

REPUBLIC OF AZERBAIJAN

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ABSTRACT

of the dissertation for the degree of Doctor of Philosophy

**DIRECTIONS OF EXPANDING THE APPLICATION OF
NANOTECHNOLOGIES IN THE OIL AND GAS
EXTRACTION INDUSTRY OF AZERBAIJAN**

Speciality: 5309.01 – “Organization of industry and public policy”

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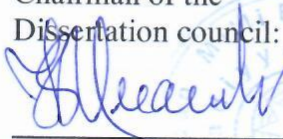
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GENERAL DESCRIPTION OF THE RESEARCH

Relevance of the topic and research degree. The oil and gas industry has always been an industry that needs new technologies and is more innovative than most sectors in terms of their application. Because the production of oil and gas is a complex process, and in addition to the role of knowledge and skills and qualified personnel in the sector, new technologies occupy a special place in oil and gas production. Nowadays, oil cannot be produced as easily as it was at the beginning of the 20th century. Now the drilling of oil wells and production processes are carried out with the most modern technologies, and without them it is impossible to carry out the work effectively. The application of new technologies is of great importance in the conditions which production is becoming more difficult and resources are being depleted. In such situation it is impossible to imagine the economy of the oil industry without new technologies, and to study it separately. Innovations are the most important value-creators in the oil and gas sector. Large oil companies are investing and continue to be interested in new technologies and their scientific research. Thus, innovative technologies are likely to remain an important component of global and domestic energy production for a long time to come.

One of the promising new technologies is nanotechnologies. Scientific research in the field of nanotechnologies is developing continuously. Their application and results are observed in numerous economic sectors. Companies that aim to increase profitability and economic efficiency, have begun to use nanotechnologies for increasing oil and gas production, eliminating negative effects in production, extending the life cycle of equipment, increasing the efficiency of processes and etc., and their application is being further expanded. Thus, the application of nanotechnology-based products and technologies is of great importance in the oil and gas industry. A number of oil companies around the world are among the first companies which implement nanotechnologies in the industry level. The experience of companies from Norway, Saudi Arabia, Iran, the

United States and a number of other countries shows that the application of nanotechnologies in the oil industry brings great economic benefits.

Currently, the application of nanotechnologies in oil and gas extraction industry in Azerbaijan is not at a satisfactory level. By 2020, these newly introduced technologies have been applied in about 150 wells. This is only 3 percent of the wells in SOCAR's balance sheet. Although there are many negative trends, such as the decline and difficulty of oil production, the application of nanotechnologies is still at an early stage in SOCAR. Transnational companies operating in the country's oil sector do not use nanotechnologies. Despite the implementation of a number of successful applications and projects of nanotechnologies in the oil and gas extraction industry, due to a number of objective reasons explored in the dissertation, currently a small part of oil production in Azerbaijan (0.03%) is realized with the application of nanotechnologies. In order to reveal the reasons for the poor application of these technologies and to expand them in the oil industry, it is important to study them comprehensively and them to be the subject of scientific research. It is important to put forward proposals to reveal the positive effects of nanotechnologies in the oil and gas production of Azerbaijan, their economic attractiveness and application possibilities. These mentioned factors are of great importance in choosing the topic of the research and are an expression of its applicability.

Regarding the degree of development of the topic, it can be noted that the use of nanotechnologies in the oil and gas extraction industry in Azerbaijan and their economic research began in 2005. The theoretical basis of the research consists of the provisions of economic theory and innovation management. The researched subject covers the study of the theoretical and practical aspects of the application of nanotechnologies and their economic effectiveness in the oil and gas extraction sector in Azerbaijan.

The material-technical base of nanotechnologies used in oil and gas extraction in Azerbaijan is at the initial level, the transfer of

powerful technologies has not yet taken place, and no large-scale innovation-investment projects have been developed in this field. Currently, at the research level, the laboratory of nanotechnologies operates in the relevant structural institution of SOCAR, where the potential opportunities in the field of nanotechnologies are investigated.

In the area of researching the application opportunities and problems of nanotechnologies in the oil and gas extraction industry of Azerbaijan the works of A. Mirzajanzadeh, Kh. Yusifzadeh, E. Shahbazov, E. Kazimov, A. Maharramov, R. Gurbanov, E. Mammadov, E. Ramazanova, H. Mirelamov, Ch. Mammadov and others can be mentioned in particular. However, the works of all these scientists are devoted to the scientific and technical aspects of nanotechnologies.

Organization and management of national innovation system in Azerbaijan, analysis of innovation potential of the country, role of technological changes in industry, theory, models, and management issues of innovations have been studied by T. Aliyev, G. Yuzbashiyeva, G. Suleymanov, M. Atakishiyev, A. Huseynova, A. Taghiyev, I. Aslanzade, T. Huseynov, F. Gasimov, B. Khidyrov, L. Hamidova and other scientists.

The issues of using nanotechnologies in various economic fields, the application possibilities of nanotechnologies and nanomaterials in relation to solving the problems of the oil and gas industry, their importance in environmental protection, the general economic effects and regularities of nanotechnologies, and the assessment of their economic profitability have been studied by foreign scientists D. Meehan, A. El-Diasty, A. Regab, M. Bell, E. O'Rourke, M. Morrison, P. Shapira, J. Youtie, K. Bojczuk, T. Crawley, G. Foladori, N. Invernizzi, A. Bhattacharya, K. Seear, A. Petersen, D. Bowman and other scientists.

