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ANALYSIS OF METHODS FOR EVALUATING THE EFFECTIVENESS OF GEOLOGICAL AND TECHNICAL MEASURES AND DECISION-MAKING FOR THEIR SELECTION: CONCEPTUAL REVIEW

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Summary. The paper examines modern approaches to the selection and evaluation of the effectiveness of geological and technical measures (GTM) aimed at enhancing oil recovery and developing hard-to-recover reserves. The primary objective is to identify optimal methods that ensure high technical and economic efficiency under complex geological and operational conditions.

The study analyzes traditional and modern methods for assessing GTM effectiveness, including extrapolation of basic production characteristics, analysis of oil production decline curves, and forecasting using probabilistic-statistical models. The paper emphasizes the insufficient reliability of traditional approaches due to data uncertainties, multi-criteria considerations, and the non-linear interaction of factors. A review of literature highlights the potential use of fuzzy logic, "least concessions" methods, cluster analysis, and expert systems, which allow accounting parameter boundary uncertainties and making more accurate decisions in the context of incomplete data.

Examples of applying modern methods to various oil fields are provided. The possibility of developing integrated information systems on decision support, incorporating mathematical algorithms, databases, and predictive models, is discussed. Particular attention is given to selection of parameters to evaluate the effectiveness of measures, such as physical and geological characteristics, water cut, oil production rates, and economic indicators.

The paper substantiates the necessity for further improvement of approaches to GTM evaluation and planning. It proposes the integration of modern methods for data analysis, modeling, and forecasting to enhance the reliability and accuracy of decisions, thereby contributing to the successful optimization of oil field development and risk reduction.

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1. Introduction

At present, oil field development is increasingly focused on enhancing efficiency through the implementation of new technologies and geological and technical measures (GTM). The task of selecting the most effective methods, capable of ensuring high technical and economic efficiency under specific conditions is highlighted. Despite the progress made, more than half of geological oil reserves remain untapped. The primary efforts are directed towards developing extraction methods suitable for various geological conditions.

The successful development of hard-to-recover reserves requires the integration of modern mathe-

matical methods, technological solutions, and available data. Consequently, improving systems for data collection, analysis, and decision-making in selecting GTMs remains a pressing challenge.

2. Current State of Research on the Analysis and Evaluation of GTM Efficiency

Currently, there is a wide range of analytical methods available to evaluate the effectiveness of various measures. GTMs are classified into categories such as technical, maintenance, hydrocarbon production intensification, enhanced oil recovery (EOR) methods, and wellbore treatment (WBT). For instance, the EOR-Office software package, (Фахреддинов и др., 2001; Хасанов и др., 2001), automates processes and assists specialists in making well-founded decisions.

The most effective method to evaluate GTM efficiency is the «extrapolation method», which allows actual results to be compared with forecasts based on production history. However, even minor calculation errors can lead to incorrect conclusions while selecting and planning effective measures (Казаков, 2003).

The practical evaluation of GTM effectiveness is generally based on methods related to the characteristics of oil displacement by water. Simply put, the overall efficiency of GTMs can be divided into the effect caused by the specifics of the displacement process and the effect associated with fluid production intensification (Казаков, 1999).

GTM efficiency is determined analyzing oil production decline curves. There are numerous types of displacement characteristics (Казаков, 1999; Шахвердиев и др., 2014), and the main challenge lies in selecting the most suitable one. This choice should correspond to the field's development history and ensure accurate extrapolation for forecasting (Сыртланов, 2002).

In the study carried out by Glukhikh et al. (Глухих и др., 2002), the most accurate methods of evaluation are examined, along with dependencies demonstrating the technological effect achieved through increased oil production rates. The author notes that the forecast of the expected GTM effect, based on the extrapolation of oil production curves (actual and basic), is not always reliable. This indicates that the duration of GTM effects, such as hydraulic fracturing (HF), ranges from 5 to 7 years. Furthermore, the use of water cut curves for long-term forecasting is effective only when the water cut level is 50-70%. At lower water cut levels, forecast accuracy decreases, especially in the early stages of development when the forecast duration is limited to 3-6 months. In such cases, GTMs are typically carried out in wells with water-free production or low water cut levels.

In the study presented by Shpurov et al. (Шпуров и др., 2000), the forecast objects include well clusters, their groupings, formations, oil and gas production areas and other targets, with forecast intervals ranging from one month to one year. It is important to note that the structure and sequence of upcoming measures require numerous calculations, considering various scenarios. This necessitates the use of modern and highly efficient mathematical methods.

Pyankov, Filev (Пьянков, Филев, 2000) outline methods to calculate basic scenarios and provide a classification of indicators reflecting the technological efficiency of various measures in their work. An example is the Ershovsky oil field, where the effectiveness of different geological and technical measures is evaluated.

The authors emphasize that the use of this software significantly improves the accuracy and effectiveness of evaluations as well as the forecasting of qualitative characteristics for the examined oil field. The core principle of the methodology lies in calculating displacement process parameters that best approximate the actual production data obtained during previous stages of field development. Users can independently set the approximation interval based on production history. The method of the least squares is applied to assess approximation errors, enabling comparisons between predicted results and actual production figures obtained during operational activities (Пьянков, Филев, 2000).

