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РЕЗЮМЕ

В данной статье рассмотрены электронные системы управления двигателем на автомобиле и средства контроля их технического состояния, состояния. Предложены диагностические параметры, оценивающие техническое состояние электронных систем управления двигателем с обоснованием их нормативных значений.

Электронные системы управления двигателем и контроль их технического состояния играют решающую роль в современной автомобильной промышленности. Данная тема охватывает основные аспекты электронных систем управления двигателем, включая принципы их работы, основные компоненты и функциональные возможности. Рассматриваются также средства контроля технического состояния электронных систем, включая диагностические приборы, программное обеспечение и методы анализа данных. Также анализируются средства мониторинга технического состояния двигателя, включая датчики, диагностические сканеры, программное обеспечение и методы обнаружения неисправностей. В аннотации подчеркивается важность этих технологий для обеспечения эффективной работы двигателя, повышения безопасности и экономичности автотранспортных средств, а также их влияния на экологическую устойчивость транспортного сектора. Работа над этой темой позволит лучше понять современные требования к системам управления и контроля автомобилей, а также их вклад в развитие автомобильных технологий в целом.

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MAGNETIC CARBON MATERIALS AS SORBENTS FOR WATER PURIFICATION FROM PETROLEUM PRODUCTS

ANNOTATION

The development of effective sorbents for water purification is crucial to reduce environmental pollution with petroleum products. A method for obtaining a complex adsorbent with magnetic properties for the elimination of oil spills from the water surface using a controlled magnetic field is proposed. In this study, methods for the synthesis of magnetite-carbon composites by co-deposition and the synthesis of magnetite-carbon composites by mechanical grinding in a ball mill were proposed. Magnetic carbon sorbents were synthesized using activated carbon and magnetic nanoparticles by co-deposition, after which physicochemical characteristics were obtained using methods such as infrared spectroscopy and X-ray fluorescence analysis. The adsorption capacity is estimated under conditions of competitive adsorption of water and oil on the surface of magnetite, coal and their composite. The results show that magneto-carbon materials have good adsorption efficiency, rapid separation from water due to their magnetic properties and excellent reusability, which makes them promising candidates for water purification. These results suggest that magneto-carbon sorbents can play a significant role in environmental remediation efforts by providing an effective solution for the treatment of water contaminated with petroleum products.

Key words: *magnetite, magnetite-carbon composite, activated porous coal, sorbents, adsorption.*

Introduction. Oil spills, whether caused by natural disasters, human activities, or industrial accidents, pose significant threats to water resources and ecosystems. This environmental hazard has prompted extensive efforts within the scientific community to develop effective strategies for pollution control and oil spill response [1,2]. When oil spills occur, they form a thin layer on the water surface, which can lead to devastating consequences for marine life [3]. Moreover, the remediation of oil spills is a costly endeavor, and many conventional cleanup methods struggle to completely remove oil from water. Techniques such as boom barriers, skimmers, sorbents, dispersants, in-situ incineration, bioremediation, and magnetic nanocomposites are employed for oil-water separation. Recent advancements in this field emphasize factors like surface wettability (hydrophobicity), as well as the porosity and roughness of filtration and absorption materials. These surface-modified materials are crafted into various forms such as meshes, textiles, foams, sponges, films, and membranes [4,5]. Traditionally, materials like polypropylene, hydrazine hydrate, and graphene oxide have been used in oil spill cleanup efforts. However, these synthetic substances are expensive, environmentally harmful, and slow to biodegrade. There is now a growing interest in natural alternatives, such as sea sponges treated with vegetable waxes, which offer potential solutions to these drawbacks. Furthermore, the integration of hydrophobic surfaces with magnetic components has gained attention for its ability to efficiently extract oil from water post-separation. The ongoing research and innovation in oil-water separation technologies reflect a commitment to mitigating the impacts of oil spills and safeguarding aquatic environments. By advancing both the materials and methodologies involved, scientists aim to enhance the effectiveness and sustainability of oil spill response measures, ultimately minimizing environmental harm and promoting ecosystem recovery. [6].