The economic aspects of the development and application of nanotechnologies in the oil industry of Azerbaijan have not been studied. Therefore, the need to solve the problems in the industry has increased the applicability of the dissertation.

Research purpose and objectives. The purpose of the dissertation work is to investigate the current application level, opportunities and economic effects of nanotechnologies in the oil and gas extraction industry of Azerbaijan, to determine the directions and ways of expanding their application and increasing their economic efficiency.

It has become a necessity in the current conditions to ensure serious growth of the country's economy by carrying out economic reforms on the basis of innovative-technological novelties. The experience of developed countries shows that the economic growth of these countries in the conditions of globalization is based on the economic system leaning on innovative technological innovations.

Taking into account the above, it is envisaged to implement the following tasks, which are organically connected to each other, in order to realize the set goal:

- Researching the theoretical bases of nanotechnologies applied in the oil and gas extraction industry;
- Substantiating of the factors necessitating the application of nanotechnologies in oil and gas extraction;
- Analyzing the current state of application of nanotechnologies in Azerbaijan's oil and gas extraction industry and discovering its problems, identifying shortcomings in the work of institutions operating in this field;
- Evaluation of existing methods used to determine the economic profitability of nanotechnologies applied in oil and gas extraction;
- Determination of necessary proposals for increasing the economic profitability of nanotechnologies;
- Determination of directions for investigation and elimination of organizational-management problems in the development and application of nanotechnologies in the oil and gas extraction sector;
- Providing proposals related to the expansion and stimulation of the application of nanotechnologies in the oil and gas extraction industry.

The object and subject of the research. The object of the

research is the oil and gas extraction industry within the State Oil Company of the Republic of Azerbaijan. The subject of the study is the investigation of the problems related to the expansion of the application of nanotechnologies in the oil and gas extraction industry and the increase of their economic profitability.

Research methods. The historical and logical approach was taken as a basis in the dissertation work, and a methodological complex, which includes the methods of logical generalization and systematization, analysis and synthesis, economic and statistical analysis was used. In this process, special attention was paid to the features and practice of innovations in the oil sector.

In methodological approaches, the scientific works of foreign countries' and our country's economists about the importance of nanotechnologies and innovations in the oil industry, publications in periodicals, scientific reports and articles, relevant reports of SOCAR and annual reports and data of the Department of Nanotechnologies were used. For evaluation analytical work of international companies and expert opinions, financial security approaches, the "Unified Methodology for the Economic Evaluation of Investment Projects in Oil and Gas Extraction" developed by the Oil and Gas Research and Design Institute of SOCAR, the "Methodology for Conducting Independent Expertise for Determining the Innovation Orientation of Technologies" developed by the Institute for Scientific Research on Economic Reforms under the Ministry of Economy and appropriate methods developed by the author were used.

Key provisions provided for defense: The main provisions of the thesis defended are:

- Intensive application of high technologies in the oil and gas extraction sector of Azerbaijan is of great importance in the period of deepening technological development and IV industrial revolution, as well as in the conditions of decreasing reserves and production difficulties;

- There is a serious need to create an economic strategy for the development and application of nanotechnologies, which includes

important mechanisms and tools in the oil and gas extraction sector through the application of nanotechnologies;

- Application of nanotechnologies and products/materials developed on the basis of these technologies in the oil and gas extraction sector is economically profitable;

- The directions for organization of application of nanotechnologies in real mode and for improvement of management forms at the macro and micro economic levels in the country have been determined;

- There are serious deficiencies in the financing of the development and application of nanotechnologies in the oil industry, and purposeful steps should be taken to eliminate them;

- Since the preparation and application of nanotechnologies in our country, and especially in the oil and gas extraction industry, is carried out in an unsystematic and uncoordinated manner, there is a need to adopt a state program covering all spheres in this field and to establish a Coordination Council within the program;

- Development and application of nanotechnologies in developed countries and leading oil companies show similar characteristics;

- Based on the realities and perspectives of the modern era, the development and application of nanotechnologies in the oil and gas extraction industry should be implemented in new directions.

Scientific novelty of the research. The following scientific novelties have been achieved in the dissertation work:

- The objective and subjective reasons for the unsatisfactory level of application of nanotechnologies in the oil industry, including the imperfection of legislation, limited financial sources, lack of management structures related to nanotechnologies, weak promotion of nanotechnologies, consideration of investments in this field as risky, and the problems of training highly qualified specialists in this field are explained;

- For the first time in Azerbaijan, the profitability of the application of nanotechnologies in the oil and gas extraction industry was evaluated for the implemented projects and the risks were

calculated for the success indicators of the projects. Based on the analysis of current data on the additional oil production that will be obtained from the expansion of the application of nanotechnologies in SOCAR, a forecast for maximizing the production was developed;

- The importance of nanotechnologies and directions for the formation of nanoindustry from the point of view of carrying out reforms in the economy of Azerbaijan are substantiated. Besides, the importance of developing targeted projects on the basis of nanotechnologies for the return to operation of the wells that are on SOCAR's balance sheet and have been decommissioned for many years, but have oil reserves potential, and of attracting direct investments to this field has been substantiated;

- The creation and development directions of the scientific and innovative structures that condition the formation and development of the nanoindustry in our country have been determined, the block schemes of its efficient management, financial sources for the funding of nanotechnologies and mechanisms for stimulating the application of nanotechnologies in the oil industry have been developed;

- Proposals on the directions of expanding the application of nanotechnologies in the oil and gas extraction industry were prepared taking into account the near and far perspectives, also the need to adopt a state program on the development, adoption and application of nanotechnologies in the oil and gas extraction sector taking into account the directions of technological development in the world and the requirements of the IV industrial revolution was substantiated;

- The importance of creating a structure of complex and systematic management of nanotechnologies in oil and gas extraction industry enterprises was shown, and the expediency of creating an institution that coordinates the development, preparation, and scientific research of nanotechnologies in our country was justified. Also, in order to improve management, the need to define mechanisms for strengthening cooperation between the private, public sector and scientific institutions in the field of nanotechnologies was substantiated;

- Opportunities and directions of using foreign experience for the formation and development of the nanotechnology economy in Azerbaijan and especially in the oil industry have been determined.