In the paper of Sarvaretdinov et al. (Сарваретдинов и др., 2001) the authors employing the «method of fuzzy sets» explore the aspects of forming a database for GTM applications in wells recommended for production. A fuzzy set refers to an object the degree of membership of which is defined not by an absolute value but with a certain degree of confidence. The primary principle of this method is classifying wells based on their suitability for production, i.e., as "recommended for production." However, the multi-criteria nature of the task presents significant challenges in decision-making.

The paper focuses on the application of this method in the decision-making process and highlights the effectiveness of the «least concessions» approach, which facilitates the calculation of predicted GTM efficiency values (Strekov et al., 2013). Methods such as combining criteria into a single generalized measure, the "least concessions" method, and the principles of L. Zadeh's fuzzy set theory are successfully applied under conditions of uncertainty. The classification of uncertainties helps in selection the appropriate decision-making method. To assess the type of uncertainty, the distribution of data criteria and their correspondence to standard distribution laws are analyzed.

The «least concessions» method reduces a multi-criteria decision-making task to the sequential optimization of individual criteria while considering acceptable concessions. The criteria are prioritized by importance, and a concession value is assigned to each, starting with the most significant. This process is repeated on all criteria until optimal strategies are achieved.

The study carried by Strekov et al. (2013) presents the results and approaches for decision-making in selecting the optimal GTM based on variant calculations and a comparative analysis of the effectiveness of different methods under varying conditions. Five criteria were used to determine the best GTM:

1. Duration of the effect;
2. Additional oil production;
3. Increase in oil flow rate;
4. Oil flow rate after GTM implementation;
5. Water cut level after GTM.

The proposed approach enables forecasting efficiency indicators for various targets based on the chosen GTM.

The possibility of calculating GTM qualitative characteristics based on data on technological parameters, physical and geological features, and operational factors is emphasized (Абасов и др., 2003). This data forms a comprehensive data base that serves as a foundation to assess different targets, select optimal technologies for implementing measures, and analyze the degree of their impact on the final outcome. This approach enhances the validity of decision-making and improves the predictability of GTM effectiveness.

The paper by Ilyushin et al. (Илюшин и др., 2015) analyzes a range of fields grouped by geographical location. It highlights that modern GTM methods play a critical role in ensuring stable oil and gas production and in reducing potential risks associated with geological and engineering factors. However, natural systems are highly complex, data is multidimensional, and influence of individual factors remains uncertain. These characteristics limit the accuracy of traditional methods to assess GTM effectiveness. The development of mathematical models and modern information technologies opens new possibilities for analysis and problem-solving, even under conditions of the limited initial data.

Based on the above mentioned, it can be concluded that there is a pressing need to develop and implement new approaches that enable a more adequate and comprehensive techno-economic evaluation not only of individual geological and technical measures (GTM) but also of their collective efficiency. Such approaches would allow optimizing the selection and application of measures for both individual wells and entire reservoirs, ensuring a holistic approach to managing hydrocarbon production processes.

One promising direction in addressing this challenge is the use of the integrated methods that combine probabilistic-statistical approaches with elements of fuzzy logic. This approach allows more precise evaluation of the effectiveness of measures under high uncertainty conditions particularly (Strekov et al., 2013; Zadeh, 1978; Золотухин и др., 1991). In recent years, technologies such as expert information systems (Wiseman, Gradijan, 2011; Кравченко, Махно, 2009; Выбор геолого-технических мероприятий ..., 2004; Well Flo, electronic resources) and methods of cluster analysis (Савченко, 2010; Эфендиев и др., 2018, 2016; Akhmetov et al., 2018) have been actively implemented.

The paper by Glukhikh et al. (Глухих и др., 2002) presents key issues regarding the selection of the most accurate methods for evaluating GTM efficiency. The authers present dependencies that illustrate different options for differentiating the technological effects of methods aimed at improving the oil recovery factor. In their opinion, forecasting the GTM effect (i.e., calculating the expected impact) based on the extrapolation of actual and basic oil production curves using characteristic methods may be unreliable due to several factors. In particular, this is related to the duration of the effect from certain types of GTMs, such as hydraulic fracturing (HF). As it is noted the use of water cut curves for long-term forecasting is effective only at high water cut levels exceeding 50-70% due to HF effect lasting 5-7 years. It is advisable to limit the forecasting period to 3-6 months at earlier stages of development, with low water cut levels. However, a significant proportion of GTMs are carried out in water-free or low-water-cut wells, making such forecasts less accurate.

Nevertheless, reliable extrapolation of displacement characteristics becomes possible with sufficient data on the dynamics of oil production after GTM implementation (at least 4-6 observation points). In such cases, forecasting methods based on oil production decline coefficients can be effective. If post-GTM oil production data is limited, the authors recommend using decline coefficients calculated on similar wells with a longer operating period after the measures.

