ISSN 2518-170X (Online)
ISSN 2224-5278 (Print)

«ҚАЗАҚСТАН РЕСПУБЛИКАСЫ ҰЛТТЫҚ ҒЫЛЫМ АКАДЕМИЯСЫ» РҚБ

«ҚАЗАҚСТАН РЕСПУБЛИКАСЫ
ҰЛТТЫҚ ҒЫЛЫМ АКАДЕМИЯСЫ» РҚБ
«ХАЛЫҚ» ЖҚ

ҚАЙЫРЫМДЫЛЫҚ ҚОРЫ HALYK CHARITY FOUNDATION

ХАБАРЛАРЫ

ИЗВЕСТИЯ

РОО «НАЦИОНАЛЬНОЙ
АКАДЕМИИ НАУК РЕСПУБЛИКИ
КАЗАХСТАН»
ЧФ «Халық»

NEWS

OF THE ACADEMY OF SCIENCES
OF THE REPUBLIC OF
KAZAKHSTAN
«Halyk» Private Foundation

SERIES

OF GEOLOGY AND TECHNICAL SCIENCES

3 (465)

MAY – JUNE 2024

THE JOURNAL WAS FOUNDED IN 1940

PUBLISHED 6 TIMES A YEAR

ALMATY, NAS RK

Clarivate Analytics

NAS RK is pleased to announce that News of NAS RK. Series of geology and technical sciences scientific journal has been accepted for indexing in the Emerging Sources Citation Index, a new edition of Web of Science. Content in this index is under consideration by Clarivate Analytics to be accepted in the Science Citation Index Expanded, the Social Sciences Citation Index, and the Arts & Humanities Citation Index. The quality and depth of content Web of Science offers to researchers, authors, publishers, and institutions sets it apart from other research databases. The inclusion of News of NAS RK. Series of geology and technical sciences in the Emerging Sources Citation Index demonstrates our dedication to providing the most relevant and influential content of geology and engineering sciences to our community.

Қазақстан Республикасы Ұлттық ғылым академиясы «ҚР ҰҒА Хабарлары. Геология және техникалық ғылымдар сериясы» ғылыми журналының Web of Science-тің жаңаланған нұсқасы Emerging Sources Citation Index-те индекстелуге қабылданғанын хабарлайды. Бұл индекстелу барысында Clarivate Analytics компаниясы журналды одан әрі the Science Citation Index Expanded, the Social Sciences Citation Index және the Arts & Humanities Citation Index-ке қабылдау мәселесін қарастыруда. Webof Science зерттеушілер, авторлар, баспашылар мен мекемелерге контент тереңдігі мен сапасын ұсынады. ҚР ҰҒА Хабарлары. Геология және техникалық ғылымдар сериясы Emerging Sources Citation Index-ке енуі біздің қоғамдастық үшін ең өзекті және беделді геология және техникалық ғылымдар бойынша контентке адалдығымызды білдіреді.

НАН РК сообщает, что научный журнал «Известия НАН РК. Серия геологии и технических наук» был принят для индексирования в Emerging Sources Citation Index, обновленной версии Web of Science. Содержание в этом индексировании находится в стадии рассмотрения компанией Clarivate Analytics для дальнейшего принятия журнала в the Science Citation Index Expanded, the Social Sciences Citation Index и the Arts & Humanities Citation Index. Web of Science предлагает качество и глубину контента для исследователей, авторов, издателей и учреждений. Включение Известия НАН РК. Серия геологии и технических наук в Emerging Sources Citation Index демонстрирует нашу приверженность к наиболее актуальному и влиятельному контенту по геологии и техническим наукам для нашего сообщества.

ЧФ «ХАЛЫҚ»

В 2016 году для развития и улучшения качества жизни казахстанцев был создан частный Благотворительный фонд «Халык». За годы своей деятельности на реализацию благотворительных проектов в областях образования и науки, социальной защиты, культуры, здравоохранения и спорта, Фонд выделил более 45 миллиардов тенге.

Особое внимание Благотворительный фонд «Халык» уделяет образовательным программам, считая это направление одним из ключевых в своей деятельности. Оказывая поддержку отечественному образованию, Фонд вносит свой посильный вклад в развитие качественного образования в Казахстане. Тем самым способствуя росту числа людей, способных менять жизнь в стране к лучшему – профессионалов в различных сферах, потенциальных лидеров и «великих умов». Одной из значимых инициатив фонда «Халык» в образовательной сфере стал проект Ozgeris powered by Halyk Fund – первый в стране бизнес-инкубатор для учащихся 9-11 классов, который помогает развивать необходимые в современном мире предпринимательские навыки. Так, на содействие малому бизнесу школьников было выделено более 200 грантов. Для поддержки талантливых и мотивированных детей Фонд неоднократно выделял гранты на обучение в Международной школе «Мирас» и в Astana IT University, а также помог казахстанским школьникам принять участие в престижном конкурсе «USTEM Robotics» в США. Авторские работы в рамках проекта «Тәлімгер», которому Фонд оказал поддержку, легли в основу учебной программы, учебников и учебно-методических книг по предмету «Основы предпринимательства и бизнеса», преподаваемого в 10-11 классах казахстанских школ и колледжей.

Помимо помощи школьникам, учащимся колледжей и студентам Фонд считает важным внести свой вклад в повышение квалификации педагогов, совершенствование их знаний и навыков, поскольку именно они являются проводниками знаний будущих поколений казахстанцев. При поддержке Фонда «Халык» в южной столице был организован ежегодный городской конкурс педагогов «Almaty Digital Ustaz.

Важной инициативой стал реализуемый проект по обучению основам финансовой грамотности преподавателей из восьми областей Казахстана, что должно оказать существенное влияние на воспитание финансовой грамотности и предпринимательского мышления у нового поколения граждан страны.

Необходимую помощь Фонд «Халык» оказывает и тем, кто особенно остро в ней нуждается. В рамках социальной защиты населения активно проводится работа по поддержке детей, оставшихся без родителей, детей и взрослых из социально уязвимых слоев населения, людей с ограниченными возможностями, а также обеспечению нуждающихся социальным жильем, строительству социально важных объектов, таких как детские сады, детские площадки и физкультурно-оздоровительные комплексы.

В копилку добрых дел Фонда «Халык» можно добавить оказание помощи детскому спорту, куда относится поддержка в развитии детского футбола и карате в нашей стране. Жизненно важную помощь Благотворительный фонд «Халык» оказал нашим соотечественникам во время недавней пандемии COVID-19. Тогда, в разгар тяжелой борьбы с коронавирусной инфекцией Фонд выделил свыше 11 миллиардов тенге на приобретение необходимого медицинского оборудования и дорогостоящих медицинских препаратов, автомобилей скорой медицинской помощи и средств защиты, адресную материальную помощь социально уязвимым слоям населения и денежные выплаты медицинским работникам.

В 2023 году наряду с другими проектами, нацеленными на повышение благосостояния казахстанских граждан Фонд решил уделить особое внимание науке, поскольку она является частью общественной культуры, а уровень ее развития определяет уровень развития государства.

Поддержка Фондом выпуска журналов Национальной Академии наук Республики Казахстан, которые входят в международные фонды Scopus и Wos и в которых публикуются статьи отечественных ученых, докторантов и магистрантов, а также научных сотрудников высших учебных заведений и научно-исследовательских институтов нашей страны является не менее значимым вкладом Фонда в развитие казахстанского общества.

С уважением,
Благотворительный Фонд «Халык»!

«ҚР ҰҒА» РҚБ Хабарлары. Геология және техникалық ғылымдар сериясы».
ISSN 2518-170X (Online),
ISSN 2224-5278 (Print)

Меншіктеуші: «Қазақстан Республикасының Ұлттық ғылым академиясы» РҚБ (Алматы қ.).