In general, various physical, chemical and biological methods, such as adsorption, absorption, membrane filtration, electroflotation, flocculation and coagulation, as well as biological purification, are used for the purification of petroleum, and in some cases a combination of these two methods has also been studied [7]. The proposed strategies to combat oil pollutants are fermentation with microorganisms, the use of physical and mechanical collectors (e.g. skimmers, bons, pumps with natural and synthetic sorbents, mechanical separators, etc.) and chemical dispersants (e.g. detergents, etc.). In general, therefore, the removal of petroleum by physical methods, such as boom barriers, skimmers, absorbent materials, is more environmentally friendly and economical than chemical dispersants. While the use of the chemical dispersant is the fastest, there are some parameters that could be considered a universal solution due to the cost, complexity and the need to perform additional process operations, such as film removal or on-site incineration. In situ burning of oil floating on the water surface is a quick method used in some places to deal with oil spills, but it affects the ecosystem by leaving sedimentary rocks [8]. Other possible methods, such as washing with hot and high-pressure water (spraying water with enough force to pulverize the oil in the form of tiny particles), chemical stabilization of the oil with elastomers (gelatinization or solidification of the oil on the surface of the water and stopping its spread), manual recovery (using labor to collect the oil from the surface of the water, the water goes through various physical processes) and natural regeneration have their advantages and disadvantages, and therefore its application is limited in particularly affected areas. Of all the technologies presented, adsorption (or absorption) (collectively called sorption) using solid materials is the easiest and cheapest process to remove contaminants from petroleum [9]. In recent years, the sorption process has become increasingly interesting for the extraction of petroleum from water resources due to its essential characteristics compared to other traditional methods, namely the recovery or reuse of sorbents, ease of operation, the absence of secondary pollution, the formation of sludge, the absence of production of harmful products in the system [10].

In addition to the property of absorbing oils, absorbent materials must also have the ability to evenly distribute and retain oils in their structure and pores. In addition, for better separation of oil and water, the absorbent materials should have some other important criteria, such as adsorption of a significant amount of oil per unit mass, hydrophobicity by nature and low absorption capacity with respect to water, the bulk density should be low, and they should stay in the water for a long time. it takes a long time, and the oil absorption rate should be high enough. On the other hand, the ability of the absorbent material to absorb oil depends on the properties of oil, such as concentration, temperature, specific gravity and the type of oils [11]. Sorption technology also belongs to the category of physical processes that can also be used in skimmers. The best function of the sorbent is to transfer the liquid (oil) to a semi-solid physical state for easy absorption, followed by efficient desorption and extraction of the oils. In general, the sorption process is environmentally friendly due to its inertia and zero generation of toxic substances, which opens the possibility of using a variety of low-cost materials that can be used as a sorbent in pure or modified form according to requirements. To obtain a better absorption material, the processes of oil absorption and its extraction in the sorption-desorption cycle must be more efficient, which is directly related to the possibility of reusing the materials in subsequent successive cycles. Therefore, many well-known materials, such as zeolites, organoglins, polymers, natural fibers, biomass, wastes and carbon-based products, have been presented as sorbents for the separation of petroleum and water [12,13,14]. Of the sorbents studied, carbon materials are the most versatile materials used to combat oil pollution, and their effectiveness depends on properties such as active surface area, Size and stability, with a significant focus on cost [15].

The use of sorption methods makes it possible to remove oil pollution of a wide range of nature to almost any residual concentration, regardless of their chemical stability. And giving magnetic properties to adsorbents will allow the use of physical methods for eliminating oil spills using magnetic traps. Thus, the development of an adsorbent with high sorption and magnetic properties, which would ensure its effective penetration into the layer of petroleum products and rapid removal from the water surface using a controlled magnetic field, is an urgent scientific and practical task [16].

Magnetic sorbents can be easily and quickly assembled using external magnetic fields, which greatly simplifies the process of pretreatment of samples without filtration and centrifugation. This is very valuable for large size samples. In addition, the ability to recycle and reuse sorbents makes them environmentally friendly and inexpensive materials. In addition, magnetic sorbents based on modern and highly efficient nanostructured sorbents have additional outstanding characteristics compared to others: they have a significantly higher surface area to volume ratio and higher extraction capacity, faster extraction dynamics and higher extraction efficiency [17].