Thus, the improvement of methods for selecting and evaluating the effectiveness of GTMs remains a relevant challenge. The development of new tools and analytical technologies that account for the specifics of various wells and reservoirs is essential for enhancing hydrocarbon production efficiency and ensuring sustainable management of oil and gas projects.

Several studies emphasize the necessity of the development of data, mathematical, and software tools aimed at improving the GTM design process. For instance the primary issue in GTM design is identified as the lack of a unified methodology for assessing their effectiveness in Zhanturin's papers (Жантурин, 2007, 2008, 2009). The proposed solution involves the creation of the integrated software to evaluate both actual and forecasted GTM performance, which would significantly enhance the accuracy and validity of decision-making.

From the perspective of monitoring data on the current state of field development, an important aspect is the planning of GTMs, which is examined in studies by Sarvaretdinov et al. (Сарваретдинов и др., 2001), Strekov et al. (2013), Ilyushin et al. (Илюшин и др., 2015), Zadeh (1978), Zolotukhin et al. (Золотухин и др., 1991). One of the major stages in the development of GTM selection algorithms and methods has been the implementation of expert information system technologies, as discussed in papers by Wiseman, Gradijan (2011), Kravchenko, Makhno (Кравченко, Махно, 2009) and Well Flo electronic resources. However, despite progress in creating new models and information systems for planning and forecasting GTM effectiveness, the issue of comprehensive support for all stages of the planning process remains unresolved. The existed approaches and software tools typically cover only specific fragments of the GTM planning lifecycle, limiting their applicability significantly.

Taking into account the complexity of tasks, multi-criteria and multi-factorial analysis, as well as the inaccuracy and limited nature of initial data, the development of decision-making systems for GTM design remains a pressing challenge. These systems should be based on modern probabilistic-statistical methods and fuzzy logic methods. For example, dependencies were constructed for the efficiency of one type of GTM – water inflow restriction – based on geological and technological factors in the paper by Moldabayeva et al. (2023). The calculations and error analysis confirmed the accuracy of the developed models, which allowed determining the impact of each factor within specified intervals of its variation. The models helped estimate key indicators such as the duration of isolation effects, the volume of additional oil extracted, and the amount of water restricted.

Significant factors in the model were identified and selected, simplifying the model by retaining only the variables that significantly influenced the results. Decision-making on the selection of technological solutions was carried out using mathematical statistics methods and fuzzy logic theory. First, predictive calculations of the effectiveness of water isolation measures were performed, then selection of optimal technological solutions was carried out according to geological conditions. During the analysis, the fuzzy set theory developed by L.Zadeh was applied. This approach allowed considering multiple conflicting criteria and selecting solutions that provided a balanced compromise among them. Thus, the development of methodological foundations for GTM design continues to be a priority requiring the implementation of new integrated methods and technologies.

Summing up the literary analysis, the following conclusions can be drawn. It has been determined that the traditional methods of evaluating the effectiveness of geological and technical measures (GTM) and decision-making, applied until a certain time, do not sufficiently cover the study of the influence of numerous factors, which negatively affects the quality of decisions made. Nevertheless, in recent years, significant progress has been observed in this field due to the introduction of modern mathematical methods for data processing, information analysis, and decision-making. However, there is still no unified methodology or computational framework that could take into account the uncertainty of modeling conditions and decision-making processes.

It is particularly worth noting that traditional approaches rely on models with clearly defined parameters and their boundaries. However, in real-world conditions, parameters and their values often have blurred boundaries, making the decision-making process more complex. To ensure a more accurate assessment of GTM effectiveness, it is essential to consider the following aspects of uncertainty:

– multi-criteria and multi-factorial data: GTM effectiveness depends on numerous factors, each influencing the outcome to varying degrees;

– data inaccuracy: Many parameters are difficult to measure with high precision, which complicates the development of reliable forecasts;

– non-linear interactions: In many cases, factors influence each other in a non-linear manner, reducing the accuracy of traditional analytical methods.

Modern approaches can provide more reliable and adaptable solutions to evaluate GTM effectiveness under uncertain and dynamic conditions solving these challenges.

3. Research Methods

In recent years, data processing and information analysis have increasingly relied on methods that combine mathematical statistics with fuzzy set theory. This approach allows considering uncertainty and data ambiguity, which are characteristic of GTM planning tasks. One of the key approaches applied in this area is fuzzy cluster analysis.

Fuzzy cluster analysis is a method that enables the grouping of objects or parameters while considering their uncertainty. Unlike traditional methods, where an object belongs to only one cluster, this approach allows an object belonging to several clusters simultaneously, with varying degrees of probability. This is particularly important to solve problems where data is heterogeneous and has blurred boundaries. The use of fuzzy clusters makes it possible to account for multiple aspects of uncertainty, thereby increasing the accuracy of evaluations and decision-making processes (Wiseman, Gradijan, 2011).

Thus, further development of methods for evaluating GTM effectiveness requires a comprehensive approach, combining traditional methods with the latest data analysis and processing technologies. This integration will enable the making of more substantiated and accurate decisions, even under conditions of high uncertainty and data ambiguity.