Қазақстан Республикасының Ақпарат және қоғамдық даму министрлігінің Ақпарат комитетінде 29.07.2020 ж. берілген **№ KZ39VPY00025420** мерзімдік басылым тіркеуіне қойылу туралы куәлік.

Тақырыптық бағыты: *геология, мұнай және газды өңдеудің химиялық технологиялары, мұнай химиясы, металдарды алу және олардың қосындыларының технологиясы.*

Мерзімділігі: жылына 6 рет.

Тиражы: 300 дана.

Редакцияның мекен-жайы: 050010, Алматы қ., Шевченко көш., 28, 219 бөл., тел.: 272-13-19

http://www.geolog-technical.kz/index.php/en/

«Известия РОО «НАН РК». Серия геологии и технических наук».
ISSN 2518-170X (Online),
ISSN 2224-5278 (Print)

Собственник: Республиканское общественное объединение «Национальная академия наук Республики Казахстан» (г. Алматы).

Свидетельство о постановке на учет периодического печатного издания в Комитете информации Министерства информации и общественного развития Республики Казахстан **№ KZ39VPY00025420,** выданное 29.07.2020 г.

Тематическая направленность: *геология, химические технологии переработки нефти и газа, нефтехимия, технологии извлечения металлов и их соеденений.*

Периодичность: 6 раз в год.

Тираж: 300 экземпляров.

Адрес редакции: 050010, г. Алматы, ул. Шевченко, 28, оф. 219, тел.: 272-13-19

http://www.geolog-technical.kz/index.php/en/

News of the National Academy of Sciences of the Republic of Kazakhstan. Series of geology and technology sciences.
ISSN 2518-170X (Online),
ISSN 2224-5278 (Print)
Owner: RPA «National Academy of Sciences of the Republic of Kazakhstan» (Almaty).
The certificate of registration of a periodical printed publication in the Committee of information of the Ministry of Information and Social Development of the Republic of Kazakhstan **No. KZ39VPY00025420,** issued 29.07.2020.
Thematic scope: *geology, chemical technologies for oil and gas processing, petrochemistry, technologies for extracting metals and their connections.*
Periodicity: 6 times a year.
Circulation: 300 copies.
Editorial address: 28, Shevchenko str., of. 219, Almaty, 050010, tel. 272-13-19
http://www.geolog-technical.kz/index.php/en/

NEWS of the National Academy of Sciences of the Republic of Kazakhstan
SERIES OF GEOLOGY AND TECHNICAL SCIENCES
ISSN 2224–5278
Volume 3. Number 465 (2024), 205–218
https://doi.org/10.32014/2024.2518-170X.420

UDC 665.6/.7: 665.733.3

© B. Orazbayev1, A. Zhiyenbek1*, G. Uskenbayeva1, Zh. Abdugulova1, L. Rzayeva2, 2024
1 L.N. Gumilyov Eurasian National University, Astana, Kazakhstan;
2Astana IT University, Astana, Kazakhstan.
E-mail: arai_nur_nao@mail.ru

MODELING AND OPTIMIZATION OF OIL PRODUCTION PROCESSES FOR REGULATION OF OIL WELL FUND

Batyrbai Bidaibekovich Orazbayev — Professor of the Department of System Analysis and Control, Gumilyov Eurasian National University, Doctor of Technical Sciences, Professor, Kazakhstan, Astana, Pushkin St., 11
E-mail: batyr_o@mail.ru, https://orcid.org/0000-0003-2109-6999;
Zhiyenbek Arailym Oteuliyevna — Doctoral student of the Department of System Analysis and Control, Gumilyov Eurasian National University, Kazakhstan, Astana, Pushkin St., 11
E-mail: arai_nur_nao@mail.ru, https://orcid.org/0009-0005-0360-2108;
Gulzhan Amangazievna Uskenbayeva — Associate professor of the Department of System Analysis and Control, Gumilyov Eurasian National University, PhD, Kazakhstan, Astana, Pushkin St., 11
E-mail: gulzhum_01@mail.ru. https://orcid.org/0000-0001-6904-8000;
Abdugulova Zhanat Kaparovna — associate Professor of the Department of System Analysis and Control, Gumilyov Eurasian National University, Candidate of Economic Sciences, Associate Professor, Kazakhstan, Astana, Pushkin S., 11
E-mail: janat_6767@mail.ru, https://orcid.org/0000-0001-7462;
Leila Gummetovna Rzayeva — Professor assistant of the Department of Intelligent Systems and Cybersecurity, Astana IT University, PhD, Kazakhstan, Astana, Mangilik El avenue, 55/11
E-mail: leila2186@mail.ru, https://orcid.org/0000-0002-3382-4685.

Abstract. The issues of development of mathematical models and optimization based on the modeling of oil production processes by forecasting and regulating the stock of oil wells have been studied. A technique for developing mathematical models and modeling and optimizing the stock of oil wells based on the Markov chain is proposed and described. The proposed methodology is implemented to analyze the state of operation of the well stock at the studied Kenkiyak field. An approach is proposed for formalizing and obtaining a correct mathematical formulation of the problem of multi-criteria optimization of field development and oil production processes in a fuzzy environment by adapting various optimality principles. Based on the modification of the Pareto optimality principle, a heuristic method for optimizing oil production processes has been developed based on models that describe the processes occurring in oil wells. In the paper, the processes of transition of the well stock from one category to another, for example, from active to idle, characterized with different intensity, are described by the Markov chain theory based on differential equations for the probabilities of wells being in certain categories. Such processes of transition of the well stock from one category to another are analyzed on the example of the operation data of the stock of operating and idle wells of the Kenkiyak field for the study period. On the basis of the general scheme for writing the equations of Markov processes and taking into account the peculiarities of the operation of the operating fund, a system of differential equations is obtained, which is a mathematical model that allows predicting and regulating the fund of oil wells. The scheme of using the developed model based on the Markov chain for modeling, forecasting and regulation of the well stock is described. Graphs of the dynamics of the well stock are constructed based on the data of the studied field and the actual and estimated number of wells of the operating and idle stock of oil wells are compared.

Keywords: mathematical model, Markov chains, optimization, heuristic method, oil well fund

© **Б.Б. Оразбаев1, А.О. Жиенбек1*, Г.А. Ускенбаева1, Ж.К. Абдугулова1, Л.Г. Рзаева2, 2024**

1Л.Н. Гумилев атындағы Еуразия ұлттық университеті, Астана, Қазақстан;

2Astana IT University, Астана, Қазақстан.