Theoretical and practical significance of the research. The research determines the priority areas of application of nanotechnologies to ensure economic efficiency in the oil and gas extraction industry. The analysis of the current problems in the oil sector and the proposals for their solution with the application of nanotechnologies can serve as a conceptual basis for the comprehensive preparation of the foundations of the oil industry's strategic development in the coming years.

The results of the dissertation work can be used as a methodological basis for improving the application of nanotechnologies in oil and gas extraction, and for determining the mechanisms and tools of their use in oil companies.

The results of the dissertation work were used in the activity of the Department of Nanotechnologies of the State Oil Company of the Republic of Azerbaijan, in the assessment of new technologies' application in oil fields.

Approbation and application of the research. The main points of the dissertation were presented by the author at the conferences "Economic development strategy of Azerbaijan" (Baku, 2019), "Current problems of sustainable development and humanitarian sciences" (Baku, 2019) and "Scientific research and innovation" (New York, 2019).

The results of the research were reported in twelve scientific works, including 1 article in a journal considered reputational by the international community, 1 article in a journal published in Russia, 2 scientific works at local conferences, 1 scientific work at an international conference and 7 articles in periodical scientific journals that are recommended publications in the Republic of Azerbaijan for the main results of dissertations. The main scientific results of the dissertation were accepted for application by State Oil Company of the Republic of Azerbaijan (certificate dated 13.03.2020).

Total volume of the dissertation with characters, indicating the volume of the structural units of the dissertation separately. Cover and table of contents (2495 characters), introduction (15633 characters), chapter I (72553 characters), chapter II (79038 characters), chapter III (101737 characters), conclusion (11966 characters), bibliography (25628 characters) and appendices (11364 characters), and the total is 175 pages and 320444 characters. The volume of the dissertation consists of 268622 characters, excluding pictures, tables, graphs, bibliography and appendices.

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KEY PROVISIONS SUBMITTED TO DEFENSE

1. Intensive application of high technologies in the oil and gas extraction sector of Azerbaijan is of great importance in the period of deepening technological development and IV industrial revolution, as well as in the conditions of decreasing reserves and production difficulties.

Oil production in Azerbaijan has been showing a decline in recent years, which can be attributed to the exhaustion of the energy of most onshore fields, the increasing complexity of the production process in the oil and gas industry due to the fact that production is carried out in deeper and offshore fields. Table 1 shows the dynamics of oil production in the Republic of Azerbaijan.

**Table 1. Dynamics of oil production
in the Republic of Azerbaijan (thousand tons)**

| Years | whole country | including | | | |
|-------|---------------|-------------------------|--------|--|-------|
| | | Transnational companies | SOCAR | | |
| | | | total | with the application of nanotechnologies | % |
| 2011 | 45625.4 | 37224.5 | 8400.9 | 0.168 | 0.002 |
| 2012 | 43389.8 | 35100 | 8289.8 | 0.608 | 0.007 |
| 2013 | 43483.9 | 35169 | 8314.9 | 2.022 | 0.024 |
| 2014 | 42022.7 | 33702.3 | 8320.4 | 2,420 | 0.029 |
| 2015 | 41586 | 33425.5 | 8160.5 | 2,767 | 0.034 |
| 2016 | 41034.5 | 33512.1 | 7522.4 | 3.021 | 0.040 |
| 2017 | 38688.9 | 31261.8 | 7427.1 | 5.008 | 0.067 |
| 2018 | 38814 | 31272 | 7542 | 6,940 | 0.092 |
| 2019 | 37453.7 | 29770.6 | 7683.1 | 9.142 | 0.119 |
| 2020* | 34585.4 | 27178.2 | 7407.2 | - | - |
| 2021* | 34575.9 | 26683.8 | 7892.1 | - | - |

Source: compiled by the author based on SOCAR's official website (<http://socar.az>) and annual reports.

*Note: In 2020-2021, research on nanotechnology was not conducted due to the coronavirus pandemic.

At the same time, an analysis of oil prices shows that prices have actually tended to fall over recent years and have shown volatility. The price changes of Brent which is considered benchmark oil, Russia's Urals, and Azerbaijan's AzeriLight in 2010-2020 years are shown in the graph in Figure 1.

