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

NEWS OF THE NATIONAL ACADEMY OF SCIENCES OF THE REPUBLIC OF KAZAKHSTAN, SERIES OF GEOLOGY AND TECHNICAL SCIENCES

№2
2026

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

CENTRAL ASIAN ACADEMIC
RESEARCH CENTER

N E W S
OF THE NATIONAL ACADEMY OF SCIENCES OF THE REPUBLIC OF KAZAKHSTAN, SERIES OF GEOLOGY AND TECHNICAL SCIENCES

2 (476)

MARCH – APRIL 2026

THE JOURNAL WAS FOUNDED IN 1940

PUBLISHED 6 TIMES A YEAR

ALMATY, 2026

The scientific journal News of the National Academy of Sciences of the Republic of Kazakhstan, Series of Geology and Technical Sciences has been indexed in the international abstract and citation database Scopus since 2016 and demonstrates stable bibliometric performance.

The journal is also included in the Emerging Sources Citation Index (ESCI) of the Web of Science platform (Clarivate Analytics, since 2018).

Indexing in ESCI confirms the journal's compliance with international standards of scientific peer review and editorial ethics and is considered by Clarivate Analytics as part of the evaluation process for potential inclusion in the Science Citation Index Expanded (SCIE), Social Sciences Citation Index (SSCI), and Arts & Humanities Citation Index (AHCI).

Indexing in Scopus and Web of Science ensures high international visibility of publications, promotes citation growth, and reflects the editorial board's commitment to publishing relevant, original, and scientifically significant research in the fields of geology and technical sciences.

«Қазақстан Республикасы Ұлттық ғылым академиясының Хабарлары. Геология және техникалық ғылымдар сериясы» ғылыми журналы 2016 жылдан бастап халықаралық реферативтік және ғылыметриялық Scopus дерекқорында индекстеледі және тұрақты библиометриялық көрсеткіштерді көрсетіп келеді.

Сонымен қатар журнал Web of Science платформасының (Clarivate Analytics, 2018) халықаралық реферативтік және наукометриялық дерекқоры Emerging Sources Citation Index (ESCI) тізіміне енгізілген.

ESCI дерекқорында индекстелуі журналдың халықаралық ғылыми рецензиялау талаптары мен редакциялық этика стандарттарына сәйкестігін растайды, сондай-ақ Clarivate Analytics компаниясы тарапынан басылымды Science Citation Index Expanded (SCIE), Social Sciences Citation Index (SSCI) және Arts & Humanities Citation Index (AHCI) дерекқорларына енгізу қарастырылуда.

Scopus және Web of Science дерекқорларында индекстелуі жарияланымдардың халықаралық деңгейде жоғары сұранысқа ие болуын қамтамасыз етеді, олардың дәйексөз алу көрсеткіштерінің артуына ықпал етеді және редакциялық алқаның геология мен техникалық ғылымдар саласындағы өзекті, бірегей және ғылыми тұрғыдан маңызды зерттеулерді жариялауға ұмтылысын айқындайды.

Научный журнал «News of the National Academy of Sciences of the Republic of Kazakhstan, Series of Geology and Technical Sciences» с 2016 года индексируется в международной реферативной и наукометрической базе данных Scopus и демонстрирует стабильные библиометрические показатели.

Журнал также включён в международную реферативную и наукометрическую базу данных Emerging Sources Citation Index (ESCI) платформы Web of Science (Clarivate Analytics, 2018).

Индексирование в ESCI подтверждает соответствие журнала международным стандартам научного рецензирования и редакционной этики, а также рассматривается компанией Clarivate Analytics в рамках дальнейшего включения издания в Science Citation Index Expanded (SCIE), Social Sciences Citation Index (SSCI) и Arts & Humanities Citation Index (AHCI).

Индексирование в Scopus и Web of Science обеспечивает высокую международную востребованность публикаций, способствует росту цитируемости и подтверждает стремление редакционной коллегии публиковать актуальные, оригинальные и научно значимые исследования в области геологии и технических наук.

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: «Central Asian Academic Research Center» LLP (Almaty).
The certificate of registration of a periodical printed publication in the Committee of information of the Ministry of Information and Communications of the Republic of Kazakhstan № KZ50VPY00121155, issued on 05.06.2025
Thematic scope: *geology, hydrogeology, geography, mining and chemical technologies of oil, gas and metals*
Periodicity: 6 times a year.
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)
Меншіктеуші: «Орталық Азия академиялық ғылыми орталығы» ЖШС (Алматы қ.).
Қазақстан Республикасының Ақпарат және коммуникациялар министрлігінің Ақпарат комитетінде 05.06.2025 ж. берілген № KZ50VPY00121155 мерзімдік басылым тіркеуіне қойылу туралы куәлік.
Тақырыптық бағыты: *геология, гидрогеология, география, тау-кен ісі, мұнай, газ және металдардың химиялық технологиялары*
Мерзімділігі: жылына 6 рет.
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)
Собственник: ТОО «Центрально-Азиатский академический научный центр» (г. Алматы).
Свидетельство о постановке на учет периодического печатного издания в Комитете информации Министерства информации и коммуникаций и Республики Казахстан № KZ50VPY00121155, выданное 05.06.2025 г.
Тематическая направленность: *геология, гидрогеология, география, горное дело и химические технологии нефти, газа и металлов*
Периодичность: 6 раз в год.
http://www.geolog-technical.kz/index.php/en/