Materials and methods. Synthesis of magnetite. The Elmore deposition method was used to produce magnetite particles [18]. In the molar ratio of solutions of iron salts $FeCl \cdot 6H_2O$ and $FeSO_4 \cdot 7H_2O$ 1: 2, under mild conditions (at room temperature and normal pressure), an aqueous solution of ammonium (8.3%) is added, the resulting suspension is mixed at room temperature for 30 minutes, filtered and washed with distilled water 2-3 times, rinsing at 100-and dried in the oven at 130 ° C. The resulting suspension of magnetite has a black color, which after drying turns into a dark brown powder, the main reaction is:

$$2FeCl_3 + FeSO_4 + 8NH_4OH => Fe_3O_4 + 6NH_4Cl + (NH_4)_2SO_4 + 10H_2O \quad (1)$$

Synthesis of magnetite-carbon composites by co-precipitation method. An effective method for obtaining magnetic sorbents is the introduction of magnetite into the carbon structure. The convenience of using coal particles depends on their porosity, which allows them to immobilize or synthesize magnetite particles. Magnetite-carbon composite is boiled according to the Elmore method in a soft state in distilled water, in the presence of 0.1 M aqueous $NaOH$ solution at a temperature of T = 298 K and within pH = 8-9.5 for an hour. This ensures that the iron ions are well sorbed on the surface of the coal and that their pores open well. Then solutions of $FeSO_4 \cdot 7H_2O$ with a solution of $FeCl \cdot 6H_2O$ are precipitated in a ratio of 2:1 in ammonia water at pH = 9.5-11.0 and T = 298 K and washed several times with distilled water and dried in an oven at 100-130 ° C, resulting in matte black magnetite carbon composites [19].

Synthesis of magnetite-carbon composites by mechanical grinding in a ball mill. Mechanical grinding of carbon sorbent together with iron compounds in a ball mill is an effective method for obtaining powdered magneto-carbon sorbents. In the work, magnetic iron particles ($Fe, \alpha - Fe_2O_3$ or Fe_3O_4) are uniformly dispersed on a carbon matrix of activated carbon and biochar in a ball mill. The diameter of the particles produced by this process depends on the grinding time. In addition, during grinding, not only the particle size of the sorbent decreases, but also the uniformity of the adsorbent powder increases significantly. This method allows the inclusion of iron particles in the sorbent matrix without the addition of any solvents. The ball mill is also a promising and environmentally preferable method for the production of magneto-carbon sorbents [20].

Infrared spectroscopy. The study of magnetite, activated carbon and particles of a magnetite composite obtained on the basis of coal was carried out in the wavelength range 440-4000 cm-1, infrared (IR) Fourier spectrophotoscopy was performed on the Spectrum 65 (PerkinElmer) installation. In this case, the IR spectra of the samples were subjected to hot treatment in the form of a film with a thickness of 0.07-0.09 mm (70-90 microns).

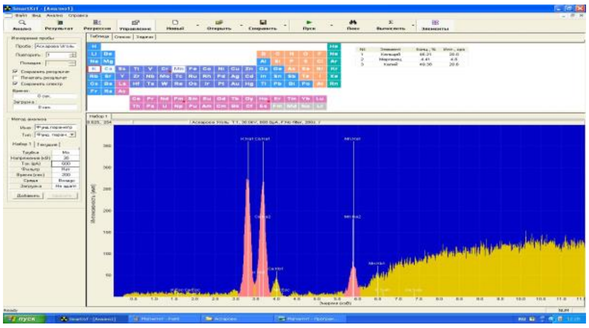
X-ray fluorescence analysis method. Quantitative analysis of the chemical composition of magnetite, activated carbon and magnetite-carbon composites by X-ray fluorescence analysis was performed on a FOCUS 2m wave spectrometer. The samples were placed in special round cuvettes of variable depth, which were covered with a polypropylene film on top so that they would not spill. An X-ray tube with a power of 4 kW was used as a source of exciting radiation. The use of a polypropylene film made it possible to analyze the composition of elements in the range from Na to U. The spectra were processed using a special ZSX software package.

