Bulgarian Chemical Communications, Volume 49, Number 2, (pp. 335 – 338) 2017

Sorption capacity of the oil sorbents for removing of thin films of oil

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Received April 27, 2014; Revised July 27, 2016

Object of research are different sorbents of thin films of oil. The dependence of the sorption capacity of the sorbents on the amount of sorbent, sorption duration, the thickness of the oil film, as well as on the number of cycles of use of the sorbent was investigated. The maximum sorption for each type of oil took happened on the sorbents with the definite values of bulk density. It follows from the obtained results that the synthesized sorbents may be used as adsorbents for the removal of thin oil films.

Keywords: oil sorbent, sorption capacity, thin film of oil.

INTRODUCTION

Currently, the pollution of surface water objects by petroleum hydrocarbons happens not only under accident oil spills, but also during routine maintenance. The process of timely removal of oil pollution from the water surface is topical because of the increasing technogenic influence on the ecosystem. It is therefore particularly important to find ways to solving this problem. There is a search of materials suitable for collecting oil from the surface of water and sewage industrial water.

Cleaning of the surface of water bodies from contamination involves the removal of the oil film by mechanical and/or physical and chemical methods. The most perspective and environmentally expedient is the method of removing oil films with the help of oil sorbents [1]. The materials used for the collection of oil and petroleum products from water, are commonly called oil sorbents, collectors of oil and oil absorbers. One of the main problems during cleaning surface of water bodies from pollution is the removal of a thin oil film having the ability to spread over vast distances in the shortest terms, violating the oxygen exchange [2-3].

For the obtaining oil sorbents various raw materials are used [4]. By the mechanism of oil removal the sorbents are distinguished, which act through physical surface adsorption. Here, the collection of oil occurs due to adhesion to the surface of the sorbent particles. In this case, the amount of oil absorbed is determined by the value of the specific surface of the material and its properties (hydrophobic and oleophilic). Literature and patent data show that such a mechanism for collecting oil and petroleum products is realized for oleophilic powders and granular materials with closed porous structure and materials in which no appropriately sized pores are available for the molecules of the removable substances [5].

EXPERIMENTAL

All researches experiments were carried out using the methods described in [6-8]. A Petri dish was filled with water and weighed, and then an oil slick was applied to the water surface without touching the walls of the dish, followed by cup reweighing. Then, on the oil slick a sample of sorbent was applied in order to absorb it and the dish was reweighed. Gain of oil weight to the sorbent weight gave the value of the absorption capacity of the sorbent in water.

The weight of dry dish was 134.15 g and with water - 178.93 g. The weight of the oil slick was 0.4 g and the weight of the dish became 179.33 g. After the total absorption of the oil slick modified by carbon sorbent with weight of 0.04 g, the weight of the cup amounted to 179.37 g, and the sorption capacity was 10.0 g/g.

The weight of dish with water was 173.44 g and with the oil spill - 173.90, after applying of the sample of carbon sorbent of vegetable origin with weight of 0.22 g, the oil spill was absorbed by the sorbent. The sorption capacity of the sorbent was 5.0 g/g, i.e. 1 g of sorbent could adsorb 5 g of oil.

After repeating the experiment under mixing of oil and sorbent, the total absorption of the oil slick has been achieved with 0.05 g of modified carbon sorbent, i.e. the sorption capacity increased to 10.9 g /g.

For creation of oil film in a Petri dish about 40 ml of water with a salt concentration of 17-20 g/l (seawater) was poured and a few drops of oil were dropped. The diameter and thickness of the formed oil slick film were determined.

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RESULTS AND DISCUSSION

For the laboratory tests the medium viscous oil of Karazhanbas field (Kazakhstan) was used (Figure 1). The dependence of the sorption capacity of the obtained carbonized sorbents based on rice husks (CRH) on the amount of sorbent, the sorption time, the thickness of the oil film, as well as on the number of cycles of use of the sorbent was studied.

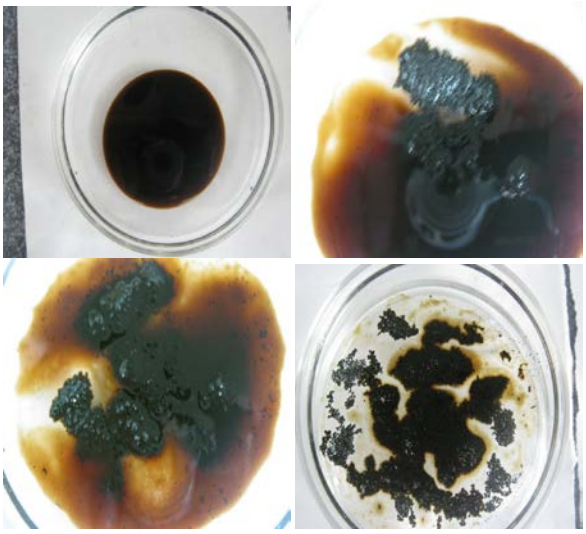

Fig.1. Sorption of Karazhanbas oil

Figure 2 shows the sorption capacity of the sorbents as a function of the sorption time. As can be seen from the presented data, the maximum sorption of oil is in the first ~ 3-4 min, after which the sorbent based on foam rubber and sunflower husk carbonizate (FRCSH- 300) was able to retain the sorbed oil for two days, whereas the sorbents on the basis of polystyrene foam and carbonizate of rice husk PFCRH-400 and modified foam rubber (MFR-300) gradually began to release it after 4 h of active sorption.