E-mail: arai_nur_nao@mail.ru

МҰНАЙ ӨНДІРУ ПРОЦЕСТЕРІН МОДЕЛЬДЕУ НЕГІЗІНДЕ МҰНАЙ ҰҢҒЫМАЛАРЫ ҚОРЫН РЕТТЕУ ЖӘНЕ ОПТИМИЗАЦИЯЛАУ

Аннотация. Модельдеу арқылы мұнай мұнай өндіру процесстерінде мұнай ұңғымалары қорын болжау және реттеуге қажетті математикалық модельдерді құру, олардың негізінде оптимизациялау мәселелері зерттелді. Марков тізбегі негізінде мұнай ұңғымалары қорын модельдеу және оптимизациялау үшін математикалық модельдер құру әдістемесі ұсынылып, сипатталған. Ұсынылған әдістеме зерттелген НЕ Кеңқияқ мұнай кенорнындағы ұңғыма қорының пайдалану жағдайын талдау үшін жүзеге асырылды. Түрлі оңтималдық принциптерін бейімдеу арқылы айқын емес ортада кен орындарын игеру мен мұнай өндіру процестерін көпкритерийлі оптимизациялау есебінің математикалық қойылымын ресімдеу және алу тәсілі ұсынылған. Парето оптималдық принципін модификациялау арқылы мұнай ұңғымаларында болып жатқан процестерді сипаттайтын модельдер негізінде мұнай өндіру процестерін оптимизациялау эвристикалық тәсілі жасақталған. Зерттеу жұмысындва ұңғыма қорының бір категориядан екінші категорияға ауысу процестері, мысалы, түрлі қарқындылықпен жұмыс жасап тұрған категориядан бос тұрған категорияға ауысу, ұңғымалардың белгілі бір категорияда болу ықтималдығын анықтайтын дифференциалдық теңдеулер негізде Марков тізбегі теориясымен сипатталған. Ұңғымалар қорының бір категориядан екінші категорияға өтуінің мұндай процестерін зерттеуде Кеңқияқ кен орнының жұмыс жасап тұрған және тоқтап тұрған ұңғымалары қорының деректерін пайдалану мысалында талданған. Марков процестерінің теңдеулерін жазудың жалпы схемасы негізінде және эксплуатациялық ұңғымалардың жұмыс жасау ерекшеліктерін ескере отырып, мұнай ұңғымалары қорын болжауға және реттеуге мүмкіндік беретін математикалық модель болып табылатын дифференциалдық теңдеулер жүйесі алынған. Марков тізбегі негізінде құрылған модельді ұңғыма қорын модельдеу, болжау және реттеу үшін пайдалану схемасы сипатталған. Зерттелген мұнай кен орнының деректері негізінде ұңғыма қоры динамикасының графиктері тұрғызылды және мұнай ұңғымаларының жұмыс жасап тұрған және тоқтап тұрған қорының ұңғымаларының нақты және есептік саны салыстырылады.

Түйін сөздер: математикалық модель, Марков тізбектері, оптимизациялау, эвристикалық тәсіл, мұнай ұңғымалары қоры

© Б.Б. Оразбаев1, А.О. Жиенбек1*, Г.А. Ускенбаева1, Ж.К. Абдугулова1, Л.Г. Рзаева2, 2024
1Евразийский национальный университет имени Л.Н. Гумилев, Астана, Казахстан;
2Astana IT University, Астана, Казахстан.
E-mail: arai_nur_nao@mail.ru

МОДЕЛИРОВАНИЕ И ОПТИМИЗАЦИИ ПРОЦЕССОВ ДОБЫЧИ НЕФТИ ДЛЯ РЕГУЛИРОВАНИЯ ФОНДА НЕФТЯНЫХ СКВАЖИН

Аннотация. Исследованы вопросы разработки математических моделей и оптимизации на основе моделирования процессов добычи нефти путем прогнозирования и регулирования фонда нефтяных скважин. Предложена и описана методика разработки математических моделей и моделирования, а также оптимизации фонда нефтяных скважин на основе цепи Маркова. Предложенная методика реализована для анализа состояния эксплуатации фонда скважин на исследуемом месторождении Кенкияк. Предложен подход формализации и получения корректной математической постановки задачи многокритериальной оптимизации процессов разработки месторождений и добычи нефти в нечеткой среде путем адаптации различных принципов оптимальности. На основе модификации принципа Парето оптимальности разработан эвристический метод оптимизации процессов добычи нефти на основе моделей, описывающих процессы, протекающие в нефтяных скважинах. В работе процессы перехода фонда скважин из одной категории в другую, например, с действующих на простаивающие, характеризующиеся различной интенсивностью, описаны теорией цепи Маркова на основе дифференциальных уравнений для вероятностей пребывания скважин в определенных категориях. Такие процессы перехода фонда скважин из одной категории в другую проанализированы на примере данных эксплуатации фонда действующих и простаивающих скважин Кенкиякского месторождения за исследуемый период. На основе общей схемы записи уравнений Марковских процессов и с учетом особенностей функционирования эксплуатационного фонда получена система дифференциальных уравнений, являющейся математическими моделями, позволяющие прогнозировать и регулировать фонд нефтяных скважин. Описана схема использования разработанной модели на основе цепи Маркова для моделирования, прогнозирования и регулирования фонда скважин. Построены графики динамики фонда скважин на основе данных исследуемого месторождения и сравнены фактическое и расчетное число скважин действующего и простаивающего фонда нефтяных скважин.

Ключевые слова: математическая модель, цепи Маркова, оптимизация, эвристический метод. фонд нефтяных скважин

Introduction

Optimizing the processes of developing oil fields and oil production is the most important task for the development of the oil industry of the Republic of Kazakhstan and other oil-producing countries. And the efficiency and level of economic development of the country as a whole depends on the optimal functioning of the oil industry of any oil country (Orazbayev et al., 2022: 112–116). It should be noted that in recent years, reserves of hard-to-recover oils have been increasing in Kazakhstan. Hard-to-recover reserves, according to the international classification, include such reserves of oil fields, deposits or their individual parts that are characterized by geological conditions of oil occurrence and/or physical properties that are unfavorable for extraction, for example, they are concentrated in deposits with low-permeability reservoirs and the recovered oil is viscous and waxy.

In this context, the problems of developing mathematical models and optimizing oil production and regulating the well stock are very urgent tasks of science and practice in the oil production sector. Effective solution of these problems based on mathematical models of oil deposits and oil production processes makes it possible to create modern control systems for the development of oil fields with hard-to-recover oil reserves and oil production processes (Lambert et al., 2021).

To develop mathematical models that make it possible to adequately describe and evaluate the performance of production and idle reserves of oil wells, it is necessary to apply an approach based on the principles of Markov chain theory (Gagniuc, 2017). In this approach, each subsequent state of the wells depends on their previous state. Thus, for high-quality, adequate modeling of the state and process of functioning of the well stock, diagrams of the practical application of a given system of equations are consistently presented (Zhang et al., 2019). The presented technique based on the Markov chain is implemented in this work to analyze the state of operation of the well stock at the Kenkiyak field, which is located in the Aktobe region. At the same time, a consistent search for an effective solution to the problems of optimizing oil production processes is implemented based on the developed models of oil wells, taking into account their previous state. Formalization and practical use of random information, which is interrelated and describes oil production processes, involves the use of methods of probability theory and mathematical statistics (Spirina, 2019; Weiwei Zhuang et al., 2022). The proposed heuristic approach to optimizing oil production processes using mathematical models describing processes in oil wells is based on the use of the Pareto principle of optimality (Kuanbayeva et al., 2022; Orazbayev et al., 2020). At the same time, to optimize oil production processes according to a vector of criteria, the knowledge, experience and preference of the decision maker (DM), subject matter experts are used (Orazbayev et al., 2022: 1–26). Experienced heads of oil and gas production departments, leading engineers, scientists and researchers who have the necessary knowledge and extensive experience in solving problems of oil field development and oil production act as decision makers and experts. Thus, to effectively solve the considered problems of modeling and optimizing the processes of field development, regulation of well stock and oil production from hard-to-recover oil reserves, formal and informal methods of system analysis using information of various types should be used (Pavlov et al., 2016; Goyal, 2017; Orazbayev et al., 2019; Rakhmetov et al., 2022).

Currently, the oil industry of the Republic of Kazakhstan is characterized by the state and significant number of oil producing, oil pumping and oil refining enterprises that extract, transport through trunk pipelines and process oil on an industrial scale. In this chain of the oil industry, effective management of the processes of developing oil fields and producing oil with hard-to-recover oil reserves based on modern achievements of mathematical methods and information and communication technologies is important. In this regard, it is necessary to intensify work on the creation and implementation on an industrial scale of various oil production optimization systems based on mathematical models of oil deposits and wells. This allows to regulate the well stock, effectively and efficiently manage the processes of field development and oil production and ensure uninterrupted, high-quality work of oil producing companies. As a result, oil producing companies that have implemented oil production optimization systems based on mathematical models and a systematic approach can optimize oil production processes at all stages and achieve a significant improvement in the quality of forecasting and management of oil well reserves (Gordji, 2016; Shakhverdiev et al., 2020; Shutko et al., 2017). As a result, such optimization systems in the future will allow improving oil production processes and will contribute to increasing the rate of economic development of the country and bringing the Kazakh economy to new levels in terms of GDP (GDP), improving the standard of living of the people.