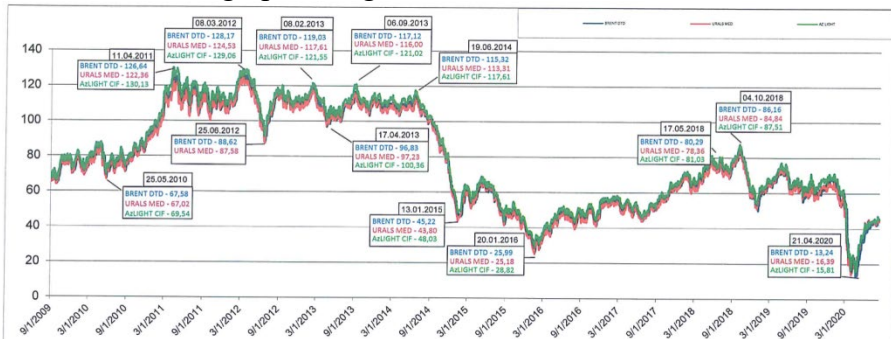


Figure 1. Changes in oil prices in 2010-2020

Source: Prepared by author based on S&P Global's Platts Crude Oil Marketwire periodicals.

The application of nanotechnologies (NT) in the oil and gas extraction industry of our country is conditioned by the following factors:

- Increasing operating costs as a result of the oil production becoming more difficult;

- The need to operate profitably by minimizing costs in any competitive environment in the background of low and unstable oil prices;

- Decrease of energy production costs via innovations in the alternative energy sector in the world market, and the need to reduce costs with increased competitive pressures on the oil sector;

- Demand for technologies that ensure the minimization of damage to the environment due to increasingly strict environmental requirements and legislations on a global scale, as well as in our country;

- In the oil and gas production, up to 60% of the hydrocarbon reserves in the fields cannot be extracted by traditional methods.

In the direction of solving the abovementioned, there are wide application possibilities of nanotechnologies in oil and gas extraction. As a result of the scientific and technical achievements in drilling and production, it is critical to use these opportunities to minimize costs and maximize production to operate competitively in low oil prices and complex conditions, as well as to minimize environmental damage.

2. There is a serious need to create an economic strategy for the development and application of nanotechnologies, which includes important mechanisms and tools in the oil and gas extraction sector through the application of nanotechnologies.

In Azerbaijan, the development and application of nanotechnologies in the oil industry has been carried out for nearly 10 years. Any kind of nanotechnology has been applied in only 3 percent of the wells on SOCAR's balance sheet. The preliminary results of the applications showed that after the application of the nanosystem in the wells, the number of minor and major repairs significantly decreased, the amount of produced oil increased, the amount of water decreased, as well as the dynamics of the mechanical mixture in the oil produced from the wells showed a decrease several times.

Table 2 shows the dynamics of additional oil and gas production achieved by SOCAR over the years as a result of the application of nanotechnologies.

Table 2. Additional oil and gas production achieved over the years in SOCAR with the use of NT

| product \ years | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 |
|--------------------------|------|------|------|------|------|------|------|------|-------------|
| oil (tonnes) | 112 | 405 | 1348 | 1613 | 1845 | 2014 | 3339 | 4625 | 5500 |
| gas (m ³) | - | - | - | - | - | - | - | - | 2.6 mln. |

Source: 2019 Annual report of Nanotechnologies Department of SOCAR

Note: In 2020-2021, research on nanotechnology was not conducted due to the coronavirus pandemic.

The industrial application of nanotechnologies has not been implemented in foreign oil companies operating in our republic.

These companies do not have specialists for research and development of nanotechnologies and no research laboratories in Azerbaijan. In the application of nanotechnologies, the characteristics of wells and fields must be taken into account, and these projects must be approached individually, so in many cases it is not possible to directly apply nanotechnologies developed in SOCAR or abroad in the fields operated by them.

It was determined that although the number of nanotechnology patents in the international patent databases showed an increase over the years, the number of nanotechnology patents published from Azerbaijan in 2014-2020 was only 5. Relatedly, table 3 shows the number of nanotechnology articles in the international science index database (Web of Science) in 2017-2021 and the position of Azerbaijan in the world.

Table 3. Number of articles related to nanotechnology in the international science index database in 2017-2021

| <i>No</i> | <i>Country</i> | <i>2017</i> | <i>2018</i> | <i>2019</i> | <i>2020</i> | <i>2021</i> |
|-----------|----------------|-------------|-------------|-------------|-------------|-------------|
| 72 | Latvia | 101 | 111 | 90 | 122 | 140 |
| 73 | Luxembourg | 82 | 96 | 111 | 114 | 128 |
| 74 | Ecuador | 55 | 84 | 99 | 109 | 124 |
| 75 | Azerbaijan | 89 | 119 | 119 | 120 | 121 |
| 76 | Peru | 36 | 30 | 65 | 71 | 121 |
| 77 | Sudan | 29 | 60 | 63 | 70 | 115 |
| 78 | Brunei | 27 | 28 | 52 | 79 | 111 |

Source: StatNano International Nanotechnology Database (<https://statnano.com>)

Azerbaijan ranks 75th in the world in this area and this cannot be considered satisfactory, as well as its position worsened compared to the previous years (70 in 2019, 72 in 2020).

The low level of development and application of nanotechnologies in Azerbaijan, the fact that a small part of oil production in SOCAR is carried out with the application of NT, the fact that it is not used in foreign oil companies in our country, certain shortcomings in the protection of intellectual property and in the detailed conduct of scientific research on nanotechnologies make it necessary to have an appropriate economic strategy at the state level.

3. Application of nanotechnologies and products/materials developed on the basis of these technologies in the oil and gas extraction sector is economically profitable.

The economic benefits of the application of nanotechnologies have been evaluated in a number of directions. Evaluation of the economic profitability of nanotechnologies was carried out in SOCAR for 14 projects. For this purpose, the wells' indicators were compared during the 12 months before and after the application.