CONTENTS

NEWS OF THE NATIONAL ACADEMY OF SCIENCES OF THE REPUBLIC
OF KAZAKHSTAN, SERIES OF GEOLOGY AND TECHNICAL SCIENCES
ISSN 2224–5278
Volume 2.
Number 476 (2026), 107–120

https://doi.org/10.32014/2026.2518-170X.618

UDC: 622.7:504.064:658.5
IRSTI: 52.13.15; 87.15.09

©Borotov A.N.[1], Karshiev F.U.[2], Igamberdiyev A.A.[3], Grigoryan A.G.[4], Sarigo N.V.[5], 2026.
[1]Tashkent Institute of Irrigation and Agricultural Mechanization Engineers National Research University, Tashkent, Uzbekistan;
[2]Termez State University, Termez, Uzbekistan;
[3]Tashkent State Technical University, Tashkent, Uzbekistan;
[4]Admiral F.F. Ushakov State Maritime University, Novorossiysk, Russia;
[5]Federal State Budgetary Educational Institution of Higher Education I.I. Ivanov Kursk State Agrarian University, Kursk, Russia.
E-mail: atxamborotov@mail.ru

ECOLOGICAL ASPECTS OF RESOURCE CONSERVATION IN THE DEVELOPMENT OF MINERAL DEPOSITS

Borotov Atkham — PhD, Associate Professor, Tashkent Institute of Irrigation and Agricultural Mechanization Engineers National Research University, Tashkent, Uzbekistan,
E-mail: atxamborotov@mail.ru, https://orcid.org/0009-0000-0010-6903;
Karshiev Fakhridin — Doctor of Technical Sciences, Professor, Termez State University, Termez, Uzbekistan,
E-mail: fkarshiev@mail.ru, https://orcid.org/0009-0003-3067-7418;
Igamberdiyev Abdulaziz — Senior Teacher, Tashkent State Technical University, Tashkent, Uzbekistan,
E-mail: abdulazizigamberdiyev699@gmail.com, https://orcid.org/0009-0000-5533-7274;
Grigoryan Anna — Senior Lecturer, Admiral F.F. Ushakov State Maritime University, Novorossiysk, Russia,
E-mail: grigoryan.anya2015@yandex.ru, https://orcid.org/0009-0002-3235-4084;
Sarigo Nadezhda — Candidate of Pedagogical Sciences, Federal State Budgetary Educational Institution of Higher Education I.I. Ivanov Kursk State Agrarian University, Kursk, Russia,
E-mail: nadezhda.sarigo@yandex.ru, https://orcid.org/0009-0002-5637-5824.

Abstract. *Relevance.* Mineral deposit development is accompanied by significant losses of water and mineral resources and increasing environmental impact, which necessitates the implementation of localized resource saving technological solutions. *Objective.* To assess the environmental and economic efficiency of optimizing tailings thickening processes and to substantiate their applicability at operating mining enterprises. *Methods.* The study applied an

integrated methodological approach including analysis of production data obtained from an operating mining enterprise, laboratory and pilot-scale testing of tailings thickening processes, hydrodynamic modeling of phase separation parameters, and a comparative environmental and economic assessment of different technological regimes. Experimental investigations were carried out using a laboratory thickening unit equipped with adjustable pulp feed rate, flocculant dosing system, and variable rake rotation speed. Process monitoring was performed using modern analytical instruments including particle size analyzers, flow meters, density sensors, and energy consumption monitoring systems. During the modeling stage, particular attention was given to evaluating the influence of solids concentration, reagent dosage, and hydrodynamic operating parameters on sedimentation efficiency and fine particle capture rate. *Results and conclusions.* The obtained results demonstrate that reagent intensification combined with optimization of operating parameters ensures a stable increase in thickened product density and a significant reduction in suspended solids concentration in the clarified overflow. An increase in the recovery of fine fractions containing a considerable proportion of valuable components was achieved, which contributed to reducing technological losses of mineral raw materials and improving the overall efficiency of resource utilization. Expansion of recycled water reuse significantly decreased the consumption of fresh process water and reduced the hydraulic load on tailings storage facilities. At the same time, a reduction in specific energy consumption associated with thickening and slurry transportation processes was observed. The environmental and economic assessment confirmed that implementation of the proposed technological solutions leads to lower operating costs, reduced environmental payments, and the formation of a positive integrated economic effect while maintaining a relatively short payback period for the modernization of the technological process.

