Experimental Modeling of Biogeosorbents

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Abstract. A new trend in the modeling algorithm oil sorption materials is the adsorptive immobilization of strains of microorganisms on mineral sorbent. The objects of study were clay and zeolite raw and biogeosorbents with oil-oxidizing microorganisms from Biotrin preparation, immobilized on them. During our work we modeled biogeosorbents and estimated their sorption and destructive properties in reference to petroleum hydrocarbons.

Keywords: Biogeosorbents · Biotrin · Petroleum hydrocarbons · Sorption · Zeolites · Clays

1 Introduction

One of the most promising ways to solve problem of oil pollution is to use biogeosorbents, which are sorbent-carriers with oil-oxidizing microorganisms immobilized on their surface (Shchemelinina et al. 2017). It is possible to use zeolite and clay raw as mineral carriers, which have high ion-exchange and sorption properties (Kotova et al. 2017). The purpose of this work is to study sorption and destructive properties of biogeosorbents based on clay and zeolite raw as mineral carriers for Biotrin preparation.

2 Methods and Approaches

The objects of study were:

1. Mineral carriers based on analcime-bearing rocks from Kainskaya zeolite area (Shushkov et al. 2006), clinoptilolite-bearing clays and glauconite-bearing rocks from Chim-Loptyugskoe oil shale deposit (Saldin et al. 2013; Simakova 2016), located in Komi Republic (Russia). For comparison, Ionsorb™ quartz-glauconite sand from Bondarskoe deposit of Tambov region was taken as a control.

2. Strains of microorganisms in the composition of Biotrin biopreparation (Conclusion ... 2017): bacteria *Pseudomonas yamanorum* VKM B-3033D, isolated from heavily soiled railway bed near the city of Syktyvkar (Patent 2615458 RU); yeast *Rhodotorula glutinis* VKM Y-2998D (Patent 2658134 RU); microalgae *Chlorella vulgaris* Beijer. f. *globosa* V. Andr. A1123. Microorganisms (cell titer 10^9) were cultivated according to standard methods. Immobilization of the biopreparation on mineral carriers was carried out in the ratio of 1 part of the biopreparation to 6 parts of the sorbent. Initial sorbents (without Biotrin) and biogeosorbents were added to oil-contaminated water, aerated for 4 days, and total petroleum hydrocarbons (TPH) content in water samples, filtered initial sorbents and biogeosorbents was measured (Method ... 1998).

3 Results and Discussion

Norms for maximum permissible concentration (MPC) of TPH in water of fishery value are 0.05 mg/dm^3 (Order ... 2016). The TPH content in the control water sample is 2.4 times higher than MPC (Table 1).

Experiments showed that samples of the initial analcime-bearing rocks (551, 56403, 1/83) presented adsorption activity in relation to oil products. As a result of the introduction of these samples into oil-polluted water, the content of pollutant in water decreases 2.5–3 times in 4 days, to the MPC. When biogeosorbents are applied to contaminated water (551-B, 56403-B, 1/83-B), the efficiency of water purification decreases and does not reach MPC standards, which indicates decreasing sorption properties after immobilization of microorganisms on the mineral carriers. This is probably due to decreasing surface area of the mineral carriers covered by microorganisms. During the study of initial samples and Biotrin treated samples for destructive properties we revealed that the efficiency of oxidation of oil products in samples 551-B, 56403-B, 1/83-B increases in 4.4, 3.5 and 1.14 times, respectively.

The sorption properties of clinoptilolite-bearing clays are most attractive in sample 541-31. However, taking into account a highly destructive activity of microorganisms in 538-35-B biogeosorbent, it is preferred for remediation of oil contaminated water.

Samples of initial glauconite-bearing rocks have high sorption properties (539-40, 531-56, 315-10, TG). The TPH content in the experimental water is reduced by 3.4–5 times in 4 days relative to a control sample. Biodegradation of hydrocarbons in samples of Biotrin immobilized glauconite-bearing rocks (539-40-B, 531-56-B, 315-10-B, TG-B) ranges from 62 to 76%.

Table 1. Change in the concentration of oil products in water in the presence of initial mineral carriers and biogeosorbents

Initial samples	TPH content*	Biotrin treated samples	TPH content*
<i>Analtime-bearing rocks</i>			
551	0.04 ± 0.014 250 ± 60	551-B	0.11 ± 0.04 57 ± 23
56403	0.046 ± 0.016 130 ± 50	56403-B	0.061 ± 0.021 37 ± 15
1/83	0.048 ± 0.017 250 ± 60	1/83-B	0.071 ± 0.025 220 ± 90
58603	0.071 ± 0.025 250 ± 60	58603-B	0.064 ± 0.022 90 ± 40
<i>Clinoptilolite-bearing clays</i>			
538-35	0.085 ± 0.030 50 ± 20	538-35-B	0.037 ± 0.013 40 ± 16
541-31	0.035 ± 0.012 250 ± 60	541-31-B	0.058 ± 0.021 100 ± 40
<i>Glauconite-bearing rocks</i>			
539-40	0.024 ± 0.009 58 ± 23	539-40-B	0.072 ± 0.025 20 ± 8
531-56	0.027 ± 0.009 63 ± 25	531-56-B	** 15 ± 6
315-10	0.09 ± 0.03 11 ± 4	315-10-B	0.021 ± 0.007 17 ± 7
TG	0.035 ± 0.012 90 ± 40	TG-B	0.045 ± 0.016 34 ± 14
Oil-contaminated water (control)	0.12 ± 0.041		

Note: * – in the numerator, TPH content in the experimental water, mg/dm³, in the denominator – TPH content in the initial sorbents and biogeosorbents after the experiment, mg/g. ** – no data

4 Conclusions

Our experiments resulted in modeling of biogeosorbents based on clay and zeolite raw and oil-oxidizing microorganisms from Biotrin biopreparation immobilized on them. We determined that samples of initial sorbents showed a high adsorption activity with respect to oil products. TPH content in water was reduced by 2.5–5 times, up to or substantially below MPC. We revealed that microorganism cells could reduce sorption properties of mineral carriers, at the same time providing oil destruction. Biodestruction of oil products with biogeosorbents for 4 days was 12–77%.

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