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ҰЛТТЫҚ ҒЫЛЫМ
АКАДЕМИЯСЫ» РҚБ

«ҚАЗАҚСТАН РЕСПУБЛИКАСЫ
ҰЛТТЫҚ ҒЫЛЫМ АКАДЕМИЯСЫ» РҚБ

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METHOD OF RECULTIVATION OF POLLUTED SOILS WITH OIL PRODUCTS

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Abstract. This article presents results of assessing monitoring state of technogenic load on natural environment in the context of development of the Zhanazhol oil field in the Aktobe region and activities of other oil-producing enterprises in Kazakhstan. It is demonstrated that, due to production activities of several large oil-producing enterprises, significant accumulations of oil-contaminated soils have formed on the territory of the Republic, causing substantial environmental pollution. Principal potential sources of soil contamination with oil and petroleum products include on-land transport vehicles, oil storage facilities, oil refineries, and transportation systems for petroleum products. The most problematic environmental situations associated with land pollution, particularly during accidental spills of oil and petroleum products during production and transportation, have been identified

and evaluated.. Therefore, within oil-producing fields, it is crucial to implement reclamation measures aimed at restoring soil fertility. Reclamation method has been developed for soils contaminated with petroleum products using biopreparations derived from plant and food industry waste. Scientific significance of this study lies in the advancement of oil spill remediation methods based on the use of rice husks and biopreparations that contribute to mitigating and eliminating environmental impacts of oil production and transportation. Study results can be applied to reclamation of oil-contaminated lands in other regions and serve as a reference for master's and PhD dissertations at the Kazakh National Research Technical University named after K.I. Satpayev.

Key words: oil fields, development, oil products, oil spill, soil pollution, natural environment, bioreclamation

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МҰНАЙ ҚАЛДЫҚТАРЫМЕН ЛАСТАНҒАН ТОПЫРАҚТЫ ҚАЛПЫНА КЕЛТІРУ ТӘСІЛІ

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Аннотация. Мақалада Ақтөбе облысындағы Жаңажол кен орнын игеру кезінде және Қазақстандағы басқа да мұнай өндіруші кәсіпорындардың қызметі нәтижесінде табиғи ортаға техногендік жүктеменің мониторингі жағдайын бағалау нәтижелері берілген. Республика аумағында бірқатар ірі мұнай өндіруші кәсіпорындардың өндірістік қызметі нәтижесінде мұнаймен ластанған топырақтың орасан зор мөлшері жинақталып, қоршаған ортаны айтарлықтай ластағаны көрсетілген. Топырақтың мұнай және мұнай өнімдерімен ластануының негізгі әлеуетті көздеріне жерүсті көліктері, мұнай қоймалары, мұнай өңдеу зауыттары, сондай-ақ мұнай өнімдерін тасымалдайтын көліктер жатады. Мұнай өндіру және тасымалдау кезінде мұнай мен мұнай өнімдерінің төтенше төгілуі кезінде жер ресурстарының ластануының ең проблемалық экологиялық жағдайлары анықталды және бағаланды. Төтенше мұнай төгілулері нәтижесінде ластанған жер учаскелері ұлғаюын жалғастыруда. Сондықтан мұнай кен орындарының аумағында жердің құнарлылығын қалпына келтіру үшін мелиоративтік шараларды жүргізу өте маңызды мәселе болып есептеледі. Өсімдік және тағамдық қалдықтар негізіндегі биологиялық өнімдерді пайдалана отырып, мұнаймен ластанған жерлерді биоремедиациялау технологиясы әзірленді. Жұмыстың ғылыми маңыздылығы мұнай өндіру мен тасымалдаудың табиғи ортаға әсерін азайтуға және жоюға көмектесетін күріш қауызы мен биопрепаратты қолдану негізінде төгілген мұнай қалдықтарын жою әдістерін жетілдіруде. Зерттеу нәтижелері басқа аймақтардағы мұнаймен ластанған жерлерді рекультивациялауда және олардың өсімдік жамылғысын қалпына келтірумен айналысатын эколог-ғалымдар, сонымен қатар Қ.И. Сәтбаев атындағы Қазақ ұлттық техникалық зерттеу университетінің магистранттары мен докторанттары диссертациялық жұмыстарында пайдалана алады.