Such behavior of the sorbents may be due to the lower level of hydrophobicity and oleophilicity of sorbents based on PFCRH-400 and MFR-300, and to the different structure of the sorbents.

The sorption capacity of vegetable materials without polymers was studied. With the increase in mass of the taken sorbent the amount of sorbed oil gradually increased. After reaching the optimal sorption time (4 h), the speed of the active sorption markedly decreased, which may be explained on the one hand by the oil saturation of the sorbents, and on the other, by the process of desorption (in the case of CRH-400 and -300).

The dependence of the sorption capacity of the sorbents on the thickness of the oil film was also studied (Fig.3).

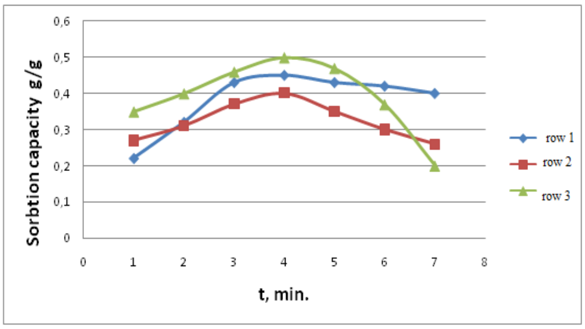

Fig.2. Dependence of the sorption capacity of the sorbents on the sorption duration: 1 - rubber foam + carbonizate of sunflower husk (FRCSH- 300) ; 2 - polystyrene foam + carbonizate of rice husk (FPCRH-400) ; 3 - modified rubber foam (MFR -300)

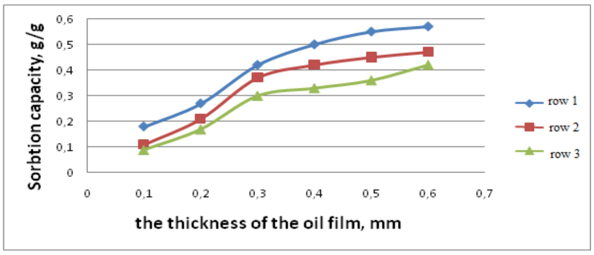

Fig.3. Dependence of the sorption capacity of the sorbent on the thickness of the oil film: 1 - rubber foam + carbonizate of sunflower husk (FRCRH- 300); 2- polystyrene foam + carbonizate of rice husk (FPCRH - 400); 3- modified rubber foam (MFR-300)

It is known that the maximum absorption capacity of the sorbent is exhibited with excess amount of absorbed oil [9,10]. As seen in Fig. 3, an increase of the thickness of the oil film increases the oil absorption capacity of the sorbents.

The results of the study of the dependence of the sorption capacity of the sorbents on the number of used cycles are presented in Table 1.

The regenerability of the sorbents is one of their basic characteristics. The obtained results show a good regenerability of the sorbents and a possibility of their repeated use.

Regeneration of the sorbents was carried out by centrifugation and washing with a hydrocarbon solvent followed by air drying.

The data in Table 1 demonstrate the suitability of the sorbents synthesized by us as adsorbents for the removal of thin oil films.

We have also studied the maximum oil absorption by CKP-400 depending on the viscosity and the physical state of aggregation, i.e. the sorbed oil product was petroleum oil, oil, gasoline and diesel fuel.

In those cases, when the thickness of the oil spill layer was less than the thickness of the sorbent, the collection of oil from the water surface also occurred. Table 2 shows that the sorbent absorbs the oil «Mobil» to a higher degree than gasoline and diesel. This is possibly because of the increased affinity of the sorbent to the sorbed oil.

On increasing the film thickness, the oil sorption capacity of the sorbent increases.

From the data in Table 2 it is clear that the collection of products of relatively low viscosity (gasoline and diesel) depends on their excess and the real-absorbing properties of the sorbent are characterized by amount of oil absorption at the level of 30-40 g/g.

This sorbent is easily regenerated by simplest squeezing of the absorbed oil. Despite the high oil absorption of sorbent "CRH- 400", its application in dispersed form is time consuming and not technological due to significant technical difficulties that arise on spraying the sorbent on the surface of the oil spills and subsequent collecting of the spent sorbent.

As the performance of the sorbent strongly depends on the ambient temperature, for example, in winter conditions, in this work was also investigated the influence of temperature and volume weight of sorbents on the basis of apricot stone CAS-400 and rice husk CRH-400.