While addressing tasks related to the comparative assessment of GTM effectiveness and selecting optimal solutions, researchers focus on the following critical aspects:

1. Determining Parameters for Analysis.

The effectiveness of GTMs depends on a variety of parameters, each reflecting geological and technological conditions. Key parameters identified by researchers include:

– Total reservoir thickness;
– Oil-saturated thickness;
– Sandiness coefficient;
– Porosity and permeability;
– Oil viscosity and density;
– Gas content and reservoir temperature;
– Oil and fluid production rates before GTM;
– Water cut prior to GTM;
– Economic indicators (e.g., cost of measures, implementation timelines).

These parameters are used for analysis as they have the greatest impact on the selection and effectiveness of the measures undertaken.

2. Data Set Formation.

For each of the listed parameters, value ranges are defined and described using fuzzy sets. For example, parameter efficiency levels can be categorized as “low”, “medium” or “high”. This approach allows taking into account data uncertainty and blurred boundaries, which is particularly important in conditions of the limited data.

3. Application of Fuzzy Clustering Algorithms.

To process and group data, fuzzy clustering algorithms, such as Fuzzy C-Means (FCM) are applied. This algorithm distributes data into clusters based on object characteristics and the degree of their membership in each cluster.

4. Assessing Object Membership in Clusters.

In fuzzy clustering, each parameter of an object is assigned a degree of membership to a specific cluster. This approach accounts for the possibility of a single object belonging to multiple clusters with varying degrees of probability. Such a method provides a more accurate representation of the data and its impact on the final outcome.

In the context of evaluating GTM effectiveness, fuzzy cluster analysis helps grouping various factor combinations into clusters, determining their closest alignment with specific development conditions or scenarios. This method is particularly valuable in situations where:

– Initial data is incomplete or contains significant inaccuracies;
– Geological conditions are highly variable;
– Engineering outcomes are conflicting or ambiguous.

Key Stages of Applying the Method.

1. Defining Fundamental Parameters, such as the duration of the effect, oil production rate increase, reduction in water cut, and the economic feasibility of the measures are identified as primary criteria.

2. Creating an Input Data Matrix, where each parameter is described using fuzzy values (e.g., "low," "medium," "high").

3. Analysis and Clustering of Results which help determining the group of effectiveness each measure belongs to. This process also helps identify potential risks and weaknesses in the proposed solutions.

Thus, fuzzy cluster analysis allows obtaining a more complete and accurate picture of the efficiency of GTM by integrating uncertain and variable data into the decision-making process.

4. Comparative Evaluation of GTM Effectiveness Using Probabilistic-Statistical Methods and Fuzzy Logic

Several studies (Moldabayeva et al., 2023), propose a decision-making framework for selecting optimal measures to restrict water inflows. The key elements of the framework include:

– multi-criteria analysis: decisions are made considering various factors that influence effectiveness, such as geological and physical conditions and past GTM performance;

– model development: mathematical models are created for each indicator, incorporating comprehensive statistical assessments and uncertainty;

– optimization of decisions: algorithms are developed to select the best technological solutions based on the significance of factors, models, and their evaluations.

The paper by Efendiyev et al. (Эфендиев и др., 2025) analyses factors influencing GTM efficiency metrics including:

– duration of the effect;
– average increase in oil production;
– reduction of water inflows;
– profitability of measures.

To address the multi-criteria analysis problem, the following steps are highlighted:

1. Aggregation of Efficiency Indicators: combining various efficiency metrics into a single comprehensive assessment.

2. Data Clustering: dividing data into three homogeneous groups (clusters) using a fuzzy clustering algorithm.

3. Assignment of Linguistic Values such as "high," "low," "medium" to each cluster and their correspondence to the aggregated indicators.

4. Fuzzy Rule Construction: developing rules based on the "if..., then..." principle to forecast GTM effectiveness under different conditions.

The effectiveness of measures is categorized into several levels:

– high;
– good;
– average;
– satisfactory.

This framework, combining probabilistic-statistical methods and fuzzy logic, enables a more comprehensive and adaptable evaluation of GTM performance, especially in conditions with uncertainty and variability. It helps optimizing decisions by integrating key performance indicators and aligning measures with specific field conditions.

The calculation methodology allows determining which GTMs are most effective under specific conditions. Membership functions are used to predict the effectiveness of measures for each oil field.

Forecasting based on fuzzy models helps determining the correspondence between reservoirs and GTMs with high effectiveness. For instance, Fig.1 demonstrates the alignment between reservoirs and GTM types characterized by «high effectiveness». As there, the most effective GTMs were «optimization», «perforation», and «hydraulic fracturing + perforation».

Zhanturin (2008) notes that the best results for specific reservoirs are achieved when combinations such as «hydraulic fracturing + perforation» are applied. Similar figures have been constructed for other clusters, each representing a corresponding level of effectiveness (Fig.1).

This visual representation highlights the practical applications of the fuzzy model, ensuring that GTM selection corresponds to specific geological and operational conditions ultimately improving the accuracy and reliability of decision-making.