Investigation of the sorption properties of magnetite, coal and magnetite-coal composites in decane and petroleum. Sorption properties in magnetite, coal and magnetite-coal composites (1 ± 0.0005 g) in various concentrations of decane and oil with water at room temperature under static conditions have been studied. To carry out adsorption, a solution of the test substance (10 ± 0.1 ml) is added to the sorbent and left for adsorption for two hours with complete stirring. Then the adsorbate was isolated with a sorbent and the post-adsorption amounts of adsorbate were determined.

Results and discussion. X-ray fluorescence analysis of magnetite, coal and magnetite-carbon composite. As a result of the synthesis, complex composites of activated carbon and magnetite were obtained. X-ray fluorescence analysis reveals elements with an atomic mass of more than 16 g. The chemical composition of the identified sorbents based on X-ray fluorescence analysis is presented in table 1.

Table 1 – Chemical composition of activated carbon, magnetite and their composites

№	Systems	Coal	Magnetite	Magnetite-coal composition
	Elements	size, %	size, %	size, %
1	Iron	-	99.81	84.33
2	Chrome	-	0.19	0.16
3	Calcium	46.21	-	1.50
4	Manganese	4.41	-	0.49
5	Potassium	49.38	-	-
6	Chlorine	-	-	11.77
7	Sulfur	-	-	1.75



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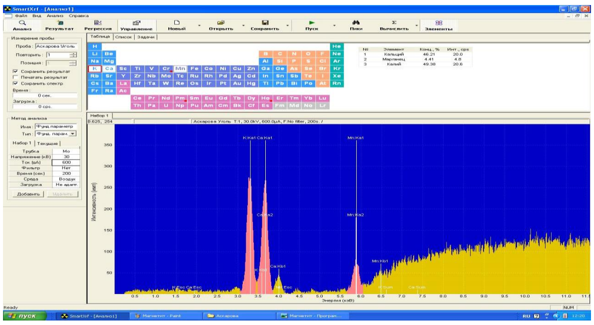

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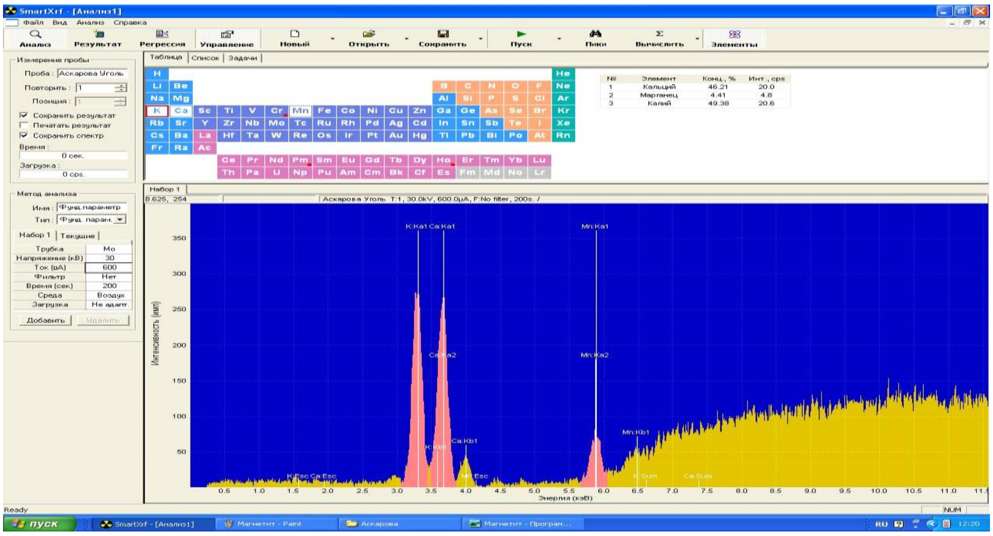

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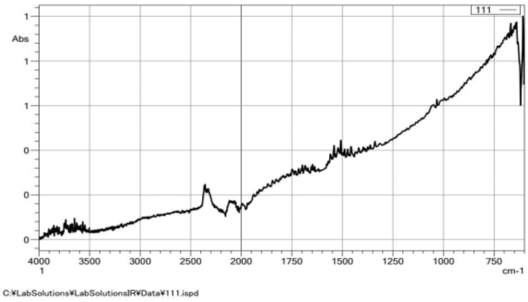
Figure 1 – X-ray fluorescence images of activated carbon, magnetite and magnetite-carbon composite: a-coal, b-magnetite, c-magnetite-carbon composite.

