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АКАДЕМИЯСЫ» РҚБ

«ҚАЗАҚСТАН РЕСПУБЛИКАСЫ
ҰЛТТЫҚ ҒЫЛЫМ АКАДЕМИЯСЫ» РҚБ

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ИЗВЕСТИЯ

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STRENGTHENING OF SOILS BASED ON OILED SOIL

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Abstract. Large-scale oil pollution of the environment, as well as the increasing volume of oil production in the Republic of Kazakhstan brings to the forefront the problem of localization, elimination of pollution and development of the method of utilization of oil-contaminated soils. Consequently, it is necessary to develop more convenient and cheaper ways of utilization of oil-contaminated soils. To solve the problem of utilization of oil contaminated soils, a number of studies have been carried out in recent years on the disposal of oil contaminated soils. In the work

investigated the level of "background value" of the content of oil hydrocarbons in the oiled soil of industrial zone Oil and gas production department-1 (OGPD-1) of JSC "Ozenmunaigas". It was found that on average per 1 kg of oiled soil the content of oil hydrocarbons is 119.294 g, in percentage terms 13%. The level of pollution of oiled soil of industrial zone of OGPD-1 of JSC "Ozenmunaigas" belongs to the third level of background value, self-cleaning ability of soil is very heavy. Nine new formulations of the composition for soil strengthening on the basis of oiled soil of industrial zone OGPD-1 of JSC "Ozenmunaigas" were developed. The test results showed that the reinforced soils on the basis of oiled soils of industrial zone OGPD-1 of JSC "Ozenmunaigas" have strengths M20 and M10. According to the code of regulations CR RK 24-75 and standard ST RK 973-2015 it is recommended to use the new reinforced soil composition in the construction of unpaved roads in the bottom layer of bases or as an additional base layer for III, IV, V categories of highway. The developed method of utilization of oiled soils makes it possible to use oiled soil in the construction of in-field unpaved roads, allows to expand the raw material base for obtaining construction materials for road construction, solves one of the most important environmental problems in the field of soil and atmosphere protection.

Keywords: soil, reinforcement, organic binders, oiled soil, utilisation, road construction.

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МҰНАЙМЕН ЛАСТАНҒАН ТОПЫРАҚ НЕГІЗІНДЕ ТАС ЖОЛДЫҢ ТӨМЕНГІ ҚАБАТЫН НЫҒАЙТУ

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Аннотация. Қоршаған ортаның кең ауқымда мұнаймен ластануы, сондай-ақ Қазақстан Республикасында мұнай өндіру көлемінің артуы ластануды оқшаулау, жою және мұнаймен ластанған топырақты кәдеге жарату тәсілін әзірлеу өзекті мәселелердің біріне айналды. Сондықтан мұнаймен ластанған топырақты жоюдың ыңғайлы және арзан әдістерін жасау қажет. Ластанған топырақты жою мәселесін шешу үшін соңғы жылдары мұнай ластануын жою бойынша бірқатар зерттеулер жүргізілді. Жұмыста «Өзенмұнайгаз» АҚ мұнай газ-өндіру басқармасы-1 (МГӨБ-1) өндірістік аймағынан ластанған топырақтағы мұнай көмірсутектерінің құрамынан «фондық мән» деңгейі зерттелді. Орташа есеппен 1 кг ластанған топыраққа мұнай көмірсутектерінің мөлшері 119,294 г., пайыздық мәнде 13% құрайтыны анықталды. Бұл «Өзенмұнайгаз» АҚ МГӨБ-1 өндірістік аймағынан ластанған топырақтың ластану деңгейі фондық мәннің үшінші деңгейіне жатады, яғни топырақтың өзін-өзі тазарту қабілеті өте ауыр жағдайда. «Өзенмұнайгаз» АҚ МГӨБ-1 өндірістік аймағынан ластанған топырақ негізінде топырақты нығайту үшін 9 жаңа композициялық рецептура әзірленді. Сынақ нәтижелері «Өзенмұнайгаз» АҚ МГӨБ-1 өндірістік аймағынан алынған ластанған топырақ негізінде нығайтылған топырақтардың М20 және М10 беріктігі бар екенін көрсетті. ҚР қағидалар жинағы 3.01-101-2013 құрылыс нормасына және ҚР СТ 973-2015 сәйкес негіздердің төменгі қабатында немесе автомобиль жолының III, IV, V санаттары үшін негіздің қосымша қабаты ретінде жаңа нығайтылған топырақ құрамын пайдалану ұсынылады. Ластанған топырақты кәдеге жаратудың әзірленген тәсілі кәсіпшілік ішіндегі топырақ жолдарын салуда ластанған топырақты пайдалануға мүмкіндік береді, жолдарды салу кезінде құрылыс материалдарын алу үшін шикізат базасын кеңейтуге мүмкіндік береді, топырақ пен атмосфераны қорғау саласындағы маңызды экологиялық міндеттердің бірін шешеді.