The main goal of this work is to study methods and prospects for the development and practical application of systems for optimizing oil production processes based on a systems approach and mathematical models for regulating hard-to-recover oil reserves. Since in oil production processes the main active elements are people who control these processes, it is necessary to use available information of a different nature (theoretical, stochastic, fuzzy), based on the methodology of system analysis.

Research materials and methods

The research materials in this work are experimental and statistical data collected from the Kenkiyak field and the results of their processing (Aidnalieva, 2022; Ilin et all, 2017), as well as the results of expert assessment processed by methods of fuzzy set theories (Jorgensen, 2019; Sabzi, 2017; Zimmerman, 2018; Romanov, 2019). The methodological approach of this study is based on the integrated use of systems analysis methods, which cover the necessary aspects of the development and practical application of mathematical models and methods for optimizing oil production based on available information of various types. These materials and methods allow analyzing and exploring the prospects for using mathematical models and optimization methods for effective regulation and forecasting of well reserves.

Based on the identified system of models and the proposed heuristic method of multi-criteria optimization based on a modification of the Pareto optimality principle, this study proposes an approach to creating a system for optimizing operating modes of oil wells. At the same time, to effectively solve the assigned problems for developing models and modeling in a fuzzy environment, it is recommended to use the Fuzzy Logic Toolbox applications of the MATLAB system. This allows, based on expert information, to synthesize fuzzy models, rule bases and visualize the results of fuzzy modeling and select the best solution. In addition, this study is based on existing theoretical results obtained from a synthesis of analyzed works and publications on the development and application of mathematical models and systems for optimizing oil production. As well as experimental and statistical data collected in the processes of regulating the well stock of the studied Kenkiyak oil field.

This scientific research was carried out in the following stages:

– the stage of preparing a theoretical base and collecting and processing experimental and statistical data, as well as expert information. At this stage, the main issues of the development and practical application of mathematical models and systems for optimizing oil production processes based on information of various types have been systematically studied;

– the stage of developing mathematical models based on the results of the previous stage and a heuristic method for solving the multi-criteria optimization problem. At this stage, an analysis of the prospects for using the developed models and optimization method in regulating the oil well stock was also carried out;

– the final stage contains formulated conclusions and a generalization of the results of scientific research and development. The conclusions formulated and the research results obtained can be used as a methodological basis for effectively conducting further research on optimization systems for regulating the oil well stock based on mathematical models in various situations.

Let us formalize the formulation of the problem of multi-criteria optimization of oil production processes in a fuzzy environment, and propose a heuristic method for solving it.

Let Let $\boldsymbol{\mu}(\mathbf{x}) = (\mu_C^1(\mathbf{x}), \mu_C^2(\mathbf{x}), \dots, \mu_C^m(\mathbf{x}))$ – vector of membership functions of fuzzy criteria or a normalized vector of criteria that evaluates the quality of the oil production process. Here and below, $\mathbf{x} = (x_1, \dots, x_n)$ denotes the vector of input, operating parameters of the oil production process , affecting the oil production process $x_i, i = \overline{1, n}$,, the values of the criteria and restrictions characterizing the oil production process. Let us assume that membership functions have been constructed that estimate the degree of fulfillment of fuzzy constraints: $\mu_q(\mathbf{x}), q = \overline{1, L}$, , where L - the number of fuzzy restrictions. Let's also assume that the priority series for local criteria $I_C = \{1, \dots, m\}$ and constraints $I_R = \{1, \dots, L\}$ or vectors of weighting coefficients, reflecting the mutual importance of criteria $\boldsymbol{\gamma} = (\gamma_1, \dots, \gamma_m)$ and constraints $\boldsymbol{\beta} = (\beta_1, \dots, \beta_L)$, are known.

Then, based on various principles of optimality (compromise schemes) for working in a fuzzy environment, it is possible to obtain different mathematical formulations of multi-criteria optimization problems in a fuzzy environment in the form of fuzzy mathematical programming (FMP) problems and propose methods for solving them. For example, modifying, using the Pareto optimality principle, the general FMP problem with several criteria and fuzzy constraints (Orazbayev et al., 2020):

$$\max_{\mathbf{x} \in X} \mu_C^j(\mathbf{x}), j = \overline{1, m},$$

$$X = \left\{\mathbf{x}: \arg \max_{\mathbf{x} \in \Omega} \mu_q(\mathbf{x}), q = \overline{1, L}\right\},$$

let write it in the form of the following correct formulation:

$$\max_{\mathbf{x} \in X} \left(\sum_{j=1}^{m} \gamma_j \mu_C^j(\mathbf{x}) \right), \tag{1}$$

$$X = \left\{ \mathbf{x}: \arg \max_{\mathbf{x} \in \Omega} \sum_{q=1}^{L} \beta_q \mu_q(\mathbf{x}) \wedge \sum_{q=1}^{L} \beta_q = 1 \wedge \beta_q(\mathbf{x}) \geq 0, q = \overline{1, L} \right\}. \tag{2}$$

In the resulting formulation of the FMP problem (1)–(2), an effective set of solutions is sought at the points of the Pareto set formed by fuzzy constraints.

To solve the problem of multi-criteria optimization with fuzzy constraints (1)–(2), the following heuristic method is proposed, developed on the basis of a modification of the Pareto optimality principle (PO) for criteria and fuzzy constraints.

Heuristic method PO+PO.

1. With the involvement of decision makers and experts, determine the values of the weighting coefficients of the vector $\boldsymbol{\gamma} = (\gamma_1, \dots, \gamma_m)$ and $\boldsymbol{\beta} = (\beta_1, \dots, \beta_L)$, respectively, assessing the mutual importance of the criteria and restrictions.

2. To find optimal solutions, set the number of steps $p_q, q = \overline{1, L}$ for each *q*-th coordinate.

3. Calculate the step sizes for changing the coordinates of the weight vector using the formula: $h_q = {}^1/_{p_q}, q = \overline{1, L}$.

4. By varying coordinates on segments [0,1] with step determine a set of weight vectors $\boldsymbol{\beta}^1, \boldsymbol{\beta}^2, \dots, \boldsymbol{\beta}^N, N = (p_1 + 1) \times (p_2 + 1) \times \dots \times (p_L + 1)$.

5. Based on information from decision makers and experts, select term sets to describe fuzzy constraints and construct membership functions for each term that evaluate the degree of fulfillment of fuzzy constraints: $\mu_q(\mathbf{x}), q = \overline{1, L}$.

6. Solve the problem of maximizing the integrated criterion (1), obtained on the basis of the Pareto principle for the set of feasible solutions *X*, i.e., taking into account the conditions of fuzzy restrictions (2). In this case, the criterion values are determined on the basis of mathematical models that make it possible to describe the dependence of the criteria on the input factors of oil production processes $x_1, \dots, x_n$. As a result, the current solutions are determined: vector of input parameters $\mathbf{x} = (x_1, \dots, x_n)$, which provides the corresponding values of the criteria $\mu_C^j(\mathbf{x}), j = \overline{1, m}$ and the degree of fulfillment of fuzzy restrictions $\mu_q(\mathbf{x}), q = \overline{1, L}$. Since these results depend on the values of the weight vectors $\boldsymbol{\gamma}$ and $\boldsymbol{\beta}^r$, let write the obtained result as a function: input, mode parameters – $\mathbf{x}(\boldsymbol{\gamma}, \boldsymbol{\beta}^r), r = \overline{1, N}$; criterion – $\mu_C^1(\mathbf{x}(\boldsymbol{\gamma}, \boldsymbol{\beta}^r))$, $\mu_C^m(\mathbf{x}(\boldsymbol{\gamma}, \boldsymbol{\beta}^r)), r = \overline{1, N}$; fuzzy constraint fulfillment functions – $\mu_1(\mathbf{x}(\boldsymbol{\gamma}, \boldsymbol{\beta}^r)), \dots, \mu_L(\mathbf{x}(\boldsymbol{\gamma}, \boldsymbol{\beta}^r)), r = \overline{1, N}$.