Table 1 shows that the composition of activated carbon is dominated by the proportion of potassium and calcium, as well as a small amount of manganese. First of all, the detection of carbon, oxygen and hydrogen was expected here, but due to the limited capabilities of the method, only elements with a higher atomic weight are detected. For this reason, only iron is found in the composition of magnetite without oxygen detection. Accordingly, elements found in the composition of individual coals and magnetites are found in the composition of the magnetite-carbon composite. And as for X-ray fluorescence images, each element is characterized by its corresponding peaks, and their intensity is directly proportional to the mass fraction.

The results of infrared spectroscopic examination of magnetite, coal and magnetite-carbon composite are shown in Figure 2.



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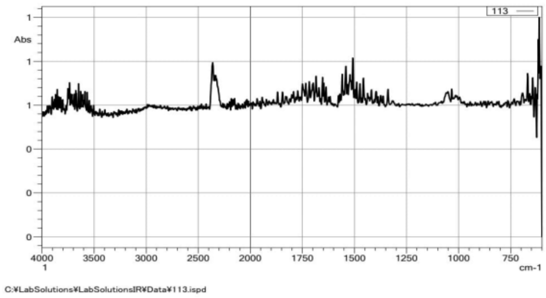

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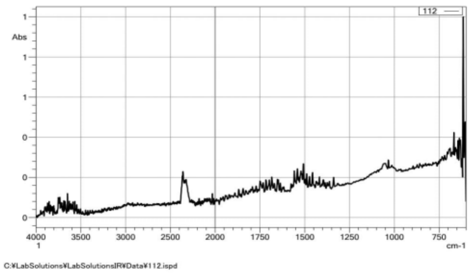

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Figure 2 – IR spectra of magnetite, activated carbon and magnetite-carbon composite: a-coal, b-magnetite, b-magnetite-carbon composite

In the IR spectrum of activated carbon, O-H, N-H bonds of the compounds contained in it were found in the oscillation frequency range 3500-4000 cm^{-1}. Between 2000-2500 cm^{-1}, there may be alkynes and C-H bonds of the aromatic ring, and at an oscillation frequency of 770 cm^{-1}, there may be Me-C, Me-X bonds. The last peak can be attributed to metal compounds Ca, K, Mn, detected in X-ray fluorescence analysis.

Peaks in the oscillation frequency range of 3500-4000 cm^{-1} in the INFRARED spectrum of magnetite can correspond to deformation fluctuations of O-H bonds, i.e. this is the proportion of water in the composition of magnetite. At an oscillation frequency of 1500.770 cm^{-1}, the Fe-O bond is determined.

In the IR spectrum of the magnetite-coal composite, the oscillation band in the IR spectra of coal and magnetite is preserved, and this proves that the composite was formed, that is, magnetite particles penetrated into the structure of coal particles.

Determination of the adsorption of decane on the surface of magnetite, coal and magnetite-carbon composite. Since the composite adsorbent is used to separate petroleum products from water, it was necessary to determine the degree of absorption of water and oil from a mixture of water and oil. Saturated liquid hydrocarbon decane was used as the fat phase. To do this, mixtures of water and oil in various ratios were taken and their adsorption on the surface of the adsorbents was determined. The results of adsorption are presented in Table 2. These results showed that 3 sorbents also better separate decane from water. However, the adsorbent of coal prevailed over other adsorbents and can be justified by the hydrophobicity of coal.

