ABSTRACT

of the dissertation by Khozhanepesova Fariza Musabekovna on the topic "Development of a Method for Remediation of Oil-Contaminated Soils Using Adsorption-Immobilized Microorganism Destructors" submitted for the degree of Doctor of Philosophy (PhD) in the educational program 6D05201 (6D060800) - "Ecology"

Assessment of the current state of the scientific or scientific-technological problem being solved

The strategy of the Republic of Kazakhstan to enter the top 30 most developed countries in the world is closely linked to the transition to a "green economy." In this direction, priority tasks include the restoration of contaminated areas and effective management of industrial waste. The intensive development of the oil and gas industry, especially in the West Kazakhstan and Mangistau regions, leads to large-scale oil contamination of soils. In these regions, arid climate, high salinity, and low biological activity complicate soil restoration. Although various carriers are used in global practice for immobilizing microorganisms, the use of agroindustrial plant waste and their effectiveness in arid regions has not been sufficiently studied, which determines the relevance of scientific research in this direction.

Basis and initial data for developing the topic

The basis for developing the dissertation topic was the relevance of ensuring the environmental safety of the Republic of Kazakhstan, protecting the natural environment of oil and gas producing regions, and restoring oil-contaminated soils. The intensive development of oil production in the western regions of Kazakhstan, especially in the Mangistau region, leads to an increase in the level of soil contamination with petroleum hydrocarbons, causing ecosystem degradation and increased technogenic load.

The research topic was chosen in accordance with the priorities of scientific and technological development of the Republic of Kazakhstan, the concept of transition to a "green economy," as well as state programs in the field of environmental protection and rational use of natural resources. In addition, the results of laboratory experiments conducted by the author in previous years, data from microbiological, physicochemical, and analytical analyses, as well as materials obtained within the framework of a research project (IRN AP25796069) under the "Young Scientist" program of the Republic of Kazakhstan were used as initial research sources.

Thus, the dissertation topic arises from specific environmental problems, is developed based on modern scientific data and experimental results, and its scientific and practical significance is fully substantiated by the initial data.

Justification for the necessity of conducting scientific research work

Currently, the intensive development of the oil and gas industry, especially in the western regions of Kazakhstan, including the Mangistau region, leads to large-scale contamination of soils with petroleum hydrocarbons. Petroleum hydrocarbons disrupt the physicochemical and biological properties of soils, limiting the natural recovery of ecosystems. The high cost of traditional physicochemical methods for cleaning oil-contaminated soils, their environmental risks, and low efficiency in arid climate conditions necessitate the development of environmentally safe bioremediation methods.

In recent years, the use of hydrocarbon-oxidizing microorganisms has been considered an effective method; however, the low resistance of free cells to adverse environmental factors limits their practical application. In this regard, improving methods for immobilizing microorganisms on carriers is an urgent scientific task. Literature data indicate a number of disadvantages of mineral carriers, which requires the search for cheap, accessible, and environmentally clean alternative carriers.

In this context, the use of plant-based carriers from agroindustrial waste is relevant from a scientific and practical perspective. Their potential in enhancing the viability of microorganisms and the effectiveness of biodegradation in arid climate conditions has not been sufficiently studied. Therefore, approaches are based on developing technologies for bioremediation of oil-contaminated soils through the immobilization of hydrocarbon-oxidizing microorganisms on plant carriers.

Scientific novelty

In the course of the dissertation research, the following scientific results were obtained, which determined its scientific novelty:

- For the first time in standard laboratory conditions (25-28°C, ph 7.0-7.5), the biodegradation efficiency of the consortium Dietzia maris 22K and Rhodococcus erythropolis AT7 immobilized on mineral (zeolite, expanded clay) and agro-industrial waste (buckwheat and rice husks) was compared, and a 1.3-4.7-fold advantage of organic carriers was revealed (buckwheat husks 58.4%, rice husks 52.1 zeolite 42%, expanded Clay 23%).

- Based on the combination of adsorption immobilization and local agro-industrial waste, a method of bioremediation of oil-contaminated soil adapted to the arid conditions of the Mangystau region has been developed. In the method, buckwheat and rice husks were compared as carriers, as a result of which buckwheat husks were identified as the optimal carrier (cellulose 20-27%, lignin 8-15%, rutin ≥28.0 mg/100g; immobilization efficiency 92.3%, fixation density 3.2±0.4×10 кл cell/cm2). The effectiveness of the method was confirmed in field tests: a biopreparation based on buckwheat husk showed a degradation efficiency of 94.0% TMP. The difference in laboratory (58.4%) and field (94.0%) results is due to synergism with local microflora, daily temperature fluctuations and outdated composition of Field oil.

- The role of rutin (28.8 mg/100g) in buckwheat husk in the protection of microorganisms was substantiated. Buckwheat husk prevailed over rice husk in all studied conditions: 52.1% versus 58.4% under standard conditions, 75.0% versus

35.0% at optimum temperature high salinity (+32°C, 10% NaCl), 54.0% versus 38.4% in combination stress (+42°C, 10% NaCl). However, as extreme conditions intensify, the degree of predominance of buckwheat decreases: a difference of 2.1 times at +32°C and 1.4 times at +42°C, which indicates that rutin has a limit on its antioxidant defense ability. In field tests (+22-28°C), the priority of buckwheat husk was confirmed: 57.9% (1.6 times) against 94.0%.