Table 3 shows the temperature dependence of the sorption capacity of sorbents (with weight by volume of 50 g/cm^3 of CAS-400 and 150 g/cm^3 of CRH-400) on oil and petroleum products in the temperature interval from 10 to 50^{o}C. After analyses of the data of Table 3, it is possible to claim the following regularities: in the case of oil and fuel oil, the temperature increase leads to a constant growth of the sorption capacity of sorbents from CAS-400 with weight by volume of 50 g/cm^3.

In this case, the established temperature limit for the sorbents is not the limit of saturation by oil and fuel oil. The maximum adsorption capacities of these sorbents are 22.5 and 24.2 g/g, respectively. In the case of gasoline and diesel fuel in the sorbent CAS-400 with weight by volume of 50 g/m^3 the maximum sorption of diesel fuel increased with temperature and at 30 ^{0}C was equal to 3.5 g/g.

Table 1. Dependence of the sorption capacity of the sorbents on the number of used cycles.

Cycles used	Sorption capacity, g/g		
	FRCRH-300	FPCRH-400	MFR -300
1	0.45	0.49	0.42
2	0.44	0.40	0.40
3	0.35	0.38	0.40
4	0.33	0.35	0.32

Table 2. Effect of the thickness of oil and oil products on the sorption capacity of the sorbent CRH-400, g/g

Collected oil product	Layer thickness, cm	Amount (g/g of of the sorbent) on the collected oil product		Degree of squeezing, %
		absorbed	squeezed	
Oil field "Kumkol"	4.1	38-40	28	86
Oil "Mobil"	1.1	53-60	43	87
Motor car gasoline	3	32-33	25	78
Diesel fuel	4	24-30	19	77

Table 3. Influence of temperature of the medium and bulk density of sorbents on the sorption capacity for oil and petroleum products (g/g)

Weight by volume, g/cm^3	Temperature of medium, ^{0}C	Sorption capacity of sorbents, g/g: Oil	Fuel oil	Diesel fuel	Gasoline
CAS-400 50 g/cm^3	10	9.3	7.4	1.6	1.4
	15	12.4	11.5	2.4	2.1
	25	15.6	16.2	3.5	3.0
	30	17.4	17.3	3.5	2.4
	35	20.4	21.4	2.4	-
	40	22.5	24.2	1.0	-
CRH-400 150 g/cm^3	10	4.0	2.2	8.3	7.2
	15	5.3	2.5	9.2	8.1
	20	5.4	2.6	10.3	9.1
	25	6.2	3.4	11.4	12.1
	30	8.1	5.2	12.5	12.1
	35	8.8	6.3	12.4	-
	40	10.2	7.2	12.0	-

A further increase in temperature of the medium caused a decrease in the sorption capacity of the sorbent for diesel fuel. This is due to the fact that the sorbents AS-400 are of sufficiently large mesh size ensuring that the forces of attraction between sorbate molecules are higher than those between sorbate and sorbent molecules, resulting in a liquid phase portion flowing from the cells of a solid sorbent during weighing [11].

In Table 3 the regularities of changes of the sorption capacity of sorbents CRH-400 with a bulk density of 150 g/m^3 on temperature are presented. By analogy, in this case, regardless of the type of the sorbate, a regular increase of the temperature of sorption capacity was observed. This is due to the fact that with increasing temperature, the viscosity of oil and petroleum products is reduced and thereby accelerates the migration of sorbate to a diffusion region of fine-mesh macrostructure of the sorbents. However, here the opposite picture is observed, the sorption capacity for diesel fuel and gasoline is higher than that of oil and fuel oil. In this case, we are confronted with the specifics of selective sorption of sorbents and their ability to selectively sorb oil and petroleum products depending on the size of the cells and bulk density. The studies showed the potential application of the sorbents synthesized by us as adsorbents for the removal of thin oil films. On the basis of experimental data it was revealed that the maximum absorption of crude oil is reached when the film thickness of dispersed sorbent is of equal proportions as the thickness of the oil spill layer, i.e. in the case of oil «Mobil» with a layer thickness of 1.1 cm the maximum quantity of oil products - 53-60 g is adsorbed.

CONCLUSION

It was shown that irrespective of the type of oil and volume weight of the sorbent, with an increase in the thickness of the oil layer from 1.0 to 7.0 mm there was a general tendency to increase the sorption capacity. It should be note that the maximum sorption for each type of oil occurred on the sorbents with the definite values of bulk density.

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СОРБЦИОНЕН КАПАЦИТЕТ НА СОРБЕНТ ЗА ОТСТРАНЯВАНЕТО НА ТЪНКИ СЛОЕВЕ ОТ ПЕТРОЛ

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Постъпила на 27 април, 2015 г.; приета на 27 юли, 2016 г.

(Резюме)

Изследвани са зависимостта на сорбционния капацитет от количеството на сорбента, времето на сорбция дебелината на филма от петрол, както и броя на циклите на използване. В резултат е установено, че може да се използват изследваните синтетични сорбенти за отстраняването на тънки филми от петрол.