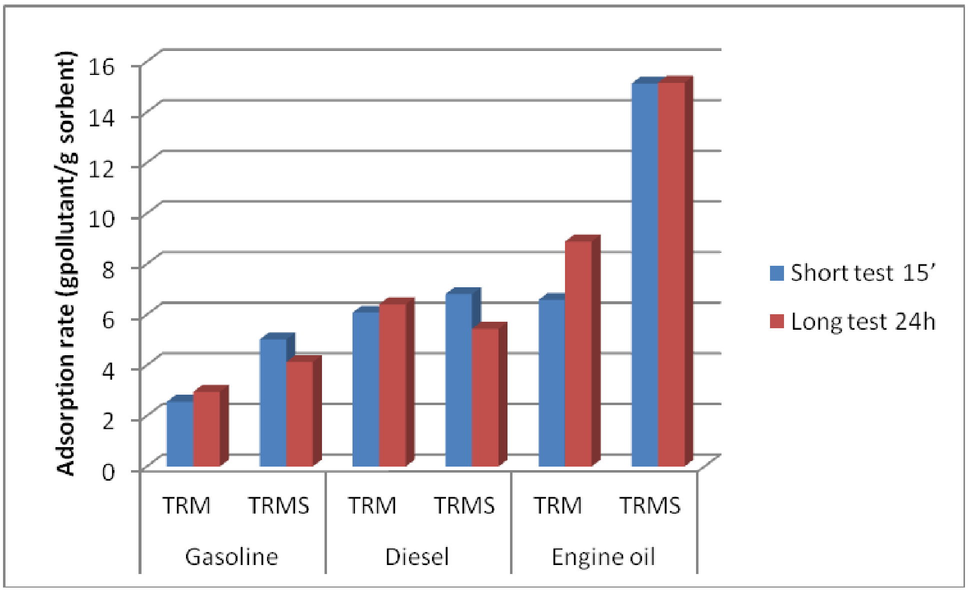

Fig.5. The variation of the adsorption capacity depending on sorbent preparation procedure and viscozity of adsorbed pollutant

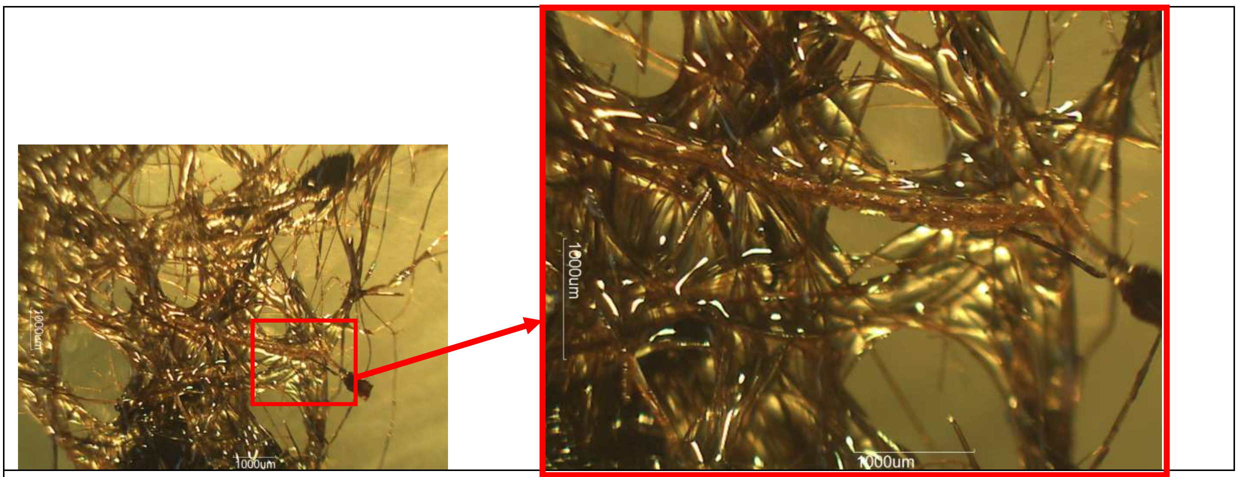

Fig. 6. Stereomicroscopic images of peat moss fibers network with adsorbed engine oil

Conclusions

Starting from a raw peat moss sample, three products were obtained and tested according to the testing protocol described in ASTM F726-12 Standard Test Method for Sorbent Performance of Adsorbents. The product obtained by fine grinding failed the floatability test and registered inferior adsorption performances compared to the next two products. The products obtained by mincing or mincing and sieving passed successfully the dynamic floatability test as less than 10 % of the product settled at the base of the test vessel.

The red oligotrophic peat sample prepared by sorting, mincing (with or without sieving) proved to be a suitable sorbent for the tested petroleum hydrocarbons – gasoline, diesel and engine oil – products that are most common in auto services. The results of the laboratory trials recommend the product as a sorbent on areas where accidental oil spills occurs. The adsorption capacity of the tested sorbent varies significantly according to the nature of the oil product in the series of gasoline, diesel and motor oil. The adsorption capacity of the tested peat sample is similar to other commercial products.

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