Түйін сөздер: топырақ, нығайту, органикалық тұтқыр, мұнаймен ластанған топырақ, кәдеге жарату, жол құрылысы.

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УКРЕПЛЕНИЯ ГРУНТОВ НА ОСНОВЕ ЗАМАЗУЧЕННОЙ ПОЧВЫ

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Аннотация. Широкомасштабное нефтезагрязнение окружающей среды, а также возрастающий объем добычи нефти в Республике Казахстан вызывает на первый план проблему локализации, устранения загрязнений и разработку способа утилизации нефтезагрязненных почв. Следовательно, необходимо разрабатывать более удобные и дешевые способы утилизации нефтезагрязненных почв. Для решения проблемы утилизации замазученных почв в последние годы проведены ряд исследований по ликвидации нефтяных загрязнений. В работе исследован уровень «фонового значения» содержания углеводородов нефти в замазученной почве промзоны нефтегазодобывающего управления-1 (НГДУ-1) АО «Озенмунайгаз». Установлено, что в среднем на 1 кг замазученной почвы содержание углеводородов нефти составляют 119,294 г., в процентном выражении 13%. Уровень загрязнения замазученной почвы промзоны НГДУ-1 АО «Озенмунайгаз» относится к третьему уровню фонового значения, самоочищающиеся способности почвы очень тяжелые. Разработаны 9 новые рецептуры состава для укрепления грунтов на основе замазученной почвы промзоны НГДУ-1 АО «Озенмунайгаз». Результаты испытания показали, что укрепленные грунты на основе замазученных почв промзоны

НГДУ-1 АО «Озенмунайгаз» имеют прочности М20 и М10. В соответствии строительной нормы СП РК 3.01-101-2013 и СТ РК 973-2015 рекомендовано использовать новый укрепленный состав грунта при строительстве грунтовой дороги в нижнем слое основании или в качестве дополнительного слоя основания для III, IV, V категорий автомобильной дороги. Разработанный способ утилизации замазученных почв даёт возможность использовать замазученную почву в строительстве внутрипромысловых грунтовых дорог, позволяет расширить сырьевую базу для получения строительных материалов при строительстве дорог, решает одну из важнейших экологических задач в области охраны почвы и атмосферы.

Ключевые слова: грунт, укрепление, органические вяжущие, замазученная почва, утилизация, строительство дороги

Introduction. Soil contamination by total petroleum hydrocarbons (TPH) in oil fields is a worldwide environmental problem (Kerimbekova, et.al., 2024). In particular, the dense distribution of oil wells in low-permeability oil reservoirs has led to regional overlapping of contamination (Tauova, et.al., 2022).