Table 2 – Adsorption of water and decane on the surface of solid adsorbents under conditions of competitive adsorption

Adsorption on the surface of magnetite		
The mass ratio of water and oil before adsorption	Mass ratio of water and oil after adsorption	Percentage of water and oil after adsorption, %
1	2	3
0.7 : 9	0,56 : 8,4	80 : 93
1.4 : 8	1,12 : 7,8	80 : 97,5
2.8 : 6	2,38 : 5,6	85 : 93
4.2 : 4	3,64 : 3,6	88 : 90
5.6 : 2	5,04 : 1, 6	90 : 80
7 : 0	6,44 : 0	92 : 0
Surface adsorption of coal		
The mass ratio of water and oil before adsorption	Mass ratio of water and oil after adsorption	Percentage of water and oil after adsorption, %
0.7 : 9	0 : 8,6	0 : 80
1.4 : 8	0 : 7,7	0 : 96
2.8 : 6	1,05 : 5,7	37,5 : 95

1	2	3
4.2 : 4	2,31 : 3,8	55 : 95
5.6 : 2	3,64 : 1,8	65 : 90
7 : 0	5,04 : 0	72 :0
Magnetite-adsorption on the surface of coal composter		
The mass ratio of water and oil before adsorption	Mass ratio of water and oil after adsorption	Percentage of water and oil after adsorption, %
0.7 : 9	0,42 : 8,6	60 : 96
1.4 : 8	0,84 : 6,5	60 : 81
2.8 : 6	1,89 : 4,8	68 : 80
4.2 : 4	3,01 : 3,1	72 : 78
5.6 : 2	4,20 : 1,3	75 : 65
7 : 0	5,52 : 0	79: 0

Determination of adsorption of magnetite, coal and magnetite-coal composites in oil. In the following studies, adsorption originating from a mixture of water and oil was studied, and magnetite, coal, and magnetite-carbon composite were used as an adsorbent (Table 3). In these studies, the adsorption of oil on the surface of coal also prevails, which means that the nonpolar adsorbate is better adsorbed on the surface of the nonpolar adsorbent.

Table 3 – Adsorption of water and oil on the surface of solid adsorbents under conditions of competitive adsorption

Adsorption on the surface of magnetite		
The mass ratio of water and oil before adsorption	Mass ratio of water and oil after adsorption	Percentage of water and oil after adsorption, %
1	2	3
0.7 : 9	0,56 : 8,8	80 : 97,7
1.4 : 8	1,12 :7,8	80 : 97,5
2.8 : 6	2,26 : 5,6	80,7 : 93,3
4.2 : 4	3,57 : 3,5	85 : 87,5
5.6 : 2	4,97 : 1,5	88,75 : 75
7 : 0	6,44 : 0	92 : 0
Surface adsorption of coal		
The mass ratio of water and oil before adsorption	Mass ratio of water and oil after adsorption	Percentage of water and oil after adsorption, %
0.7 : 9	0 : 8,8	0 : 97,7
1.4 : 8	0 : 6,8	0 : 97,5
2.8 : 6	0,98 : 5.5	35 : 91,6
4.2 : 4	2,17 : 3,1	51,6 : 77,5
5.6 : 2	3,5 : 0,9	68,7 : 45
7 : 0	5,04 : 0	72 : 0
Magnetite-adsorption on the surface of coal composter		
The mass ratio of water and oil before adsorption	Mass ratio of water and oil after adsorption	Percentage of water and oil after adsorption, %
0.7 : 9	0,42 : 8,8	60 : 84
1.4 : 8	0,7 : 7,6	50 : 95
2.8 : 6	1,68 : 5,2	60 : 87
4.2 : 4	2,94 : 2,9	70 : 70
5.6 : 2	4,13 : 0,8	74 : 45
7 : 0	5,42 : 0	77 : 0

The adsorption values were compared with each other. On the surface of coal, the adsorption of decane and oil is high, and the adsorption of water is much lower. Adsorption on the surface of magnetite and composite occurred in the oil-decane-water sequence, and the adsorption values of the 3 substances were close. However, if we compare the adsorption values for 3 adsorbents, then the adsorption on the surface of coal is high, and on the surface of magnetite is low. The reason is due to the presence of a hydrophobic component of coal and composite.

Conclusions. The use of magneto-carbon sorbents can provide a sustainable and effective solution to the problem of water pollution with petroleum products. Sorbents based on activated carbon have been developed by the method of co-deposition. The elemental composition of the resulting magnetite-carbon composite was determined by X-ray fluorescence analysis, most of which, as shown, is Fe.