Түйін сөздер: мұнай кен орындары, игеру, мұнай өнімдері, мұнай төгінділері, топырақтың ластануы, табиғи орта, биологиялық қалпына келтіру

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СПОСОБ РЕКУЛЬТИВАЦИИ ЗАГРЯЗНЕННЫХ ПОЧВ НЕФТЕПРОДУКТАМИ

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Аннотация. В статье приведены результаты оценки состояния мониторинга техногенной нагрузки на природную среду в условиях освоения нефтяного месторождения Жанажол в Актюбинской области, а также в результате деятельности других нефтедобывающих предприятий Казахстана. Показано, что на территории республики в результате производственной деятельности ряда крупных нефтедобывающих предприятий накопились огромные количества нефтезамазученных грунтов, существенно загрязняющих окружающую природную среду. К основным потенциальным источникам загрязнения почв нефтью и нефтепродуктами можно отнести наземные транспортные средства, нефтехранилища, нефтеперерабатывающие предприятия, а также транспорт, перевозящий нефтепродукты. Установлены и оценены наиболее проблемные экологические ситуации загрязнения земельных ресурсов при аварийном разливе нефти и нефтепродуктов в процессе добычи и транспортировки нефти. Площади же загрязненных земель продолжают увеличиваться в результате аварийных разливов нефти. Поэтому

на территории нефтедобывающих месторождений, весьма актуальным является проведение рекультивационных мероприятий по восстановлению плодородия земель. Разработан способ рекультивации загрязненных почв нефтепродуктами с использованием биопрепаратов на основе отходов растительного и пищевого происхождения. *Научное значение* работы заключается в совершенствовании методов утилизации нефтяных разливов на основе применения рисовой шелухи и биопрепарата, способствующих снижению и устранению воздействия добычи и транспортировки нефти на природную среду. Результаты исследования могут быть использованы при рекультивации нефтезагрязненных земель других регионов при восстановлении их растительности, а также в диссертационных работах магистрантов и докторантов Казахского национального исследовательского технического университета имени К.И. Сатпаева.

Ключевые слова: нефтяные месторождения, разработка, нефтепродукты, разлив нефти, загрязнение почвы, природная среда, биорекультивация

Introduction. One of the serious problems of environmental protection during the development of oil fields is the elimination of the consequences of oil pollution of soil. Pollution of soil with oil products disturbs its ecological state and deforms the natural structure of biogeocenoses. Elimination of oil spills can significantly improve the environmental situation in areas immediately adjacent to technological facilities.

On the territory of Kazakhstan, as a result of production activities of a number of large oil producing enterprises, huge amounts of oil-soiled soils have accumulated, significantly polluting the natural environment. The areas of contaminated land continue to increase as a result of accidental oil spills. This leads to irreversible changes in the morphological composition, physicochemical and microbiological properties of the soil cover. Further accumulation of oiled soils is unacceptable and requires immediate reclamation activities to restore land fertility. The existing technologies of oil-contaminated land remediation, namely mechanical, physical-chemical and thermal, do not meet the requirements of ecological and economic efficiency and can cause long-term damage to the ecosystem (Kuldeev, et al., 2021; Bekbasarov, et al., 2007; Baidhzhanov, et al., 2021).

The section of the Caspian pipeline Kenkiyak-Kumkol passes through three regions of the Republic: Aktobe, Ulytau, Kyzylorda (Fig.1).

Figure 1 – CPC oil fields

For the conditions of Kenkiyak, Zhanazhol, Kumkol fields the most environmentally friendly method of oil-contaminated soil remediation is the use of various biological additives and preparations that intensify the activity of hydrocarbon-oxidizing microorganisms, resulting in the purification of oil-contaminated soils by microbiological destruction of oil hydrocarbons contained in them. In this connection, the development of oiled soil remediation technology based on the use of cheap and highly effective biopreparations is an urgent task (Novoselova, et al., 2009; Stupin, 2009).

The aim of the work is to develop an effective technology for reclamation of oiled lands through the use of highly effective biopreparations to ensure the normal functioning of the ecosystem in the conditions of the Zhanazhol field.

Materials and research methods. Samples of oil-contaminated soils of different sites of Zhanazhol deposit in Aktobe region of Kazakhstan were used for the research.