In order to solve the problem of utilization of oiled soils, a number of studies have been carried out in recent years to eliminate oil contamination. The concentration of total petroleum hydrocarbons in the soil of each oil field was calculated by Monte Carlo modeling. Risks were evaluated considering multiple receptors and sources of risk. The results showed that the average concentration of total petroleum hydrocarbons exceeded 2100 $mg \cdot kg^{-1}$ (Bo Wu, et.al., 2021).

The results of studies of neutralization process of soil contaminated with crude oil using neutralizer obtained on the basis of humic substances are presented. It is established that during neutralization hydrocarbon fractions with low boiling point (C12-C17) completely disappear, the content of hydrocarbon fractions with high boiling point (C20-C23) significantly increases, the content of oil components and metals, including toxic ones, decreases (Ergozhin, et.al., 2020).

The use of oiled soil as materials for civil construction is considered as one of the effective alternative methods of utilization of contaminated soil. It has been shown in (Oluremi, et.al., 2014; Oluremi, et.al., 2015) that geochemical and geotechnical properties of oil promote the accumulation of heavy high-molecular-weight asphalt-resin components in the upper part of the soil, which increase its binding properties. Therefore, contaminated soils were tested for possible use as engineering material.

In (Karkush, et.al., 2018) the influence of artificial oil contamination of soil on its mechanical properties (in particular, on the "modulus of soil reaction", defined as the ratio of applied pressure to the value of soil subsidence) was studied. A mixture of 49% light fuel oil, 21% kerosene and 30% water (mixture No.1) and 70% light fuel oil with 30% kerosene (mixture No.2) were used as model pollutants. The tests were carried out in static and cyclic loading mode. In static mode there was observed a 28 and 42% decrease of reaction modulus in

comparison with uncontaminated soil at contamination with mixture No. 1 and No. 2 respectively; in cyclic loading mode the decrease of reaction modulus amounted to 32 and 47%. Morphological description of soils by horizons was carried out, granulometric composition, physico-chemical properties of soils and content of petroleum products were studied. The results of the study will serve as a reference point in the study of contaminated soils in case of an accidental oil spill, as well as allow to reliably determine the rate and degree of their contamination (Kanbetov, et.al., 2023).

Increasing the degree of contamination of clayey soil with crude oil leads to a slight decrease in its density (according to (Akinwumi, et.al., 2014), by 4% at an oil content of 10%) and an increase in the Atterberg limit. The effects on soil fertility of crude oil contaminated soil were studied, depending on the type and amount of clay. No correlation between density and soil compaction was found, and some density determinations were found to be unreliable due to interference from petroleum products. The water repellency of kaolinite-based soil was low or zero (especially for 30 and 40 % clay), but the water repellency of smectite-based soil was three orders of magnitude higher (Alvarez-Coronel, et. al., 2023).

Oil-contaminated soil has geotechnical and environmental problems that arise from leaks in oil storage tanks, accidental spills, and inlet and outlet pipelines. For example, a leakage was recorded at an oil refinery station in the vicinity of Nineveh province, where the soil is known for its high plasticity. The study conducted a comprehensive investigation of the engineering properties of soil contaminated with crude oil, diesel, kerosene and gasoline on both the dry and wet sides of the compaction curve. The results show that the shape of the compaction curve changes to a curve with two peaks, while the maximum dry density decreases by 6% due to oil contamination. The study shows that the addition of oil contamination to coarse-grained soils significantly reduces the surface roughness of the particles. It has been found that the geotechnical properties of oil-contaminated soils are mainly determined by physicochemical and/or physical interactions between the soil and the contaminant (Karabash, et. al., 2023; Haghsheno, et. al., 2022; Walied, et. al., 2022).

Petroleum is a complex multicomponent system consisting mainly of various hydrocarbons such as alkanes, cycloalkanes, mono-, bi- and polyaromatic compounds, resins and asphaltenes. A review (Stepanova, et. al., 2022) discusses bioremediation, a biological approach to oil degradation carried out mainly by microbes. The data indicate the great potential of bioremediation methods for cleaning up soils from oil.