7. Present the current solutions to the problem to the decision maker for analysis and selection of the final best solution based on his preferences, experience and knowledge, as well as taking into account the current situation in production and the market. If the current solutions do not satisfy the decision maker, then in order to improve the solution, he adjusts the values of the vectors $\boldsymbol{\gamma}$ and $\boldsymbol{\beta}^r$. Then, starting from point 6, the next cycle of searching for the best solution begins. The cycle is repeated until the decision maker makes the final decision. If the presented current solutions satisfy the decision maker, then he selects the final best solutions and moves on to the next point.

8. Stop searching for a solution and present the final, best solutions chosen by the decision maker taking into account the current situation: $\mathbf{x}^*(\boldsymbol{\gamma}, \boldsymbol{\beta}^r), r = \overline{1, N}$ – optimal values of input parameters providing maximum values of criteria: $\mu_C^1(\mathbf{x}^*(\boldsymbol{\gamma}, \boldsymbol{\beta}^r)), \dots, \mu_C^m(\mathbf{x}^*(\boldsymbol{\gamma}, \boldsymbol{\beta}^r)), r = \overline{1, N}$ and functions for fulfilling fuzzy constraints: $\mu_1(\mathbf{x}^*(\boldsymbol{\gamma}, \boldsymbol{\beta}^r)), \dots, \mu_L(\mathbf{x}^*(\boldsymbol{\gamma}, \boldsymbol{\beta}^r)), r = \overline{1, N}$ If some values of criteria need to be minimized, this is achieved by changing the sign of these criteria to the opposite.

Results

When conducting a study of the problems of developing and applying mathematical models and systems for optimizing oil production based on various available information for regulating the stock of oil wells, the following results were obtained. Currently, the application of mathematical modeling and optimization methods in oil production practice is the most effective way to solve problems of increasing oil production and rational use of oil wells. To improve engineering and oil production technology, a set of repair, preventative measures and industrial research, carried out at a scheduled time throughout the entire well stock, ensures the effective functioning of the well stock. Solving these problems requires the consistent implementation of a system of measures aimed at increasing the time between repairs of wells, increasing the productivity of repair crews, ensuring the quality of repair work and the required number of crews, etc. To do this, it is necessary to correctly plan and rationally distribute the necessary resources, taking into account the oil production development strategy, which allows increasing the well stock and improving the technical level of the equipment used. In this case, it is necessary to take into account the impact of possible changes in the context of current decisions, choosing the most technically and economically optimal options (Liu et al., 2017).

The technical and economic indicators of well operation modes are determined by many factors, the main ones of which are uncontrollable. The total operating well stock consists of production-producing wells and those undergoing preventive maintenance. And the idle well stock consists of wells that are undergoing major repairs and awaiting such repairs, as well as wells that are being developed and awaiting development after repairs.

The number of these categories of wells is constantly changing, as wells move from one category to another with varying intensity. Such processes have been studied and are well described by the Markov chain theory based on differential equations for the probabilities of wells being in certain categories.

We described this process using the example of an analysis of the stock of active and idle wells at the Kenkiyak field for the period from 01.01.2018 to 01.01.2023. The analysis data are presented in Table 1.

For a qualitative description and development of the necessary mathematical models, a notation system has been introduced: t – time; $x_1(t)$ – active wells; $x_2(t)$ – wells undergoing major repairs or awaiting such repairs; $x_3(t)$ – wells under development or awaiting development; $q(t)$ – intensity of commissioning of new wells.

Table 1 – Current actual state of the oil well stock of the Kenkiyak field

Well stock	2018		2019		2020		2021		2022		2023
	01.01	01.07	01.01	01.07	01.01	01.07	01.01	01.07	01.01	01.07	01.01
Operating wells, including:	200	505	645	847	1030	1200	1525	1817	2100	2250	2415
- production wells;	196	495	634	830	1010	1176	1494	1783	2060	2205	2368
- undergoing preventative maintenance	4	10	11	17	20	22	31	34	40	45	47
Idle wells, including:	77	100	132	147	130	112	119	138	170	190	210
- undergoing major repairs and awaiting such repairs	49	63	84	92	83	72	74	88	110	119	133

- under development or awaiting development	28	37	48	55	47	40	45	50	60	71	77

Then, in accordance with the general scheme for writing the equations of Markov processes, taking into account the peculiarities of the functioning of the operational fund, we can write the following system of equations:

$$\begin{cases} \frac{dx_1}{dt} = -ax_1 + bx_3, \\ \frac{dx_2}{dt} = ax_1 - cx_2, \\ \frac{dx_3}{dt} = cx_2 - bx_3 + q. \end{cases} \qquad (1)$$

The first equation $\frac{dx_1}{dt} = -ax_1 + bx_3$ from the system of differential equations given above (1) reflects the fact that the number of wells in the active stock per unit of time $\frac{dx_1}{dt}$ changes due to the retirement of wells from operation with intensity *a*(*ax*) and the commissioning of wells after development with intensity *b*(*bz*). The remaining equations of the system of equations (1) are presented similarly. Thus, the change in the total number of production wells per unit time *N*(*t*) will be equal to the intensity of commissioning new wells *q*(*t*). Summing up all three equations of system (1), we obtain:

$$\frac{dN}{dt} = \frac{dx_1}{dt} + \frac{dx_2}{dt} + \frac{dx_3}{dt} = q. \qquad (2)$$

To model the process of functioning of the well stock, consider the scheme of using the system of equations (1), which is as follows. Based on data on the dynamics of the well stock over a certain period of time, the parameters a*, b, c* of the equations are estimated. Then, based on the given intensity of commissioning new wells *q*(*t*) it is possible to predict the dynamics of change $x_1(t), x_2(t), x_3(t)$.. Since the value of parameter a is inversely proportional to the duration of the turnaround period, and the value of *b* and *c* is proportional to the productivity of well repair services, using the model system (1) it is possible to simulate and predict the consequences caused, for example, by increasing the rate of commissioning of new wells or introducing measures to increase the duration of the between-repairs period, etc. Typically, such calculations are performed without taking into account the time lag, which does not allow reliably predicting emerging trends in changes in the structure of the existing fund. A distinctive feature of the approach under consideration is the possibility of obtaining both operational estimates and long-term forecasts.

The system of models (1) for the existing well stock $x_1(t)$, can be reduced to the equation:

$$x_1''' + (a+b+c)x_1'' + (ab+ac+bc)x_1' = bcq; \quad x_1(t_0) = x_1^0, \qquad (3)$$

The solution to equation (2) is determined by the following expression:

$$x_1(t) = A_1 + A_2 e^{y_2 t} + A_3 e^{y_2 t} + \alpha t, \quad at \quad \alpha = \frac{bcq}{ac+ab+bc} \qquad (4)$$

with real roots

$$\gamma_1 = 0, \quad \gamma_{2,3} = -\frac{a+b+c}{2} \pm \sqrt{\left(\frac{a+b+c}{2}\right)^2 - ab - ac - bc} < 0. \quad (5)$$

The stock of wells that are undergoing major repairs and development is determined by sequentially substituting $x_1(t)$, into the second equation of system (1) and then $x_2(t)$ into the third equation:

$$x_2(t) = Be^{-ct} + e^{-ct}\int ax(\tau)e^{c\tau}d\tau; \quad x_2(t_0) = x_2^0; \quad (6)$$

$$x_2(t) = Be^{-ct} + e^{-ct}\int ax(\tau)e^{c\tau}d\tau; \quad x_2(t_0) = x_2^0; \quad (7)$$