Reservoir (symbols)	GTM types		
	Optimization	Perforation	HF+perform.
1	⊕	⊕	
2	⊕		
3	⊕		
4	⊕		
5	⊕		
6			⊕
7	⊕		
8	⊕		
9			⊕
10	⊕		
11	⊕		
12			⊕
13	⊕		
14	⊕		

Fig. 1. Correlation between reservoirs and GTM types characterized as «High effectiveness»

The results based on GTM technology data provide the ability to:

– select the most suitable measures for specific geological conditions;
– take into account the information gaps;
– make well-grounded decisions.

Similar conclusions were drawn for the conditions analyzed in (Жантурин, 2008). These conclusions, based on actual GTM application data, serve as a guideline to select measures for specific reservoirs, especially in situations with the limited data.

The use of fuzzy modeling and forecasting enables an assessment of the interaction between GTM effectiveness and geological objects, facilitating the optimal selection of measures for various operational conditions.

Thus, modeling and forecasting are crucial tools for addressing data ambiguity and uncertainty, which enhances the accuracy of GTM selection and their effectiveness under operational conditions. The application of modern mathematical methods plays a significant role in achieving these improvements.

5. Conclusions

The problems discussed in this paper are examined from both specific and systemic perspectives incorporating research methods such as probabilistic-statistical approaches and fuzzy logic-based methods. Using these methods, the authors developed models for various GTM efficiency indicators and outlined decision-making pathways under conditions of uncertainty.

The analysis shows that, despite the significant number of results accumulated to date, the improvement of GTM selection methods remains a pressing task. The necessity of integrating mathematical, informational, and software solutions is evident to enhance the accuracy of effectiveness evaluations.

The introduction of comprehensive analytical systems based on modern methods, such as cluster analysis and fuzzy logic, will optimize the decision-making process and adapt it to complex geological conditions. This approach ensures more reliable, accurate, and context-sensitive GTM planning and implementation.

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REFERENCES

Abasov M.T., Efendiyev G.M., Strekov A.S. et al. Comparative evaluation of GTM effectiveness based on comprehensive information. Oil Industry, No. 10, 2003, pp. 70-73 (in Russian).

Akhmetov D.A., Efendiyev G.M., Karazhanova M.K., Koylibaev B.N. Classification of hard-to-recover hydrocarbon reserves in Kazakhstan using fuzzy cluster analysis. 13th International Conference on Application of Fuzzy Systems and Soft Computing, ICAFS 2018. Warsaw, Poland, August 27-28, 2018, pp. 865-872.

Efendiyev G.M., Mammadov P.Z., Piriverdiyev I.A., Mammadov V.N. Clustering of geological objects using the FCM algorithm and evaluation of the rate of lost circulation. Procedia Computer Science, Vol. 102, 2016, pp. 159-162, DOI:10.1016/S1877-0509(16)32664-3.

Efendiyev G.M., Mammadov P.Z., Piriverdiyev I.A., Mammadov V.N. Estimation of lost circulation rate using fuzzy clustering of geological objects by petrophysical properties. Visnyk Taras Shevchenko National University of Kyiv, Geology, Vol. 2 (81), 2018, pp. 28-33, DOI:10.17721/1728-2713.81.04.

Efendiyev G.M., Moldabayeva G.Z., Abbasova S.V., Tuzelbayeva Sh.R. Models and methods of analysis and decision-making in controlling technological processes of oil and gas production under conditions of uncertainty. SOCAR Proceedings, No. 1, 2025.

Fakhretdinov R.N., Kaledin Yu.A., Zhitkova M.V. The potential of modern information technologies in assessing the effectiveness of enhanced oil recovery methods. Oil Industry, No. 3, 2001, pp. 54-55 (in Russian).

Glukhikh I.N., Pyankov V.N., Zabolotnov A.R. Situational models in corporate knowledge bases for geological and technical measures. Oil Industry, No. 6, 2002, pp. 45-48 (in Russian).

Ilyushin P.Yu., Rakhimzyanov R.M., Solovyev D.Yu., Kolychev I.Yu. Analysis of well intervention aimed at oil production enhancement in the Perm krai's fields. Bulletin of the Perm National Research Polytechnic University. Geology, Oil, Gas and Mining. Perm, No. 15, 2015, pp. 81-89, DOI:10.15593/2224-9923/2015.15.9 (in Russian).

Kazakov A.A. Methodological support for unified approaches to assessing the effectiveness of EOR methods. Technologies of Fuel and Energy Complex, Supplement to Oil and Capital journal, No. 2, 2003, pp. 47-53 (in Russian).

Kazakov A.A. Methodology for assessing the effectiveness of GTM based on oil production decline curves. Oil Industry, No. 12, 1999, pp. 31-34 (in Russian).

Khasanov M.M., Mukhamedshin R.K., Khatmullin I.F. Computer technologies for solving multi-criteria tasks of oil field development monitoring. Vestnik inzhiniringovogo tsentra YUKOS (Bulletin of the YUKOS Engineering Center), No. 2, 2001, pp. 26-29 (in Russian).