The choice of soil monitoring methods was carried out taking into account the available sources of pollution and types of soil pollution: chemical, biochemical, biochemical, microbiological and others. The analysis of existing methods of ecological soil monitoring shows that due to high cost and technological complexity the application of a number of them is limited. Therefore, an effective approach to determine the degree of soil contamination by oil products is the use of bioindication and biotesting methods.

Research results.

Assessment of oil waste accumulation at the Zhanazhol field. In many researches devoted to the reclamation of oil-contaminated land plots, various methods have been considered, such as the use of oil waste as a secondary raw material, but only in limited areas of application, in particular, as a construction mastic, waterproofing

materials, road construction, etc. (Bek, et al., 2020; Kuldeev, et al., 2021). At the same time, further accumulation of oil waste and its negative impact on the environment undoubtedly forces to search for new and more promising areas of oil waste utilization.

Monitoring of the soil condition in the territory of the field is carried out twice a year, in spring and fall. Observations of chemical contamination of soils to the depth of 5-20 cm - three times a year, including the summer period. At that, the main indicators of physico-chemical properties of soils (chemical composition, soil extract, mechanical composition) determining their condition, degree of pollution by oil products, heavy metals, radionuclides and state of surface radiation background are recorded. Zonal subtype of soils in the characterized territory is gray-brown, desert soils. Significant areas of the territory are occupied by solonts and their complexes. The characteristic feature of saline soils is predominance of soda salts (NaHCO3) in their composition. Figure 2 shows the results of the study of heavy metals and oil products content in the soils of the field in the summer period of the year (Merekeyeva, 2024).

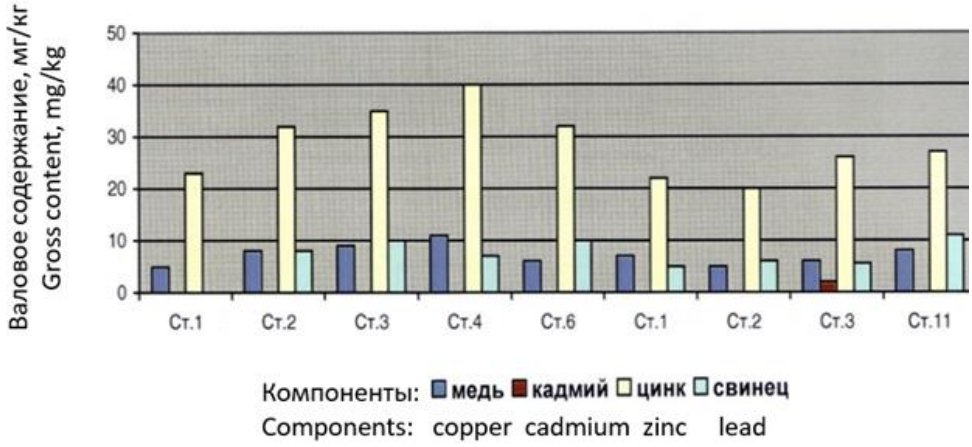

Figure 2 – Content of heavy metals in soils of the deposit

All soils of the study area are characterized by low humus content, small layer of horizon (A-HB), low content of nutrition elements, low absorption capacity. These features of soils are a consequence of bioclimatic conditions of soil formation: low precipitation, high summer plus temperatures, which determined the predominance of xerophytic semi-shrubs and saltbush with the participation of ephemerals and wormwoods in the vegetation cover.

Changes in the mechanical composition of surface soil horizons are associated with the process of deflation (wind erosion), therefore, the soils of the deposit are deflation-hazardous. The stimulating factor of deflationary processes development is mechanical disturbance of surface soil horizons and destruction of vegetation. The main measure to combat deflation on the territory of the field is sowing of

drought-resistant wild and salt-tolerant grasses, shrubs and tree plantations. The system: soil - vegetative vegetation is very sensitive to changes in the conditions of existence.

Studies of the spring period of 2023 showed that the system "soil-vegetation" contains heavy metals and hydrocarbons to a greater or lesser extent. The gross content of heavy metals in soils had a mosaic structure and was characterized by some features of cumulation. In spring period, the gross content of elements in soil samples was within the limits: zinc 18.09 - 30.01 μg/g; copper 3.09 - 6.28 μg/g; cadmium 0.08 - 0.23 μg/g; lead 0.50 - 8.17 μg/g. A clear series of metals was traced: zinc - lead - copper - cadmium. On the majority of the transects the indicators of metals leveled off. The concentration of hydrocarbons in most cases ranged from trace to 0.850 μg/g dry soil (Almatova, 2022)

To date, as a result of accidental oil spills and other violations of the technological regulations of the field Zhanazhol accumulated more than 15319.34 tons of oiled soil, as a result of which hundreds of hectares of land were out of economic turnover.