Currently, the above methods of utilization of oiled soils are not widely used, each of these methods has its own advantages and disadvantages. Currently, at the oilfields of the Republic of Kazakhstan is used mainly technical method of oil-contaminated soil remediation, which consists in removal and burial of the upper "oiled" layer of soil on special landfills. Now some of these sludge reservoirs are full and construction of new ones is required. Consequently, it was necessary to develop more convenient and cheaper ways of utilization of oil-contaminated soils

(Gilazhov, et. al., 2020). In the literature, there are almost no works on the use of oil sludge waste and oiled soils as organic binders for soil reinforcement in road construction.

The purpose of this work is to study the properties of oiled soils of the territory of oil and gas production department of OGPD-1 of JSC "Ozenmunaigas" and to study the possibility of their utilization by using them as organic binding materials for soil reinforcement.

Materials and basic methods

In determining the level of contamination of oiled soil of the industrial zone of OGPD-1 of JSC OJSC "Ozenmunaigas" the methodology of PND F 16.1:2.21-98 was used. Characteristics of oil isolated from oiled soil were investigated by various physicochemical methods and state standards for oil and petroleum products such as GOST 20287-91, GOST 2117-99, GOST 3900-2022, GOST 6356-75.

Research results

When determining the level of contamination of oiled soil of industrial zone of OGPD-1 of JSC "Ozenmunaigas", samples were taken in three glasses of 100 g of oiled soil (figures 1, 2). Hot water was added to the beakers with samples and put on heating.

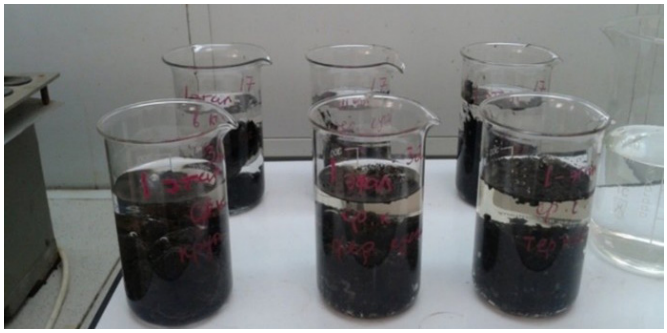

Figure 1- Sample samples before heating

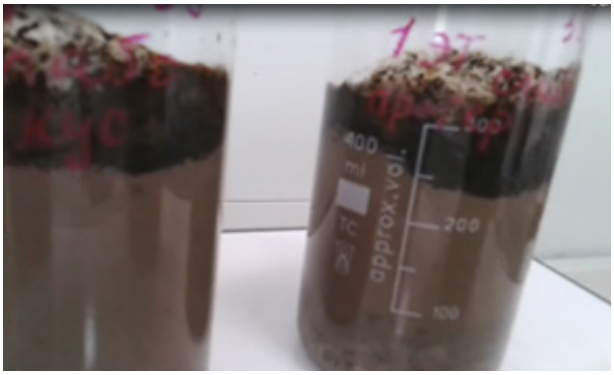

Figure 2- Oil release during heating of oiled soil

When adding boiled water, the appearance of oil film in all 3 glasses was noted. Heating was carried out at a temperature of 90 °C for 1 hour, after stopping the heating, separated the upper oil layer and weighed. The lower layer, i.e. the soil was dried and the sample was taken for hydrocarbon determination analysis. The mass of oil in the beakers amounted to: 1-11.9640 g, 2-13.6415 g, 3-10.1827 g, with an average of 11.9294 g, a percentage of 13%.

The results of studies of physical and chemical properties of oil extracted from the oiled soil of industrial zone OGPD-1 of JSC "Ozenmunaigas" are presented in Table 1. The research was carried out in order to develop new formulations for soil reinforcement and binding properties of oiled soil of industrial zone OGPD-1 of JSC "Ozenmunaigas". Nine formulations of soil reinforcement compositions based on oiled soil were developed for laboratory testing.