Keywords: resource conservation, tailings thickening, recycled water supply, environmental efficiency, mining industry, techno economic assessment

For citations: *Borotov A.N., Karshiev F.U., Igamberdiyev A.A., Grigoryan A.G., Sarigo N.V. Ecological Aspects of Resource Conservation in the Development of Mineral Deposits. News of the National Academy of Sciences of the Republic of Kazakhstan, Series of Geology and Technical Sciences. 2026. No.2. Pp. 107–120. DOI: https://doi.org/10.32014/2026.2518-170X.618*

©Боротов А.Н.[1], Каршиев Ф.У.[2], Игамбердиев А.А.[3], Григорян А.Г.[4], Сариго Н.В.[5], 2026.

[1]«Ташкент ирригация және ауыл шаруашылығын механикаландыру инженерлері институты» Ұлттық зерттеу университеті, Ташкент, Өзбекстан;
[2]Термез мемлекеттік университеті, Термез, Өзбекстан;
[3]Ташкент мемлекеттік техникалық университеті, Ташкент, Өзбекстан;
[4]Адмирал Ф.Ф. Ушаков атындағы Мемлекеттік теңіз университеті, Новороссийск, Ресей;
[5]И.И. Иванов атындағы Курск мемлекеттік аграрлық университеті, Курск, Ресей.
E-mail: atxamborotov@mail.ru

ПАЙДАЛЫ ҚАЗБАЛАР КЕН ОРЫНДАРЫН ИГЕРУ КЕЗІНДЕ РЕСУРСТАРДЫ ҮНЕМДЕУДІҢ ЭКОЛОГИЯЛЫҚ АСПЕКТІЛЕРІ

Боротов Атхам — PhD, доцент, «Ташкент ирригация және ауыл шаруашылығын механикаландыру инженерлері институты» Ұлттық зерттеу университеті, Ташкент, Өзбекстан, E-mail: atxamborotov@mail.ru, https://orcid.org/0009-0000-0010-6903;
Каршиев Фахридин — техника ғылымдарының докторы, профессор, Термез мемлекеттік университеті, Термез, Өзбекстан,
E-mail: fkarshiev@mail.ru, https://orcid.org/0009-0003-3067-7418;
Игамбердиев Абдулазиз — аға оқытушы, Ташкент мемлекеттік техникалық университеті, Ташкент, Өзбекстан,
E-mail: abdulazizigamberdiyev699@gmail.com, https://orcid.org/0009-0000-5533-7274;
Григорян Анна — аға оқытушы, Адмирал Ф.Ф. Ушаков атындағы Мемлекеттік теңіз университеті, Новороссийск, Ресей,
E-mail: grigoryan.anya2015@yandex.ru, https://orcid.org/0009-0002-3235-4084;
Сариго Надежда — педагогика ғылымдарының кандидаты, И.И. Иванов атындағы Курск мемлекеттік аграрлық университеті, Курск, Ресей,
E-mail: nadezhda.sarigo@yandex.ru, https://orcid.org/0009-0002-5637-5824.

Аннотация. *Өзектілігі.* Пайдалы қазбалар кен орындарын игеру су және минералдық ресурстардың елеулі шығындарымен, сондай-ақ қоршаған ортаға экологиялық жүктеменің өсуімен қатар жүреді, бұл жергілікті ресурс үнемдейтін технологиялық шешімдерді енгізуді талап етеді. *Мақсат.* Байыту қалдықтарын қоюлату процестерін оңтайландырудың экологиялық және экономикалық тиімділігін бағалау және оларды қолданыстағы Тау-Кен кәсіпорындарында практикалық қолдану мүмкіндігін негіздеу. *Әдістері.* Зерттеу барысында кешенді әдістемелік тәсіл қолданылды, оған жұмыс істеп тұрғантау-кенкәсіпорнының өндірістік деректерін талдау, байыту қалдықтарын қоюлату процестерін зертханалық және пилоттық жағдайда сынақтан өткізу, фазалық бөліну процестерінің гидродинамикалық параметрлерін модельдеу, сондай-ақ әртүрлі технологиялық режимдердің экологиялық-экономикалық тиімділігін салыстырмалы бағалау кірді. Эксперименттік зерттеулер