Bioreclamation of oiled land resources. Intensive development of oil production and transportation is inextricably linked with accidental spills of oil products. Oil products from the place of their spillage are removed in the form of oiled soil and stored in special authorized barns. At present, hundreds of thousands of tons of oil waste have accumulated in oil producing regions, which continue to pollute the environment with harmful emissions. Further accumulation of oil waste is inadmissible without reclamation measures to restore soil fertility, i.e. it is necessary to carry out agrotechnical, phytomeliorative and microbiological measures to clean up oil pollution. The most effective direction of oil-contaminated soils treatment is bioreclamation of oiled soils.

In ecotoxic studies of oil products, great importance is attached to the search for regulators of the process of self-cleaning of soil from oil by accelerating its degradation. In practice, the most promising direction of cleaning oil-contaminated soils is bioremediation of oiled soils using biopreparations as oil destructors. The advantage of biochemical method is ecological safety and low cost, because for utilization with the help of microorganisms 1 ton of waste requires 50-80 dollars, when buried the cost rises to 200 dollars, and when incinerated - up to 650 dollars / ton.

The reclamation process was carried out in the field near well №25, i.e. in the area where oiled soil was formed. To restore soil fertility in the field at the pilot composting site, food waste from the enterprise is used as oil-destroying ingredients along with the proposed biopreparation «Bioshel», which eliminates the need to transport multi-tonnage oil waste to a special site for its reclamation. In addition, the remediated soil will later be used as biohumus for growing cultivated or wild plants near the field, which will be the first experimental process of ecologization of oil waste at the site of its formation.

Soil soils heavily contaminated with petroleum products were collected and

bored (Fig. 3). Technological samples were taken from the oil-contaminated soil stockpile for laboratory studies on the biodegradation of petroleum products in the soil using the proposed biopreparation.

Figure 3 – Collected Oil-Contaminated Soil Stockpiles

For reclamation of oiled soils we used biopreparation «Bioshel», obtained by composting rice husk with the use of cellulose-degrading aerobic and anaerobic soil microorganisms. The biopreparation «Bioshel» is an excellent substrate for converting petroleum waste into biocompost. Production of biopreparation «Bioshel» from rice husk is a science-intensive process. The production of biopreparation is carried out on special compost fields near rice cleaning plants, where huge stocks of rice husks are accumulated. For adaptation of microorganisms (strains) of the biopreparation to oil-contaminated soils, oil-contaminated soils are added to the composition of the preparation in dosed quantities. The adapted biopreparation actively transforms oil-contaminated soils into biocompost mainly under aerobic conditions. The intensity of degradation of oil products in soil mainly depends on the amount of biopreparation, mixing time, aeration depth, temperature and pH of the soil environment. The intensity of degradation of petroleum products increases as the proportion of the preparation in the soil increases due to the increase in the porosity of the soil. The intensity of oxidation and, consequently, degradation of petroleum products is also promoted by soil mixing, which results in additional delivery of air oxygen to the lower layers of soil (Lazarev, 2013).

Discussion of the results.

Mixing of oiled soil with «Bioshel» preparation and some ingredients, including rice husks, seeds of wild plants and fillers promotes restoration and accumulation of air and moisture in them. Accumulation of moisture and air in oil-contaminated

soils creates favorable conditions for activation of indigenous soil microflora and accelerated degradation of oil products.

The results of a series of experiments show that in all variants of the experiment, as the time elapses and mixing, the oiled soil gradually loses the sharp smell of oil products and, accordingly, the color of the soil becomes darker. In all experiments without exception after 4-6 weeks the soil completely darkens and the oil odor disappears. These visual and qualitative indicators testify in favor of the fact that the biopreparation «Bioshel» is an excellent soil regulator that promotes the transfer of petroleum products into biocompost. The used biopreparation, creating conditions for biodegradation of petroleum products, improves agrophysical and agrochemical condition of soil, thus restoring its fertility. Hydrocarbons in composting conditions under the influence of mineralization and humification are transformed into biohumus. In general, the process of biodegradation of petroleum products in soil follows the scheme: Soil + Microorganisms (in conditions of greenhouse effect) = Biocompost + carbon dioxide + heat.