At $|x_2(t)| \gg 1$ the relations (3)-(5) are simplified:

$$\begin{cases} x_1(t) = x_1^0 + \alpha(t - t_0); \\ x_2(t) = x_2^0 e^{-c(t-t_0)} + \frac{a}{c}\left(x_0 - \frac{\alpha}{c}\right)\left[1 - e^{-c(t-t_0)}\right] + \frac{a\alpha}{c}(t - t_0); \\ x_3(t) x_3^0 e^{-b(t-t_0)} + \frac{1}{b-c}\left[cx_3^0 - a\left(x_1^0 - \frac{\alpha}{c}\right)\right]\left[e^{-c(t-t_0)} - e^{-b(t-t_0)}\right] + \\ \frac{1}{b}\left[q + a\left(x_1^0 - \frac{\alpha}{c} - \frac{\alpha}{b}\right)\right]\left[1 - e^{-b(t-t_0)}\right] + \frac{a\alpha}{b}(t - t_0) \end{cases} \quad (8)$$

and for $t \gg t_0$ a linear asymptote of all types of well stock in time is ensured.

$$\begin{cases} x_1 \cong x_1^0 + \alpha(t - t_0); \\ x_2 \cong \frac{a}{c}\left(x_1^0 - \frac{\alpha}{c}\right) + \frac{a\alpha}{c}(t - t_0); \\ x_3 \cong \frac{1}{b}\left[q + a\left(x_1^0 - \frac{\alpha}{c} - \frac{\alpha}{b}\right)\right] + \frac{a\alpha}{b}(t - t_0). \end{cases} \quad (9)$$

The proposed procedure can also take into account well abandonment. To do this, it is enough to assume that $q(t)$ is the total intensity of the commissioning of new wells and the abandonment of long-term idle wells; in this case $q > 0$, if the intensity of commissioning new wells exceeds the intensity of abandonment, and $q < 0$ in the opposite case.

Based on the data given in Table 1 using parametric identification methods, it is possible to determine the values *a, b* and *c*. As a result of using the REGRESS software package, which implements the least squares method, with the given data we determined: *a*=0,19 well/year; *b*=15 well/year; *c*=3 well/year. The actual and estimated number of wells in the operating $x_1(t)$ and idle $x_2(t)$+ $x_3(t)$ + stock and the dynamics of their changes in the graphs are presented in Figure 1.

Discussion

As can be seen from the graphs shown in Figure 1 of the dynamics of the well stock, the agreement between the calculated (forecast) values obtained from the models and the actual values is quite satisfactory. The significant discrepancy between them in 2019 is explained by a sharp increase in the number of idle wells this year compared to the forecast, which means a deterioration in the work of repair crews and requires special analysis. The proposed method allows us to identify the development of negative trends. For example, when analyzing changes in the calculated and operating stock of idle wells, it is clear (see Figure 1) that the trends in the number of wells in the operating stock exceeding the number of wells in the calculated stock began to develop in 2018. Based on this analysis, it is possible to timely predict the possible dynamics of the well stock and make operational decisions on organizational and technical measures.

The proposed system of models allows analyzing various situations. For example, you can find out the dependence of the dynamics of the well stock on the productivity of well repair units or determine how the productivity of repair organizations should be changed to ensure the necessary changes in the structure of the stock. The complexity of such an assessment is determined by the need to simultaneously take into account the influence and interaction of several factors, the effects of which change over time. For example, an increase in the number of overhaul teams will not immediately affect the change in the structure of the well stock, since the commissioning of wells is determined both by the time spent waiting for development and by the time of development. This type of problem can be effectively solved using the proposed system of models.

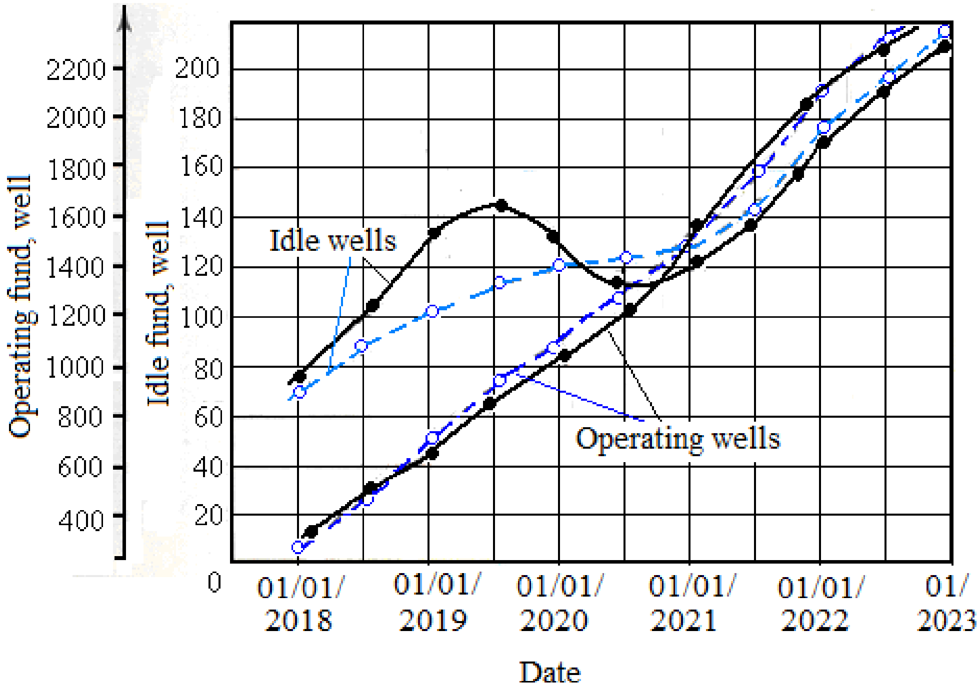

Figure 1 – Change in oil well stock:
solid line - actual data;
dashed line – calculated (model) values

Modeling is implemented according to the following scheme. Some initial values of the coefficients *a, b,* c, determined by the productivity of the repair crews and the duration of the repair period, and the structure of the current well stock are set. Then the model calculates the predicted population dynamics $x_1(t), x_2(t), x_3(t)$. . If for the forecast period the indicators of the use of the well stock do not satisfy the specified criteria (for example, the number of wells in the idle stock turns out to be unacceptably high), then by selecting the values of the coefficients of the model system (1), its solution is adjusted to the required limits. Based on the obtained coefficient values, recommendations are issued and organizational and technical decisions are made on changing the structure and equipment of repair departments.

From the results presented in Figure 1, it follows that by 2022–2023, in accordance with (9), a linear asymptote of growth of the operating and idle well stock is achieved. In this area, the growth rate of the number of idle wells is 0.07–0.08 of the growth rate of the number of operating wells.

Estimation of the indicated ratio using equation (9) gives the result $\frac{(x_2+x_3)'}{x_1'} = \frac{a(b+c)}{bc}$, the actual ratio is $K = \frac{(x_2+x_3)}{x_1}$ =0.08. Suppose 2 times, i.e. to the level $K_1 = 0.04$, maintaining the intensity of *q*, *a*, *b* and changing only the productivity of the well repair workshop *c*. Then, going straight to asymptotic estimates, from relations (9) we obtain $K_1 = \frac{a(b+c_1)}{bc_1}$, from which the required productivity of the repair department has the form:

$$c_1 = \frac{ab}{(K_1 b - a)} = \frac{0.19 \cdot 15}{0.04 \cdot 15 - 0.19} = \frac{2.85}{0.41} = 6.95 \approx 10 \frac{\text{well}}{year}.$$

To achieve the goal, it is necessary to increase the productivity of the repair department more than 3 times (c_1/c). It should be noted that the estimates performed are of an asymptotic (equilibrium) nature. To calculate the transition process, you should use relations (6)–(9) or a numerical solution of the original system (1).