Table 1- Characteristics of oil extracted from oiled soil of industrial zone of OGPD-1 of JSC "Ozenmunaigas"

Characteristics	Indicators
Hydrocarbon content, %	13
Content of impurities (sand), %	87
Density, ρ_4^{20}, g/cm^3	0.883
Solidification temperature, °C	31
Molecular weight	280
Fractional composition according to state standard 2177-82:	
Boiling point, °C	110
Boiled to temperature, °C, vol. %	
up to 200	2.0
up to 250	4.3
up to 300	15.7
up to 350	48.2

Laboratory tests of physical and mechanical properties of reinforced soil on the basis of oiled soils of industrial zone OGPD-1 of JSC "Ozenmunaigas" were conducted in the accredited testing laboratory of road-building organizations "REAL WAY" LLP. Table 2 presents the formulations of soil strengthening compositions.

Table 2- Recipe for soil reinforcement on the basis of oiled soil from industrial zone of OGPD-1 of JSC "Ozenmunaigas"

No.	Soil, g	Oiled soil from the industrial zone of OGPD-1 of JSC "Ozenmunaigas", g	Cement, g	Crushed stone, g	Hydrocarbon content, %
Lab. No. of formulation	Novo-Ozen soil (light loamy, coarse)				
1/5	470	500	30	-	5.5
1/7	570	400	30	-	4.4
1/6	620	350	30	-	3.85

2/6	718	252	30	-	4.4
2/9	418	252	30	300	4.4
2/10	450	220	30	300	3.85
	Atyrau soil (light sandy loam, dusty)				
3/2	608	315	30	-	5.5
3/3	680	290	30	-	4.4
3/4	717	253	30	-	3.85

During laboratory testing of physical and mechanical properties of reinforced soil based on oiled soils, the following characteristics were determined - compressive strength of water-saturated samples at 20°C, kgs/cm^2, strength grade and modular load. The results of the test are presented in Table 3.

Table 3- Physical and mechanical properties of reinforced soil based on oiled soils

No.	Lab. No. of formulation	Compressive strength of water-saturated samples at 20°C, MPa after 28 days	Strength grade	Modular load, MPa
1	1/5	2.17	M 20	250
2	1/7	2.44	M 20	250
3	1/6	1.34	M 10	
4	2/6	1.49	M 10	
5	2/9	0.98	M 10	
6	2/10	1.14	M 10	
7	3/2	1.62	M 10	
8	3/3	1.50	M 10	
9	3/4	1.87	M 10	

Discussion

In some regions of the country, “background values” of hydrocarbon content in soil are used as tentatively permissible levels, at which plant productivity or microbiological processes are restored within one year due to the self-purifying capacity of soil.

The following limits are currently accepted for non-agricultural land:

- Level 1 - 1,000...5,000 mg/kg, light
- Level 2 - 5 000...10 000 mg/kg, medium
- Level 3 - over 10,000 mg/kg, heavy

The results of the study show that the level of contamination of oiled soil of industrial zone OGPD-1 of JSC “Ozenmunaigas” belongs to the third level of background value, the self-cleaning ability of the soil is very heavy (Gilazhov, et. al., 2018).

For strengthening of soils mainly oil liquid bitumens of SG class of 25/40, 40/70, 70/130 grades (with viscosity not more than 100 s), MG class of 25/40, 40/70, 70/130 grades (with viscosity not more than 100 s) should be used, the quality of which should meet the requirements of state standard for oil road liquid improved

bitumens. It is allowed to use liquid bitumen that meets the requirements of state standard for liquid petroleum bitumen road, and instead of class SG should be used class A of grades A-3, A-4, A-5 and instead of class MG - class B of grades B-4 and B-5. The choice of organic binder and additives depends on the composition and properties of the reinforced soils, as well as the conditions of their operation in road and airfield pavement.