Biopreparation «Bioshel» in comparison with known imported biopreparations (Devoroil, Bioprin, etc.) is characterized by high efficiency of oil-contaminated soil remediation due to the following properties: high rate of hydrocarbons destruction; possibility of using the preparation in liquid and solid form; high activity towards oil; content of easily accessible soil microorganisms, actively working in aerobic and anaerobic conditions (Kunbazarov, et al., 2004; Slyusarenko, et al., 2013).

Soil treatment with the help of biopreparation «Bioshel» is carried out by mixing oil waste and biopreparation in the ratio of 9:1 at high humidity under conditions of «greenhouse effect». The mixture is placed in the form of a heap with a height of 1.0 m and higher, then kept for one month with periodic mixing. To reduce biopreparation costs and increase the efficiency of the composting process, freshly obtained biocompost containing active microorganisms, as well as various wastes, including food waste, is used as a bacterial «starter». Laboratory and scale-up tests were conducted on oil wastes from well №17 of Kyzylkiya field of Petro Kazakhstan Kumkol Resources JSC (the technological scheme of oiled land resources reclamation is shown in Fig. 4.

The biocompost obtained in the process of bioremediation of oiled soils is an excellent fertilizer for obtaining environmentally friendly foodstuffs, which opens a new promising direction in the use of anthropogenic wastes as secondary raw materials.

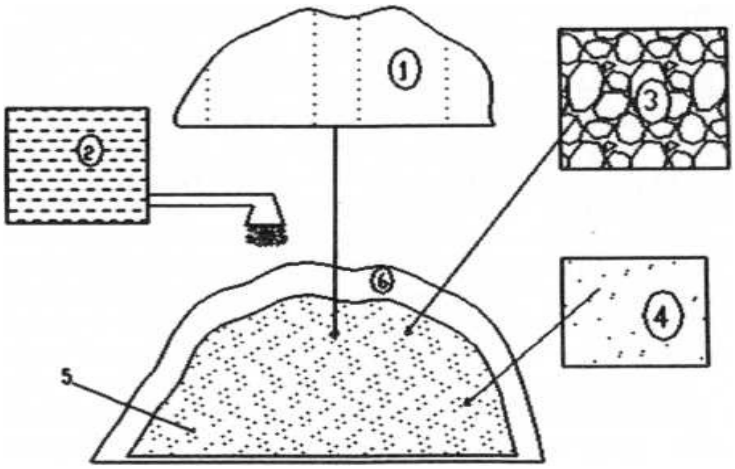

Figure 4 – Technological scheme of bioreclamation of oiled soil:
1 - oiled soil, 2 - water, 3 - food waste, 4 - bioslurry «Bioshel», 5 - biocomposting, 6 - hydro cover for creating «greenhouse effect».

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The characteristic features of the oily waste composting project are shown in Fig.5. The composted oiled soil is kept for 1-1.5 months in the conditions of «greenhouse effect» with periodic mixing with the maintenance of appropriate humidity and the presence of a sufficient number of oil-degrading aerobic and anaerobic microorganisms (Nurpeisova, et al., 2021; Urazgaliyeva et al., 2023).

Figure 5 – Pilot project of oily waste composting

Ecological and economic efficiency of using the new technology of reclamation of oiled lands simultaneously allows:

- reduce the technogenic load on the soil surface, which creates favorable conditions for the vital activity of soil microorganisms;

- utilize oil spills in the form of biohumus, while spilled oil products are subject to reclamation at the place of their formation without their transportation to special barns.

Conclusions

The conducted monitoring of soil pollution by oil and oil products shows that the main potential sources are ground transportation vehicles, oil storage tanks, oil refineries and transportation, which is the primary source of oil products.

The developed bioreclamation technology, firstly, reduces the anthropogenic load on the soil surface due to biodegradation of oil spills, and, secondly, at the same time the utilization of spilled oil in the form of biohumus is carried out. In the work, for the first time on the basis of application of a new technology of reclamation of oiled land resources with the use of biopreparation obtained from wastes of plant and food origin, a new approach to the problem of utilization of oil-contaminated soils and restoration of their fertility, with the production of biohumus is proposed.

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