Among the 14 investigated projects, 10 were evaluated as economically profitable when taken with domestic sales prices, and 11 when taken with international market prices. In general, it has been shown that the benefits obtained from the projects are several times higher than the costs spent on their development and implementation. Economic profit and profitability obtained from nanotechnology projects are reflected in table 4.

Table 4. Economic profit and profitability from nanotechnology projects

| <i>Application projects</i> | | <i>Economic profit, manat</i> | | <i>Economic profitability, %</i> | |
|-----------------------------|--------------------------------------|----------------------------------|--|----------------------------------|--|
| <i>No</i> | <i>Volume of investments, manats</i> | <i>With internal sales price</i> | <i>With international market price</i> | <i>With internal sales price</i> | <i>With international market price</i> |
| Project 1 | 18325 | 291711 | 530366 | 1591% | 2894% |
| Project 2 | 20431 | 318089 | 573666 | 1557% | 2808% |
| Project 3 | 19040 | 3302 | 11325 | 17% | 59% |
| Project 4 | 21158 | 6451 | 27575 | 31% | 130% |
| Project 5 | 18122 | -99487 | -161543 | -549% | -891% |
| Project 6 | 12459 | 83007 | 118379 | 666% | 950% |
| Project 7 | 19975 | 184505 | 306269 | 924% | 1533% |
| Project 8 | 19600 | 15691 | 31883 | 80% | 163% |
| Project 9 | 13148 | 65110 | 105419 | 495% | 802% |
| Project 10 | 18831 | 34846 | 74373 | 185% | 395% |
| Project 11 | 38327 | 111536 | 216721 | 291% | 565% |
| Project 12 | 54340 | -7342 | 28323 | -14% | 52% |
| Project 13 | 18199 | -10667 | -4899 | -58% | -27% |
| Project 14 | 52569 | -33758 | -21895 | -64% | -42% |
| Total | 344524 | 962994 | 1835962 | 280% | 533% |

Source: Calculated by the author based on the relevant reports and data of "Azneft" PU.

As a result of the comparison of NT applied wells, after the application of nanotechnologies, the production cost of one tonne of oil with domestic sales prices has become approximately 2.35 times lower. It was determined that there has been nearly 3 times economic profitability and the investment repayment period for the projects is 131 days. When taken according to the number of projects, the success rate is determined as 71 percent, but when the risk factor is calculated by taking into account the income acquired and expenses of the projects, the investments made are proven to be very successful in general. A comparison with two other new technologies that had been applied in oil and gas extraction facilities revealed that nanotechnologies were more efficient.

The additional oil production and revenues (at international market prices) that can be acquired as a result of the expansion of the application of nanotechnologies in oil and gas extraction are predicted under six scenarios as shown in the table 5:

Table 5. Oil production for 6 scenarios with expansion of nanotechnologies in SOCAR and potential revenues from additional oil production

| Scenario | Scale | Before application (tonnes) | After application (tonnes) | Additional oil production (tonnes) | Revenues from additional oil sales (manats) |
|----------|--------------|-----------------------------|----------------------------|------------------------------------|---|
| 1 | very little | 10000 | 23547 | 13547 | 8567114 |
| 2 | little | 20000 | 47094 | 27094 | 17134228 |
| 3 | satisfactory | 50000 | 117735 | 67735 | 42835570 |
| 4 | good | 100000 | 235470 | 135470 | 85671140 |
| 5 | much | 250000 | 588675 | 338675 | 214177851 |
| 6 | very much | 500000 | 1177349 | 677349 | 428355701 |

Source: Calculated by the author.

4. The directions for organization of application of nanotechnologies in real mode and for improvement of management forms at the macro and micro economic levels in the country have been determined.

To achieve the development and application of nanotechnologies in the oil industry and other sectors, the

organization of the production base of nanoproducts is one of the most important issues.

Among the technological parks in our republic, only the High Technologies Park of ANAS is conducting work on nanotechnologies. Currently, the infrastructure has been formed in this park and the production of nanomaterials that can be used in oil and gas extraction has been started. Taking into account the international experience, the development, adoption and application of nanotechnologies are mainly carried out in high-tech parks. In this regard, it is appropriate to increase targeted investments and develop projects on nanotechnologies, take into account the requirements of SOCAR more broadly, and expand the activity on nanotechnologies in that Park by attracting international investors and companies on nanotechnologies.

Although certain cooperation has been established between SOCAR and BSU at present, the level of cooperation on conducting scientific research and sharing results cannot be considered satisfactory. Other oil companies almost never cooperate with universities on scientific research. Many potential benefits of collaborations between oil companies and academic institutions to both parties have been studied.

Measures to organize the expansion of international cooperation in the field of nanotechnologies are also of great importance, and it would be appropriate for Azerbaijan to implement it in the following directions:

- 1) Sharing knowledge and skills in the field of nanotechnologies and acquiring new ones;
- 2) Obtaining information about the latest scientific-technological novelties and trends in the field of nanotechnologies, including getting informed about the latest novelties of nanotechnologies through participation in international exhibitions and conferences;
- 3) Creation of conditions for the country's scientists and researchers to practice abroad, joint scientific research projects,

seminars and lectures organized in universities for increasing the professionalism of local personnel involved in these works;

4) Creation of opportunities for the use of advanced laboratories and equipment in foreign countries;

5) Distribution of risks and costs in the development of nanotechnologies.