Kravchenko Yu.A., Makhno D.A. Principles for building decision-support systems to assess the functional state of decision-

ЛИТЕРАТУРА

Akhmetov D.A., Efendiyev G.M., Karazhanova M.K., Koylibaev B.N. Classification of hard-to-recover hydrocarbon reserves in Kazakhstan using fuzzy cluster analysis. 13th International Conference on Application of Fuzzy Systems and Soft Computing, ICAFS 2018. Warsaw, Poland, August 27-28, 2018, pp. 865-872.

Efendiyev G.M., Mammadov P.Z., Piriverdiyev I.A., Mammadov V.N. Clustering of geological objects using the FCM algorithm and evaluation of the rate of lost circulation. Procedia Computer Science, Vol. 102, 2016, pp. 159-162, DOI:10.1016/S1877-0509(16)32664-3.

Efendiyev G.M., Mammadov P.Z., Piriverdiyev I.A., Mammadov V.N. Estimation of lost circulation rate using fuzzy clustering of geological objects by petrophysical properties. Visnyk Taras Shevchenko National University of Kyiv, Geology, Vol. 2 (81), 2018, pp. 28-33, DOI:10.17721/1728-2713.81.04.

Efendiyev G.M., Moldabayeva G.Z., Abbasova S.V., Tuzelbayeva Sh.R. Models and methods of analysis and decision-making in controlling technological processes of oil and gas production under conditions of uncertainty. SOCAR Proceedings, No. 1, 2025.

Moldabayeva G.Z., Efendiyev G.M., Kozlovskiy A.L., Buktukov N.S., Abbasova S.V. Modeling and adoption of technological solutions in order to enhance the effectiveness of measures to limit water inflows into oil wells under conditions of uncertainty. ChemEngineering, Vol. 7, No. 5, 89, 2023, https://doi.org/10.3390/chemengineering7050089.

Strekov A.S., Mamedov P.Z., Koyshina A.I. Decisions-making on the choice of geological and technical measures under uncertainty. Seventh International Conference on Soft Computing, Computing with Words and Perceptions in System Analysis, Decision and Control, Izmir, Turkey, September 2-3, 2013, pp. 381-384.

Well Flo – Well modeling and design. (Electronic resource), http://www.weatherford.com/Products/Production/ProductionOptimization/Software/WellFloSoftware/index.htm.

Wiseman H., Gradijan F. Regulation of shale gas development, including hydraulic fracturing. Energy Institute, University of Texas at Austin; University of Tulsa Legal Studies, Research Paper No. 2011-11, October 31, 2011, 130 p.

Zadeh L.A. Fuzzy sets as a basis for a theory of possibility. Fuzzy Sets and Systems, 1978, No. 1, pp. 3-28, https://doi.org/10.1016/S0165-0114(99)80004-9.

Абасов М.Т., Эфендиев Г.М., Стреков А.С. и др. Оценка сравнительной эффективности геолого-технических мероприятий по комплексной информации. Нефтяное Хозяйство, No. 10, 2003, с.70-73.

Выбор геолого-технических мероприятий при воздействии на призабойную зону скважины. 2004. (электронный ресурс), https://www.oil-info.ru/content/view/31/51/.

Глухих И.Н., Пьянков В.Н, Заболотнов А.Р. Ситуационные модели в корпоративных базах знаний геолого-технологических мероприятий. Нефтяное хозяйство, No. 6, 2002, с.45-48.

makers. 2009. (Electronic resource). http://www.cawater-info.net/pdf/kravchenko-mahno.pdf (in Russian).

Moldabayeva G.Z., Efendiyev G.M., Kozlovskiy A.L., Buktukov N.S., Abbasova S.V. Modeling and adoption of technological solutions to enhance the effectiveness of measures to limit water inflows into oil wells under conditions of uncertainty. ChemEngineering, Vol. 7 (5), No. 89, 2023, https://doi.org/10.3390/chemengineering7050089.

Pyankov V.N., Filev A.I. Integral software complex "Baspro-Analyst". Oil Industry, No. 9, 2000, pp. 109-114 (in Russian).

Sarvaretdinov R.G., Gilmanova R.Kh., Khisamov R.S. et al. Formation of a database for GTM optimization in oil production. Oil Industry, No. 8, 2001, pp. 32-35 (in Russian).

Savchenko T.N. Application of cluster analysis methods for processing psychological research data. Experimental Psychology, Vol. 3, No. 2, 2010, pp. 67-86 (in Russian).

Selection of geological and technical measures for influencing the well's near-wellbore zone. 2004. (Electronic resource). https://www.oil-info.ru/content/view/31/51/ (in Russian).

Shakhverdiev A.Kh., Panakhov G.M., Abbasov E.M., Rasulova S.R. On the possibility of regulating viscosity anomalies in heterogeneous mixtures. Bulletin of the Russian Academy of Natural Sciences, No. 1, 2014, pp. 28-33 (in Russian).

Shpurov A.V., Pyankov V.N., Klochkov A.A., Brilliant L.S. Planning GTM effectiveness when forecasting oil production. Oil Industry, 2000, No. 9, pp. 105-108 (in Russian).