Functional groups in the composition of a magnetite-carbon composite have been identified by IR spectroscopy. At an oscillation frequency of 3500-4000 cm^{-1}, the O-H bond was determined, and at an oscillation frequency of 1500 and 770 cm^{-1}, the Fe-O bond was determined. These stripes prove that magnetite is part of the composite.

The competing adsorption of water and oil was investigated on the surface of magnetite, coal and their composite. On the surface of coal, the adsorption of oil and decane was high, and the adsorption of water was low. The adsorption of oil and decane on the surface of the magnetite-carbon composite decreased, but was higher than the adsorption of water. But unlike a conventional sorbent, synthesized magnetocarbon sorbents can effectively remove oil pollution from water. Their magnetic properties contribute to easy and rapid separation from water, which increases the practicality of their use in real conditions. In addition, these materials have excellent regenerative and recyclable properties, which highlights their economic and environmental benefits.

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ТҮЙІН

Суды тазарту үшін тиімді сорбенттерді әзірлеу қоршаған ортаның мұнай өнімдерімен ластануын азайту үшін өте маңызды. Осы себепті басқарылатын магнит өрісін қолдана отырып, су бетінен мұнай төгілуін жою үшін магниттік қасиеттері бар күрделі адсорбент алу әдісі ұсынылады. Бұл зерттеуде магнетит-көміртекті композиттерді бірлескен тұндыру арқылы синтездеу және магнетит-көміртекті композиттерді шар диірменінде механикалық ұнтақтау арқылы синтездеу әдістері ұсынылды. Магнитті-көміртекті сорбенттер белсендірілген көмір мен магниттік нанобөлшектерді бірге тұндыру арқылы синтезделді, содан кейін инфрақызыл спектроскопия және рентген-флуоресцентті талдау сияқты әдістерді қолдана отырып физика-химиялық сипаттамалар алынды. Магнетит, көмір және олардың композиті бетіндегі су мен мұнайдың бәсекелестік адсорбциясы жағдайында адсорбциялық қабілеттілігін бағалау жүргізілді. Нәтижелер магнитті-көміртекті материалдардың адсорбция тиімділігі жақсы екенін, магниттік қасиеттеріне байланысты судан тез бөлінетінін және оларды суды тазартуға перспективалы үміткер ететін тамаша қайта пайдалану мүмкіндігін көрсетеді. Бұл нәтижелер магнитті-көміртекті сорбенттер мұнай өнімдерімен ластанған суды тазартудың тиімді шешімін қамтамасыз ете отырып, қоршаған ортаны қалпына келтіру жұмыстарында маңызды рөл атқара алатынын көрсетеді.

РЕЗЮМЕ

Разработка эффективных сорбентов для очистки воды имеет решающее значение для снижения загрязнения окружающей среды нефтепродуктами. По этой причине предложен способ получения комплексного адсорбента с магнитными свойствами для ликвидации разливов нефти с поверхности воды с использованием управляемого магнитного поля. В этом исследовании были предложены методы синтеза магнетит-углеродных композитов путем

совместного осаждения и синтеза магнетит-углеродных композитов путем механического измельчения в шаровой мельнице. Магнито-углеродные сорбенты были синтезированы с использованием активированного угля и магнитных наночастиц путем совместного осаждения, после чего были получены физико-химические характеристики с использованием таких методов, как инфракрасная спектроскопия и рентгенофлуоресцентный анализ. Проведена оценка адсорбционной способности в условиях конкурентной адсорбции воды и нефти на поверхности магнетита, угля и их композита. Результаты показывают, что магнитоуглеродные материалы обладают хорошей эффективностью адсорбции, быстрым отделением от воды благодаря своим магнитным свойствам и отличной возможностью многократного использования, что делает их перспективными кандидатами для очистки воды. Эти результаты свидетельствуют о том, что магнитоуглеродные сорбенты могут играть значительную роль в усилиях по восстановлению окружающей среды, обеспечивая эффективное решение для очистки воды, загрязненной нефтепродуктами.