Currently, the most advanced countries in the field of nanotechnology are considered the United States, China, Japan, Germany, France, Israel and Iran. It is necessary to form cooperation with advanced institutes and institutions in these countries.

Another factor that should be paid attention to in order to expand the application of nanotechnologies is the training of highly qualified personnel in nanotechnologies area. At present, staff training on nanotechnology is being conducted only at Baku State University (master's degree and doctorate) and Baku Higher Oil School (master's degree). In oil companies operating in the country, training and retraining of personnel in this direction is not carried out. According to our assessments, the oil industry needs up to 50 nanotechnologies specialists initially and up to 20 specialists annually in later periods.

In order to strengthen the scientific base and the training of specialists in this area, the organization of teaching at the bachelor's level at Baku State University and the Baku Higher Oil School, the retraining of SOCAR's own employees and engineers of other oil companies on nanotechnologies according to the needs of the oil industry in SOCAR's Training, Education and Certification Department has been proposed.

5. There are serious deficiencies in the financing of the development and application of nanotechnologies in the oil industry, and purposeful steps should be taken to eliminate them.

Currently, the unsatisfactory industrial application of nanotechnologies in our country is directly related to the insufficiency of financial resources allocated in this direction. The insufficiency of funds allocated both for scientific research and for application in production leads to limitation of activities. Although

funds are allocated from the state budget to the fields of science and education, nanotechnologies are not directly emphasized in the cost elements, the state does not specifically allocate financial resources for the development and application of nanotechnologies. At the same time, the fact that science expenses generally have small share among the expenses allocated from the state budget in our republic requires increasing attention to this area.

Our calculations show that the annual allocation of up to 20 million manats from the state budget at the initial stage will give a great impetus to the revival and development of this field. Therefore, increasing the role of the state in financing the scientific research and application of nanotechnologies in the oil and gas sector is one of the important issues. Provision of funds for the nanotechnology purposes in the budget, direct financing of various projects, allocation of subsidies to companies operating in this field, creation of a favorable cooperation and competition environment for scientific research centers, assistance in providing them with necessary equipment, allocation of funds to specialized institutes can be ways for the state to finance such projects.

In our opinion, the use of state purchase orders for financing nanotechnologies in Azerbaijan will expand their development and application. The implementation of certain nanotechnology directions, which are predicted to be effective in the long-term perspective, can be entrusted to representatives of the private sector.

At present, taking into account that only SOCAR allocates funds in this direction in the oil industry of Azerbaijan, it is important that foreign capital oil companies also allocate funds to nanotechnology projects. SOCAR has an important role to increase its funds dedicated for scientific research in order to expand the works in this direction.

Science Development Foundation under the President of the Republic of Azerbaijan and the Science Fund of SOCAR allocate grants for the financing of nanotechnologies, but both the amount and because nanotechnologies are in competition with other projects, the number of these grants are limited. Therefore, the level of

funding of nanotechnology projects in the oil industry by these foundations is low.

Increasing the amount of grants allocated to successful scientific research projects and the availability of nano-specific grants are important in the development of the national economy. Grants from international organizations can play an important role in the development of nanotechnologies. For example, the European Union allocated 80 billion dollars (\$2 billion nano-specific) for funding scientific research within the Horizon 2014-2020 program, and 95 billion dollars within the Horizon Europe 2021-2027 program. The program includes "nanotechnologies" as part of the relevant fields of science.

We believe that the processes of obtaining grants and the process of involvement of grants in nanotechnological works should be simplified. For example, getting foreign grants for scientific research purposes up to a certain amount can be liberated. Also, it would be appropriate for the state to take educational, supporting and stimulating measures in the process of obtaining international grants.

In order to have a positive effect on the financial situation of enterprises and to stimulate the application of NT, it would be good to apply tax credits to enterprises operating in this direction, and exemption of works and services related to scientific research of nanotechnologies from VAT.

6. Since the preparation and application of nanotechnologies in our country, and especially in the oil and gas extraction industry, is carried out in an unsystematic and uncoordinated manner, there is a need to adopt a state program covering all spheres in this field and to establish a Coordination Council within the program.

One of the issues to be solved for the large-scale development of nanotechnologies in the country is the coordination of efforts for their scientific research and development, and improvement of the organization of works in this direction. Thus, although a number of state institutions (SOCAR, BSU, ANAS, etc.) are engaged in the development of nanotechnologies in the republic, the lack of a

general linking and coordinating institution causes the fragmentation of works. As a result, scientific research is repeated, acquired knowledge and experience are not mutually shared, synergistic effect is not achieved.

In order to ensure coordination, it is required to agree on the topic of scientific research works, to unite the forces operating in the field of nanotechnologies and to form a data base in this field, to ensure the sharing of scientific results among state institutions. We believe that ANAS is more appropriate as an institution that coordinates the development, preparation, and research of nanotechnologies in Azerbaijan. Thus, nanotechnologies are largely related to fundamental research, as well as a large number of scientific-research institutions and High Technologies Park operate under ANAS.

In Azerbaijan, there is no state program on nanotechnologies that systematizes the processes of scientific research, development and application of nanotechnologies and creates a basis for joint use of the potentials of state institutions. In 2007, the project of the state program on nanotechnologies was prepared at Baku State University, but later it was not accepted for a number of reasons. At the end of 2018, a decision was made to establish a Coordination Council between ANAS and Baku State University, and an agreement was reached on the preparation of a state program on nanotechnologies in the future. Unfortunately, the activity of the Coordination Council is not observed until now.