At strengthening of soils with binders physical-mechanical, physical-chemical and chemical processes occur, as a result of which a strong water- and frost-resistant road-building material - strengthened soil - is formed. As a result of regulation of the mentioned processes the reinforced soil layer acquires a given structure, maximum density, strength and frost resistance.

The authors have developed 9 formulations of the composition for soil strengthening on the basis of oiled soil of industrial zone OGPD-1 of JSC "Ozenmunaigas" for laboratory testing. Table 2 and Figures 3 and 4 show the formulations of soil strengthening compositions.

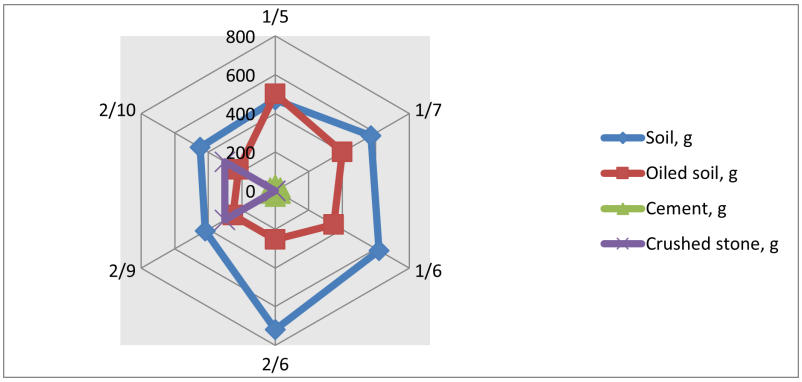

Figure 3 - Recipe of JSC "Ozenmunaigas" soil composition (light coarse loamy sandy loam) reinforced with oiled soil

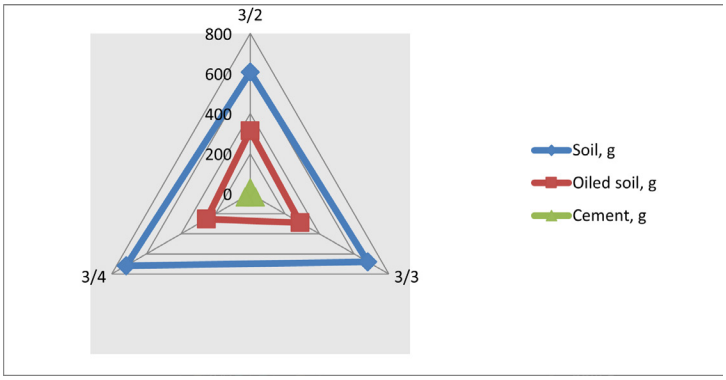

Figure 4 - Recipe of Atyrau soil composition (light sandy loam, dusty) reinforced with oiled soil

The test results (Table 3) showed that the reinforced soils based on oiled soils of the industrial zone of OGPD-1 of JSC "Ozenmunaigas" have the strength of M20 and M10. Such soils in accordance with the construction norms SP RK 3.01-101-2013 and ST RK 973-2015 are recommended to be used in the construction of unpaved roads in the bottom layer of bases or as an additional base layer for III, IV, V categories of highways.

Conclusion

The properties of oiled soils from sludge reservoirs of OGPD-1 JSC "Ozenmunaigas" were studied to develop a method of utilization of oil and gas production wastes - oiled soil. The possibility of their use as organic binding materials for soil reinforcement is shown. A new environmentally safe method of utilization of oiled soils of industrial zone OGPD-1 of JSC "Ozenmunaigas" by using them in the construction of a dirt road in the bottom layer of bases or as an additional layer of base for III, IV, V categories of road.

The developed method of utilization of oiled soil makes it possible to use oiled soil in the construction of in-field dirt roads, allows to expand the raw material base for obtaining construction materials for road construction, solves one of the most important environmental problems in the field of soil and atmosphere protection.

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