Main provisions submitted for defense:

- A comparative study of immobilization of Dietzia maris 22K and Rhodococcus erythropolis AT7 consortium on mineral (zeolite, expanded clay) and organic (buckwheat and rice husks) carriers revealed that the biodegradation efficiency of petroleum hydrocarbons on organic carriers was 1.3-4.7 times higher than on mineral carriers: buckwheat husk — 58.4%, rice husk — 52.1%, zeolite — 42%, expanded clay — 23% (standard conditions: 25-28°C, pH 7.0-7.5).

- A bioremediation method for oil-contaminated soils was developed based on the use of local agro-industrial waste as carriers for adsorption immobilization. Buckwheat husk was established as the optimal carrier: cellulose content 20-27%, lignin 8-15%, immobilization efficiency 92.3%, attachment density $3.2\pm0.4\times10^6$ CFU/cm². Degradation follows first-order kinetics ($R^2>0.95$, $k=0.0187$ day^{-1}). The method's effectiveness was confirmed under field conditions in Mangystau region — total petroleum hydrocarbon degradation reached 94.0%.

- The role of rutin (28.8 mg/100g) in buckwheat husk in protecting microorganisms from abiotic stress was experimentally demonstrated. Biodegradation efficiency of buckwheat husk exceeded rice husk under all investigated conditions: 1.1-fold under standard conditions (58.4% vs 52.1%), 2.1-fold under elevated temperature and salinity (+32°C, 10% NaCl) (75.0% vs 35.0%), and 1.4-fold under combined stress (+42°C, 10% NaCl) (54.0% vs 38.4%). It was shown that the antioxidant protective capacity of rutin has limitations as extreme conditions intensify.

Practical significance of the work

The results obtained during the dissertation research make a significant contribution to the development of theoretical and methodological foundations of the bioremediation method for oil-contaminated soils.

During the research, new scientific knowledge was obtained about the mechanisms of adsorption immobilization of microorganisms on plant materials, patterns of influence of abiotic factors of arid climate (high temperature, salinity) on the activity of immobilized biodestructors, kinetic patterns of biodegradation of petroleum hydrocarbons in oil-contaminated soils, as well as condition-dependent influence of biochemical composition of plant carriers (rutin, lignin) on microbial activity.

The results of the dissertation research can serve as a theoretical and methodological basis for setting new fundamental and applied research tasks in the field of using agroindustrial waste, developing innovative bioremediation methods, and implementing principles of transition to a "green economy."

The developed method can be applied in oil-producing regions of Western Kazakhstan (Mangistau, Atyrau regions) for cleaning oil-contaminated soils,

industrial sites, sludge collectors, as well as for eliminating consequences of emergency oil and petroleum product spills. The economic efficiency of the method is 30-40% compared to traditional physicochemical methods due to the use of accessible plant raw materials (rice and chickpea husks) and no need for expensive equipment.

An application for a utility model patent of the Republic of Kazakhstan has been filed for the developed method, which confirms the innovative nature of the method and the possibility of its application in industry.

The materials of the dissertation work can be used in higher educational institutions in the preparation of students in the specialties "Ecology," "Biotechnology," "Environmental Protection and Rational Use of Natural Resources," as well as in training environmental workers of oil and gas companies.

Author's personal contribution

The author defined the research tasks for bioremediation of oil-contaminated soils (Mangistau region), collected sample specimens, and conducted laboratory microbiological and physicochemical analyses. Performed experimental work on immobilizing microorganisms on plant carriers, determining optimal parameters, and studying biodegradation kinetics. Conducted statistical analysis and comprehensive generalization of the obtained results.

Approbation of the work

The research results were presented and discussed at the following international scientific-practical conferences: International Scientific-Practical Conference "Modern Science: New Approaches and Actual Studies," 3rd degree diploma for participation in the "Best Scientific Work" competition in the "Biological Sciences" section; April 21, 2020, Prague, Czech Republic; XVI Republican Scientific-Practical Conference of Students, Master's Students, PhD Candidates "Youth, Science and Innovation"; April 9, 2020, Aktobe; International Scientific Conference of Students and Young Scientists "Farabi World"; April 6-9, 2020, Almaty; International Scientific-Educational Forum "The Caspian Region at the Crossroads of Eras and Cultures: Problems and Prospects of the Sustainable Development Paradigm," September 22-26, 2025, Aktau; an article was accepted for the 16th International Conference "Future Environment and Energy" (ICFEE 2026), March 6-8, 2026, Fukuoka, Japan (to be published in E3S Web of Conferences indexed by Scopus).

Publications

Based on dissertation materials, 10 scientific works were published, including: 3 articles in journals recommended by the Committee for Quality Assurance in Education and Science of the Ministry of Science and Higher Education of the Republic of Kazakhstan, 2 publications in journals included in the Scopus database. Other articles were published in collections of international scientific and scientific-practical conferences.

Structure and volume of the dissertation

The dissertation consists of an introduction, four chapters, a conclusion, A list of 194 references and appendices. The total volume of the work consists of 27 pages, including 15 tables and 125 figures.

The dissertation work was completed at the Department of Ecology and Life Safety of Sh. Yessenov Caspian University of Technology and Engineering.