It is appropriate to adopt a state program in the field of nanotechnologies in order to systematize the organization and management of works to be done in the field of nanotechnologies. Here, the analysis of the current state of nanotechnologies in the country should be reflected, sources of financing should be determined, also the duties of state institutions, institutional measures, steps to improve the infrastructure, personnel and scientific potential should be reflected. For this purpose, it would be reasonable to improve and adopt the project of the "State Program on

Nanotechnologies" which was prepared in 2007, taking into account modern challenges and opportunities.

At the same time, there is a need to adopt and implement a program that includes the issues of development and production of nanotechnologies, which enable productivity growth in the oil and gas production industry. Therefore, in parallel, it is appropriate to adopt the "State Program for the Development, Adoption and Application of Nanotechnologies in the Oil and Gas Industry of the Republic of Azerbaijan", taking into account the tasks that arise from the technological requirements of the modern era and the oil companies need to overcome. Within the framework of that Program, it would be possible to strengthen the legal basis of activities on nanotechnology, attract domestic and foreign investors, diversify financial resources, further reinforce cooperation with foreign technological companies and, most importantly, combine the efforts of the parties to increase the transfer of the new generation of high technologies, i.e. technologies in accordance with the requirements of the IV industrial revolution, to our country.

7. Development and application of nanotechnologies in developed countries and leading oil companies show similar characteristics.

According to our research, a number of countries support the development and application of nanotechnologies at the state level. Thus, in Finland, nanotechnologies are obtained mainly in state-controlled research centers. Germany aims to achieve economic growth in many sectors by financing nanotechnologies, in Brazil, the state supports the practical application of scientific innovations in industry, China has included nanotechnologies in 12 mega projects within the country's development programs, and in France, the main focus is strengthening scientific research in the private sector and public-private cooperation.

Table 6 shows the state funding programs for nanotechnology.

Table 6. Funding programs for nanotechnologies

| <i>Country</i> | <i>Financing program</i> | <i>Period</i> | <i>Amount, million US dollars</i> |
|----------------|---|---------------|-----------------------------------|
| China | Mid-term and long-term Development Plan | 2006-2008 | 38 |
| India | Nano Mission | 2007-2012 | 162 |
| European Union | Framework program 7 | 2007-2013 | 3500 |
| | Horizon | 2014-2020 | 2200 |
| Russia | Nanotechnology infrastructure development program | 2008-2011 | 780 |
| France | Nano-2012 program | 2008-2012 | 625 |
| Germany | Nano Initiative Action Plan | 2008-2013 | 460 |
| Taiwan | National Nanotechnology Program | 2009-2015 | 200 |
| Malaysia | NanoMalaysia program | 2012-2020 | 3400 |
| Brazil | Brazilian Nanotechnology Initiative | 2019-2022 | 25 |
| Japan | MEXT | Every year | 725 |
| United Kingdom | British Research Councils programs | Every year | 320 |
| USA | National Nanotechnology Initiative | Every year | 2500 |

Source: https://www.nano.gov/sites/default/files/dsti_stp_nano201212.pdf and <https://statnano.com/report/n3>

Among foreign oil companies, Shell has a nanotechnology laboratory, ExxonMobil has developed a mesoporous silicate nano-product that has potential applications in other sectors, BP invites nanotechnology experts to analyze innovation strategies every quarter, Equinor holds nanotechnology conferences, Chevron has produced diamondoid using nanoparticles. It was determined that NT patents in leading oil companies around the world have a significant share (10-20% on average) among the total patents.

As a result of the analysis of the experience of developed countries, a number of trends have been identified:

- In foreign countries there is a strategy to expand the application of nanotechnologies against the decrease of oil reserves;
- In many countries, the state allocates funds from the budget specifically for the financing of nanotechnologies;

- Many countries have state programs for the development of nanotechnologies in order to coordinate and systematize the work done;
- Joint enterprises are created between the public and private sectors for the development of nanotechnologies;
- The application of nanotechnologies in the oil industry is carried out in integration with other sectors.

8. Based on the realities and perspectives of the modern era, the development and application of nanotechnologies in the oil and gas extraction industry should be implemented in new directions.

Since the current state of development and application of nanotechnologies in our country is not considered satisfactory, we have determined the directions of their expansion from the following points of view: conducting research, scientific and technical, type of wells and economic.

In terms of conducting research. At present, the research of nanotechnologies at SOCAR is being conducted at the size of 50-70 nanometers. It is important to organize the research of nanotechnologies in super small sizes (10-30 nm). Thus, NT has the potential to achieve more promising and diverse results in smaller sizes.

From a scientific and technical point of view. After studying the current situation, we have proposed that the application of nanotechnologies in the oil industry in Azerbaijan be expanded in the following scientific and technical directions:

- minimization of the wear rate of the equipments required in the drilling process;
- developing materials with strong, durable and stable properties for equipments that are used in oil production;
- improvement of corrosion resistance of materials;
- the use of nanotechnologies for the enrichment of drilling fluid characteristics;
- improving the quality of cementing in production wells;
- filtration and waste management using nanotubes;

-enhanced oil and gas production by managing field properties.