An example of estimating the duration of the transition period. We define the duration of the transition period as the time , during which in relations (3)–(9) the nonlinear terms decrease to a value less than 0.01 from the initial value at the moment of time t_0, i. e. $\tau = \frac{ln100}{min(\gamma_2,\gamma_3,c,b)}$. Then for the data defined above *b*=15 well/year, *c*=3 well/year, *a*=0,19 well/year, γ_2 = -15 (14.96) well/year, γ_3= -3.24 (3) well/year we have $\tau = \frac{4.6}{6.0}$, i. e. $\tau < 1$ year, which means a transition period should be taken into account when assessing semi-annual plans.

Currently, for the effective operation of oil fields where the oil production process is carried out, it is necessary to develop models on the basis of which the actions of all systems involved in this process are quickly managed and coordinated. In this context, it should be noted that management is the most important function of any system with different levels of organization and is designed to ensure high-quality and timely coordination of operations to create optimal conditions for achieving the desired result and solving problems of optimizing the oil production process and regulating the well stock. In general, mathematical modeling methods are the most effective and promising approach to the practical solution of a wide range of oil production issues, from the point of view of the prospects for increasing the efficiency of exploitation of oil well reserves.

Conclusion

As a result of studying the issues of synthesis and practical application of mathematical models for optimizing the processes of oil field development and oil production when regulating oil well reserves, the following conclusions were obtained:

– studying the issues of forecasting and regulating the oil well stock using mathematical models and optimizing oil production processes involves the use of a systematic approach based on various approaches to solving the problems under study;

– formalization and mathematical formulation of the problem of multi-criteria optimization of oil production processes in conditions of shortage and fuzziness of initial information, and the development of a method for solving it involves the use of a heuristic approach based on expert assessment methods and fuzzy set theories;

– solving the issues of developing mathematical models to describe oil production processes based on the theory of Markov chains involves building models that allow assessing the state of various types of oil well stock;

– the developed mathematical models based on the theory of Markov chains for forecasting and regulating the stock of oil wells allows to qualitatively assess the prospects for using the stock of operating wells, as well as the stock of wells that are under major repairs and at the development stage.

Thus, the study indicates that there are significant prospects for the practical application of mathematical models for optimizing oil production processes, for predicting and regulating the well stock, which determines the prospects for further scientific developments in order to create modern optimization systems based on mathematical models that describe the functioning and state of the oil well stock.

REFERENCES

Aidnalieva G.Z. (2022). Analysis and preparation of the geological and field basis for the design of the development of post-salt deposits of the Kenkiyak field. Report of Joint-Stock Company NIPI "Kaspimunaigas". — Atyrau, 2022. — 187 p. — ISBN 9-907-57857-3. (In Russ.).

Gagniuc P.A. (2017). Markov Chains: From Theory to Implementation and Experimentation. — USA, NJ: John Wiley & Sons. — Pp. 1–235. — ISBN 978-1-119-38755-8.

Gordji M. (2016). Theory of Approximate Functional Equations. London: Academic Press. Elsevier. — ISBN: 9780128039205

Goyal A. Systems Analysis and Design. (2017). Prentice Hall India Learning Private Limited. — 232 p. — ISBN 975-7-7385-9517-3

Ilin V., Lichun Ch., Jun K., Shakhovoy A., Aydnalieva G. (2017). Project for the development of post-salt deposits of the Kenkiyak field. Report. Xinjiang Oil and Gas Research Institute of the XUAR of the People's Republic of China, OAO NIPI "*Kaspiymunaigaz" of the Republic of Kazakhstan*. — 215 p. — ISBN 9-757-2775775

Jorgensen M. (2019). A Review of Studies on Expert Estimation of Software Development Effort. Journal of Systems and Software. — 70. — Pp. 37–60. — DOI: 10.1016/S0164-1212(02)00156-5

Kuanbayeva B., Rakhmetov M., Turkmenbayev A., Abdykerimova, Tumysheva A., (2022). The effectiveness of using interactive computer models as methodological tools in science school education. orld Trans. on Engng. and Technol. Educ., — 20, 4. — Pp. 306–311. — URL: http://www.wiete.com.au/journals/WTE&TE/Pages/TOC_V20N4.html.

Lambert W., Loures M.C. (2021). A Mathematical Study on the Viability of the Geochemical Flow for an Enhanced Oil Recovery: a Simplified Model. Applied Mathematical Modelling, — 75. — Pp. 678–691.

Orazbayev B.B., Assanova B.U., Bakiev M.N., Krawczyk J., Orazbayeva K.N. (2020). Methods of model synthesis and multi-criteria optimization of chemical-engineering systems in the fuzzy environment. Journal of Theoretical and Applied Information Technology. — 98(6). — Pp. 1021–1036. — https://www.scopus.com/record/display.uri?eid=2-s2.0-85083790104&origin=resultslist&sort=plf-f

Orazbayev B., Issa I., Iskakova S., Kurmangaziyeva L. (2022). Application of mathematical modelling methods in oil production management. — *Naukovyi Visnyk Natsio-nalnoho Hirnychoho Universytetu*. — 4. — Pp. 112–116. — https://doi.org/10.33271/nvngu/2022-4/112

Orazbayev B.B., Ospanov, Ye A., Orazbayeva K.N.' Makhatova V.E.' Urazgaliyeva M.K.' Shagayeva A.B. (2019). Development of mathematical models of R-1 reactor hydrotreatment unit using available information of various types. Journal of Physics: Conference Series. — 1399 (45), — 044024. — DOI 10.1088/1742-6596/1399/4/044024

Orazbayev B., Zhumadillayeva A., Orazbayeva K., Iskakova S., Utenova, B., Gazizov F., Ilyashenko S., Afanaseva O. (2022). The System of Models and Optimization of Operating Modes of a Catalytic Reforming Unit Using Initial Fuzzy Information. Energies. — 15(4), —1573. — Pp. 1–26. — https://doi.org/10.3390/en15041573

Pavlov S.Yu., Kulov N.N., Kerimov R.M. (2018). Improvement of Chemical Engineering Processes Using Systems Analysis // Theoretical Foundations of Chemical Engineering. — 53. (2). — Pp. 117–133. — DOI: 10.1134/S0040579514020109

Rakhmetov M., Sadvakassova A., Saltanova G., Yessekenova A. (2022). Usage and effectiveness of educational platforms in Kazakhstan during the Covid-19 pandemic., World Transactions on Engineering and Technology Education. — 20(3). — 226–231. — URL: https://www.scopus.com/record/display.uri?eid=2-s2.0-85136288448&origin=resultslist&sort=plf-f

Romanov V.N. (2019). The use of fuzzy arithmetic in decisionmaking problems. SN Applied Sciences. —1:367. https://doi.org/10.1007/s42452-019-0384-9

Sabzi H.Z. (2017). Developing an intelligent expert system for streamflow prediction, integrated in a dynamic decision support system for managing multiple reservoirs: a case study. Expert systems with applications. — 82(3). — Pp.145–163. — DOI:10.1016/j.eswa.2017.04.039

Shakhverdiev A.K., Arefyev S.V., Polishchuk A.A., Vaynerman B.P., Yunusov R.R., Denisov A.V. (2020). Updating a reservoir geological model in order to optimize waterflooding when extracting residual oil reserves from stagnant zones. Proceedings of higher educational establishments. Geology and Exploration. 63(5). — Pp. 28–41. — https://doi.org/10.32454/0016-7762-2020-63-5-28-41 (In Russ.).

Shutko S.Yu., Kozhevnikova S.D., Shutko D.S. (2017). Investment Decision-Making in the Business Segment of Exploration and Production of Oil. Subsoil use XXI century. — 3. — Pp. 132–141. https://magazine.neftegaz.ru/articles/geologorazvedka/539495-stsenarnyy-prognoz-parametrov-dobychi-nefti-iz-nizkopronitsaemykh-neftegazovykh-rezervuarov-bazhenov/ (In Russ.).

Spirina M.S. (2019). Probability Theory and Mathematical Statistics: Textbook. — M.: Academia. — P. 144. — ISBN 978-5-7695-9711-4 (In Russian).