Strekov A.S., Mamedov P.Z., Koyshina A.I. Decision-making on the choice of geological and technical measures under uncertainty. The Seventh international conference on soft computing, computing with words and perceptions in system analysis, decision and control. Turkey, Izmir, September 2-3, 2013, pp. 381-384.

Syrtlanov V.R., Kadochnikova L.M., Trushnikova O.M. Methods for evaluating the effectiveness of GTM based on three-dimensional hydrodynamic modeling. Oil Industry, No. 6, 2002, pp. 38-40 (in Russian).

Well Flo – Well modeling and design. (Electronic resource), http://www.weatherford.com/Products/Production/ProductionOptimization/Software/WellFloSoftware/index.htm.

Wiseman H., Gradijan F. Regulation of shale gas development, including hydraulic fracturing. Energy Institute, University of Texas at Austin; University of Tulsa Legal Studies, Research Paper No. 2011-11, October 31, 2011, 130 p.

Zadeh L.A. Fuzzy sets as a basis for a theory of possibility. Fuzzy Sets and Systems, 1978, No. 1, pp. 3-28, https://doi.org/10.1016/S0165-0114(99)80004-9.

Zhanturin Zh.K. Approximate assessment of GTM effectiveness indicators with limited information. Bulletin of the Atyrau İnstitute of oil and gas, No. 12, 2007, pp. 63-65 (in Russian).

Zhanturin Zh.K. Development of oil production intensification measures for implementation under various geological and physical conditions in Kazakhstan. PhD dissertation in technical sciences. Atyrau, 2009, 115 pp. (in Russian).

Zhanturin Zh.K. On forecasting GTM effectiveness based on comprehensive information. Oil and Gas, No. 4, 2008, pp. 45-49 (in Russian).

Zolotukhin A.B., Eremin N.A., Nazarova L.N., Ponomarenko E.M. Fuzzy set theory in the selection of methods for influencing oil reservoirs. Oil Industry, 1991, No. 3, pp. 21-23 (in Russian).

Жантурин Ж.К. О прогнозировании эффективности геолого-технических мероприятий по комплексной информации. Нефть и газ, No. 4, 2008, с. 45-49.

Жантурин Ж.К. Ориентировочная оценка показателей эффективности геолого-технических мероприятий при недостаточной информации. Вестник АИНиГ (Атырауский институт нефти и газа), No. 12, 2007, с. 63-65.

Жантурин Ж.К. Разработка мероприятий по интенсификации добычи нефти с целью их проведения в различных геолого-физических условиях Казахстана. Диссертация канд. технических наук. Атырау, 2009, 115 с.

Золотухин А.Б., Еремин Н.А., Назарова Л.Н., Пономаренко Е.М. Теория нечетких множеств в выборе методов воздействия на нефтяные пласты. Нефтяное хозяйство, No. 3, 1991, с. 21-23.

Илюшин П.Ю., Рахимзянов Р.М., Соловьев Д.Ю., Колычев И.Ю. Анализ проведения геолого-технических мероприятий по увеличению продуктивности добывающих скважин на нефтяных месторождениях Пермского края. Вестник Пермского национального исследовательского политехнического университета. Геология, нефтегазовое и горное дело, Пермь, No. 15, 2015, с. 81-89.

Казаков А.А. Методика оценки эффективности ГТМ по кривым падения дебита нефти. Нефтяное Хозяйство, No. 12, 1999, с. 31-34.

Казаков А.А. Методическое обеспечение единых подходов оценки эффективности методов ПНП. Технологии ТЭК (топливно-энергетического комплекса), Приложение к журналу «Нефть и капитал», No. 2, 2003, с. 47-53.

Кравченко Ю.А., Махно Д.А. Принципы построения систем поддержки принятия решений для оценки функционального состояния лица принимающего решения. 2009, (Электронный ресурс). http://www.cawater-info.net/pdf/kravchenko-mahno.pdf.

Пьянков В.Н., Филев А.И. Интегральный программный комплекс “Баспро-аналитик”. Нефтяное Хозяйство, No. 9, 2000, с.109-114.

Савченко Т.Н. Применение методов кластерного анализа для обработки данных психологических исследований. Экспериментальная психология, Том 3, No. 2, 2010, с. 67-86.

Сарваретдинов Р.Г., Гильманова Р.Х., Хисамов Р.С. и др. Формирование базы данных для разработки ГТМ оптимизации добычи нефти. Нефтяное Хозяйство, No. 8, 2001, с. 32-35.

Сыртланов В.Р., Кадочникова Л.М., Трушникова О.М. Методики оценки эффективности ГТМ на основе трехмерного гидродинамического моделирования. Нефтяное Хозяйство, No. 6, 2002, с. 38-40.

Фахретдинов Р.Н., Каледин Ю.А., Житкова М.В. Потенциал современных информационных технологий при оценке эффективности методов увеличения нефтеотдачи. Нефтяное хозяйство, No. 3, 2001, с. 54-55.