In terms of the type of wells. Within SOCAR, nanotechnologies are mainly applied in low-yield wells that are in the final stage of their operation. But nanocoatings, nanosensors, nanodrilling fluids, etc. numerous nanotechnologies can be applied in oil and gas production starting from the first stage of exploitation. For this purpose, we can specifically cite the wells that have recently started operation and yield high oil to the directions for expanding the application of nanotechnologies in Azerbaijan, because these directions have the potential to bring great economic benefits.

From economic point of view. Currently, 15 legal entities act as operators in the oil and gas extraction industry of Azerbaijan, and more than 90% of oil and gas production is carried out under the operatorship of only two enterprises (BP and SOCAR). Access to the industry is limited, and production sharing agreements for involving new companies to develop fields require approval by many government bodies, including the Parliament of the Republic of Azerbaijan.

In order to stimulate the application of nanotechnologies in the oil and gas extraction sector, it would be correct to reduce entry barriers to the sector, and the state to encourage attracting new companies.

With the application of nanotechnologies, it is possible to extract large amounts of residual oil resources from wells that have stopped functioning due to both geological and technical reasons. We offer to give the wells that are in the final stage of production or can no longer be produced by traditional methods for exploitation to innovative companies that have expressed their intention to use nanotechnologies. In this process, the most attractive ones among the applications can be selected through a competition based on technical and economic feasibility studies and other relevant evaluations, and they can be entrusted with the exploitation of these wells for 10-15 years.

CONCLUSION

As a result of our research, we have obtained the following scientific results, the use of which can lead to the improvement of the innovative development of the oil and gas extraction industry and the application process of nanotechnologies:

1. The analysis of the main points about the application of nanotechnologies in the oil and gas extraction industry and the study of economic views made it possible to determine the following: nanotechnology is the management of the characteristics of substances at the nanoscale and have many actual and potential applications in drilling and production in the oil industry. Although there are different approaches and uncertainties regarding their areas of application, economic effects and future development directions, the common opinion in the literature is that the application of nanotechnologies in oil and gas extraction will bring results of great economic value.

As a result of the research, we have determined that it is important to take into account a number of objective and subjective challenges in solving the problems of applying nanotechnologies in the oil and gas extraction industry.

2. The evaluation of nanotechnologies in the oil and gas extraction industry of Azerbaijan studied in the thesis revealed that their application level is not at a satisfactory level. At the same time, it has been shown that the application of NT in oil and gas extraction is economically profitable and they have the potential to bring greater benefits in the future. Therefore, there is a serious need to implement measures to expand the application of NT. The implementation of the proposed measures will serve to increase the economic profitability of oil production in the short-term and long-term periods, and will have a positive effect on the development of the country's economy.

3. Coordination of scientific research works, promotion of nanotechnologies in technoparks, organization of qualified staff training and acceptance of the state program in the field of nanotechnology can be important initial steps at the macro level to

improve the organizational and management mechanisms of the application of nanotechnologies in the oil and gas extraction industry.

Stimulating mechanisms such as the involvement of innovative local and foreign enterprises in field development, financial incentives, expansion of cooperation between industry and academic institutions will contribute to the process of applying nanotechnologies in the oil industry in the future.

In order to improve the financing of NT, the activities of both the public and private sectors should be expanded, the wide use of local and foreign grants should be encouraged, forming joint ventures should be considered for conducting research, and the use of venture capital should be stimulated.

Detailed information about the results is provided in the final section of the thesis.

The main content of the research is described in the following published scientific works of the author:

1. Universitetlər və sənaye arasında əməkdaşlığın mümkün qarşılıqlı təsirləri // - Bakı: AMEA İqtisadiyyat İnstitutunun “Elmi əsərlər” toplusu, - 2016. № 4, - s. 88-94.
2. Neft sənayesində nanotexnologiyalardan istifadənin bəzi məsələləri // - Bakı: AMEA İqtisadiyyat İnstitutunun “Elmi əsərlər” toplusu, - 2017. № 4, - s. 51-57.
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7. Azərbaycanın neft sənayesində nanotexnologiyalardan istifadənin cari vəziyyəti və nanotexnologiyaların iqtisadi təsirlərinin araşdırılması// Bakı: İpək Yolu jurnalı, - 2019. № 2, - s. 141-153.
8. Implementing the education of future entrepreneurs in developing countries: Agile integration of traditions and innovations // Greenwood: Journal of Entrepreneurship Education, - 2019. - 22(5), p. 1-13. (with coauthor)
9. Nanotexnologiyaların neft sənayesində tətbiqinin və maliyyələşdirilməsinin beynəlxalq təcrübəsinin tədqiqi // - Bakı: İqtisadi Artım və İctimai Rifah, 2021, № 1, - s. 71-80 (with coauthor)
10. Why nanotechnologies in oil production ? // Research and innovation conference,- New York, USA: Yunona Publishing, - March 15, 2019, - p. 70-73.
11. Nanotexnologiyalar neft şirkətlərinin innovasiya strategiyasının tərkib elementi kimi // “Davamlı inkişaf və humanitar elmlərin aktual problemləri” mövzusunda respublika elmi konfransının materialları. Bakı: Azərbaycan Universiteti, - 24 oktyabr, 2019, - s. 111-114.
12. Neft sənayesində nanotexnologiyaların idarə edilməsinin təkmilləşdirilməsi istiqamətləri // “Azərbaycanın iqtisadi inkişaf strategiyası” mövzusunda respublika elmi konfransının materialları, Bakı: UNEC, - 24 dekabr, 2019, - I cild, s. 276-279.

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