Weiwei Zhuang, Yadong Li, Guoxin Qiu (2022). Statistical inference for a relaxation index of stochastic dominance under density ratio model Journal of Applied Statistics. — 49(15). — p. 3804–3822. — DOI: 10.1080/02664763.2021.1965966

Zhang L., Chen Z., Zhao Y-L. (2019). Well Production Performance Analysis for Shale Gas Reservoirs. — Oxford: Woodhead Publishing. — p. 388. — ISBN: 9780444643155

Zimmermann H.-J. (2018). Fuzzy Set Theory – and Its Applications. Springer Science+Business Media, LLC. Fifth Edition 2018. — P. 525. — ISBN: 978-94-010-3870-6. — DOI: 10.1007/978-94-010-0646-0

CONTENT

B.N. Absadykov, L.E. Sergeev, S.I. Mendaliyeva, K.T. Sherov, M.R. Sikhimbayev
THE MECHANISM OF ACTION OF LUBRICATING AND COOLING TECHNOLOGICAL MEANS ON METAL REMOVAL DURING MAGNETIC ABRASIVE PROCESSING OF PARTS..8

© A. Begalinov, M. Shautenov, T. Almenov, B. Bektur, K. Sakhipova
RESEARCH OF GRAVITY CONCENTRATION OF THE GOLD PLACER OF EASTERN KAZAKHSTAN..17

S.V. Gladyshev, S.B. Dyussenova, A.I. Bakhshyan, R.A. Abdulvaliev, A.I. Manapova
SELECTING AND IMPROVEMENT OF A METHOD FOR PROCESSING KAOLINITE FRACTION OF BAUXITE.. 35

K.S. Dossaliyev, K. Ibragimov, K.I. Nazarov, Zh.A. Ussenkulov, F.Kh. Aubakirova
COARSE-GRAINED SOILS COMPACTION AT THE EXPERIMENTAL SITE DURING THE CONSTRUCTION OF THE EARTHEN DAM..............................58

R. Izimova, G.B. Toktaganova, M.Zh. Makhambetov, G.I. Issayev, K.T.Abdraimova
COMPARATIVE ECOLOGICAL ASSESSMENT OF SOIL CONDITION IN THE TERRITORY OF OIL FIELDS OF ATYRAU REGION..71

A.S. Madibekov, A.M. Karimov, L.T. Ismukhanova, A.O. Zhadi, K.M. Bolatov
MARKAKOL LAKE LEVEL REGIME AS INDICATOR OF CLIMATE CHANGE......82

E.K. Merekeyeva, F.K. Nurbayeva, G.I. Zhiyenbayeva, P.S. Sundetova, S.M. Cherkeshova
TECTONICS OF THE ZHAZGURLINSKY DEPRESSION OF SOUTHERN MANGYSHLAK..95

A.V. MITROFANOV, G.G. ABDULLINA, G.K. AHMEDYANOVA, D.G. Aigozhina, D.N. Kabylkaiyr
STOCHASTIC MODEL OF HYDROTRANSPORTATION OF DISPERSED ORE MATERIALS IN VERTICAL PIPELINES...107

A. Musakulkyzy, A.S. Madibekov, L.T. Ismukhanova, K.M. Bolatov
INTEGRAL ASSESSMENT OF THE WATER QUALITY OF THE MARKAKOL LAKE IN KAZAKHSTAN PART OF WESTERN ALTAI...119

L. Nurmaganbetova, A. Abilgaziyeva, S. Buktybayeva, A. Karimova, Zh. Shayakhmetova
GEOCHEMICAL CHARACTERISTICS OF THE OIL OF THE EASTERN SIDE OF THE CASPIAN BASIN ACCORDING TO THE STUDY OF CARBON ISOTOPES AND BIOMARKERS..133

O.V. Rozhkova, D.M.-K. Ibraimova, K.B. Musabekov, V.I. Rozhkov, M.T. Ermekov
DEVELOPMENT OF ANHYDROUS DRILLING FLUIDS BASED ON TAGAN DEPOSIT'S SUPERHYDROPHOBIC CLAY FOR DRILLING OIL WELLS AT THE KUMKOL FIELD....................146

Zh.Zh. Smagulov, D. Snow, D.D. Arystambekova, A.M. Sailaubek, A.Z. Tairov
STUDY OF WATER REGIME OF ZHAIYK TRANSBOUNDARY RIVER IN THE CONTEXT OF ANTHROPOGENIC AND CLIMATIC CHANGES....................164

S. Syrlybekkyzy, A. Zhidebayeva, A. Aitimova, D. Baimbetov, L. Taizhanova
DEVELOPMENT AND EVALUATION OF THE EFFECTIVENESS OF NEW DESIGNS OF SOLAR DESALINATION POOLS FOR THE PRODUCTION OF FRESH WATER IN HOT CLIMATES....................179

D.B. Shirinova, A.S. Bayramova, L.V. Huseynova, A.D. Valiyeva
WATER PURIFICATION WITH AN ADSORBENT BASED ON CARBONATE SLUDGE....................196

B. Orazbayev, A. Zhiyenbek, G. Uskenbayeva, Zh. Abdugulova, L. Rzayeva
MODELING AND OPTIMIZATION OF OIL PRODUCTION PROCESSES FOR REGULATION OF OIL WELL FUND....................205

Publication Ethics and Publication Malpractice in the journals of the National Academy of Sciences of the Republic of Kazakhstan

For information on Ethics in publishing and Ethical guidelines for journal publication see http://www.elsevier.com/publishingethics and http://www.elsevier.com/journal-authors/ethics.

Submission of an article to the National Academy of Sciences of the Republic of Kazakhstan implies that the work described has not been published previously (except in the form of an abstract or as part of a published lecture or academic thesis or as an electronic preprint, see http://www.elsevier.com/postingpolicy), that it is not under consideration for publication elsewhere, that its publication is approved by all authors and tacitly or explicitly by the responsible authorities where the work was carried out, and that, if accepted, it will not be published elsewhere in the same form, in English or in any other language, including electronically without the written consent of the copyright-holder. In particular, translations into English of papers already published in another language are not accepted.

No other forms of scientific misconduct are allowed, such as plagiarism, falsification, fraudulent data, incorrect interpretation of other works, incorrect citations, etc. The National Academy of Sciences of the Republic of Kazakhstan follows the Code of Conduct of the Committee on Publication Ethics (COPE), and follows the COPE Flowcharts for Resolving Cases of Suspected Misconduct (http://publicationethics.org/files/u2/New_Code.pdf). To verify originality, your article may be checked by the originality detection service Cross Check http://www.elsevier.com/editors/plagdetect.

The authors are obliged to participate in peer review process and be ready to provide corrections, clarifications, retractions and apologies when needed. All authors of a paper should have significantly contributed to the research.

The reviewers should provide objective judgments and should point out relevant published works which are not yet cited. Reviewed articles should be treated confidentially. The reviewers will be chosen in such a way that there is no conflict of interests with respect to the research, the authors and/or the research funders.

The editors have complete responsibility and authority to reject or accept a paper, and they will onh accept a paper when reasonably certain. They will preserve anonymity of reviewers and promote publication of corrections, clarifications, retractions and apologies when needed. The acceptance of a paper automatically implies the copyright transfer to the National Academy of sciences of the Republic of Kazakhstan.

The Editorial Board of the National Academy of sciences of the Republic of Kazakhstan will monitor and safeguard publishing ethics.

Правила оформления статьи для публикации в журнале смотреть на сайте:
www:nauka-nanrk.kz

ISSN 2518-1483 (Online), ISSN 2224-5227 (Print)
http://geolog-technical.kz/en/archive/

Подписано в печать 15.06.2024.
Формат 60x88$^{1}/_{8}$. Бумага офсетная. Печать - ризограф.
15,0 п.л. Тираж 300. Заказ 3.

РОО «Национальная академия наук РК» 050010,
Алматы, ул. Шевченко, 28, т. 272-13-19