Хасанов М.М., Мухамедшин Р.К., Хатмуллин И.Ф. Компьютерные технологии решения многокритериальных задач мониторинга разработки нефтяных месторождений. Вестник инжинирингового центра ЮКОС, No. 2, 2001, с. 26-29.

Шахвердиев А.Х., Панахов Г.М., Аббасов Э.М., Расулова С.Р. О возможности регулирования вязкостной аномалии в гетерогенных смесях. Вестник РАЕН (Российская академия естественных наук), No. 1, 2014, с. 28-33.

Шпуров А.В., Пьянков В.Н., Клочков А.А., Бриллиант Л.С. Планирование эффективности ГТМ при прогнозировании добычи нефти. Нефтяное хозяйство, No. 9, 2000, с.105-108.

АНАЛИЗ МЕТОДОВ ОЦЕНКИ ЭФФЕКТИВНОСТИ ГЕОЛОГО-ТЕХНИЧЕСКИХ МЕРОПРИЯТИЙ И ПРИНЯТИЯ РЕШЕНИЙ ПО ИХ ВЫБОРУ: КОНЦЕПТУАЛЬНЫЙ ОБЗОР

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Резюме. В статье рассматриваются современные подходы к выбору и оценке эффективности геолого-технических мероприятий (ГТМ), направленных на повышение нефтеотдачи и разработку трудноизвлекаемых запасов. Основной задачей является определение оптимальных методов, обеспечивающих высокую технико-экономическую эффективность в условиях сложных геологических, а также эксплуатационных параметров.

Анализируются традиционные и современные методы оценки эффективности ГТМ, включая экстраполяцию базовых характеристик добычи, методы анализа кривых падения дебита нефти и прогнозирования с использованием вероятностно-статистических моделей. Подчёркивается недостаточная надёжность традиционных подходов из-за неопределённости данных, многокритериальности и нелинейности взаимодействия факторов. В процессе анализа литературных источников рассмотрена возможность использования нечёткой логики, методов «наименьших уступок», кластерного анализа и экспертных систем, которые позволяют учитывать размытость границ параметров и принимать более точные решения в условиях неполноты информации.

В статье приведены примеры применения современных методов на различных месторождениях. Обсуждается возможность создания комплексных информационных систем для поддержки принятия решений, включающих математические алгоритмы, базу данных и прогнозные модели. Особое внимание уделяется выбору параметров для оценки эффективности мероприятий, таких как физико-геологические характеристики, обводнённость, дебиты нефти, а также экономические показатели.

В указанной работе обосновывается необходимость дальнейшего совершенствования подходов к оценке и планированию ГТМ. В ней предлагается интеграция современных методов анализа данных, моделирования и прогнозирования для повышения надёжности и точности решений, что способствует успешному решению задач оптимизации разработки нефтяных месторождений и снижению рисков.

Ключевые слова: *месторождение, нечёткий кластер-анализ, геолого-технические мероприятия, прогноз, принятие решений*

GEOLOJİ-TEXNİKİ TƏDBİRLƏRİN EFFEKTLİYİNİN QİYMƏTLƏNDİRİLMƏSİ ÜSULLARININ TƏHLİLİ VƏ ONLARIN SEÇİLMƏSİ ÜZRƏ QƏRARLARIN QƏBUL EDİLMƏSI: KONSEPTUAL İCMAL

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Xülasə. Məqalədə müasir yanaşmaların seçimi və qiymətləndirilməsi, geoloji-texniki tədbirlərin (GTT) effektivliyi, neft hasilatının artırılması və çətinliklə hasil olunan ehtiyyatlar müzakirə olunur. Burada əsas məsələlərdən biri optimal qərarların qəbul edilməsi bunu üçün aparılan əvvəlki mərhələlərdə müxtəlif geoloji-texniki qərarların modelləşdirirməsi gündəlikdə duran əsas məsələlərdən biridir. Onu da qeyd etmək lazımdır ki, bütün bu məsələlərin həlli hal-hazırki vaxta qədər çətinliklə çıxarılan ehtiyyatların ümumi təsnifatının olmaması səbəbindən nəzərə çarpacaq dərəcədə çətinləşir. Qeyd olunmuş istiqamətdə dərc olunmuş elmi tədqiqat işləri belə bir sistemin metodologiyasının yaranmasının və bunun çərçivəsində çətinlikə çıxarılan ehtiyytların təsnifatı müxtəlif geoloji-fiziki şəraitdə aparılan geoloji-texniki tədbirlər haqqında məlumatın toplanması və təhlili həmin prossesin modelləşdirilməsi və qərarların qəbul edilməsi məsələlərini ümumilikdə aktual bir problem kimi gündəliyə çıxarıb. Bütün bunlar irəli sürülən layihədə nəzərə alınmışdır. Layihədə ilk növbədə işin məqsədi, baxılacaq məsələlər və gözlənilən yeniliklər öz əksini tapmışdır.

Açar sözlər: *yataq, qeyri-səlis məntiq, klaster-analiz, geoloji-texniki tədbirlər, neft hasilatı, qərarın qəbul edilməsi*