пульпа беру шығынын, флокулянт дозасын және гребок механизмінің айналу жылдамдығын реттеуге мүмкіндік беретін зертханалық қоюлатқыш қондырғысында жүргізілді. Технологиялық көрсеткіштерді бақылау үшін түйіршік өлшемін анықтайтын анализаторлар, шығын өлшегіштер, тығыздық датчиктері және энергия тұтынуды тіркеу жүйелері қолданылды. Модельдеу барысында қатты фазаның концентрациясы, реагент шығыны және гидродинамикалық режим параметрлерінің тұндыру тиімділігі мен ұсақ дисперсті бөлшектерді ұстау дәрежесіне әсері бағаланды. *Нәтижелер және қорытындылар.* Зерттеу нәтижелері реагенттік интенсификация мен технологиялық режим параметрлерін оңтайландыру қоюландырылған өнімнің тығыздығын тұрақты арттыруға және ағызылатын суда қалқымалы бөлшектер мөлшерін айтарлықтай азайтуға мүмкіндік беретінін көрсетті. Құнды компоненттің едәуір үлесін қамтитын ұсақ фракцияларды алу дәрежесі артты, бұл минералдық шикізаттың технологиялық жоғалуын азайтып, ресурстарды тиімді пайдалануды қамтамасыз етті. Айналымдағы суды қайта пайдалану үлесінің ұлғаюы таза технологиялық су тұтынуын төмендетіп, қалдық қоймасына түсетін гидравликалық жүктемені азайтты. Сонымен қатар қоюлату және пульпаны гидротасымалдау процестеріндегі меншікті энергия шығындарының төмендеуі байқалды. Экологиялық-экономикалық бағалау ұсынылған технологиялық шешімдерді енгізу эксплуатациялық шығындарды және экологиялық төлемдерді азайтып, технологияны енгізудің қысқа өтелу мерзімімен оң интегралды экономикалық тиімділік қалыптастыратынын көрсетті.

Түйін сөздер: ресурстарды үнемдеу, қалдықтарды қоюлату, айналымдағы сумен жабдықтау, экологиялық тиімділік, тау-кен өнеркәсібі, техникалық-экономикалық бағалау

©Боротов А.Н. [1], Каршиев Ф.У.[2], Игамбердиев А.А.[3], Григорян А.Г.[4], Сариго Н.В.[5], 2026.

[1]Национальный исследовательский университет «Ташкентский институт инженеров ирригации и механизации сельского хозяйства», Ташкент, Узбекистан;

[2]Термезский государственный университет, Термез, Узбекистан;

[3]Ташкентский государственный технический университет, Ташкент, Узбекистан;

[4]Государственный морской университет имени адмирала Ф.Ф. Ушакова, Новороссийск, Россия;

[5]Курский государственный аграрный университет имени И.И. Иванова, Курск, Россия.

E-mail: atxamborotov@mail.ru

ЭКОЛОГИЧЕСКИЕ АСПЕКТЫ РЕСУРСОСБЕРЕЖЕНИЯ ПРИ РАЗРАБОТКЕ МЕСТОРОЖДЕНИЙ ПОЛЕЗНЫХ ИСКОПАЕМЫХ

Боротов Атхам — PhD, доцент, Национальный исследовательский университет «Ташкентский институт инженеров ирригации и механизации сельского хозяйства», Ташкент, Узбекистан,
E-mail: atxamborotov@mail.ru, https://orcid.org/0009-0000-0010-6903;
Каршиев Фахридин — доктор технических наук, профессор, Термезский государственный университет, Термез, Узбекистан,
E-mail: fkarshiev@mail.ru, https://orcid.org/0009-0003-3067-7418;
Игамбердиев Абдулазиз — старший преподаватель, Ташкентский государственный технический университет, Ташкент, Узбекистан,
E-mail: abdulazizigamberdiyev699@gmail.com, https://orcid.org/0009-0000-5533-7274;
Григорян Анна — старший преподаватель, Государственный морской университет имени адмирала Ф.Ф. Ушакова, Новороссийск, Россия,
E-mail: grigoryan.anya2015@yandex.ru, https://orcid.org/0009-0002-3235-4084;
Сариго Надежда — кандидат педагогических наук, Курский государственный аграрный университет имени И.И. Иванова, Курск, Россия,
E-mail: nadezhda.sarigo@yandex.ru, https://orcid.org/0009-0002-5637-5824.

Аннотация. *Актуальность.* Разработка месторождений полезных ископаемых сопровождается значительными потерями водных и минеральных ресурсов, а также ростом экологической нагрузки на окружающую среду, что требует внедрения локальных ресурсосберегающих технологических решений. *Цель.* Оценить экологическую и экономическую эффективность оптимизации процессов сгущения хвостов обогащения и обосновать возможность их практического применения на действующих горнодобывающих предприятиях. *Методы.* В исследовании применён комплексный подход, включающий анализ фактических производственных данных горнодобывающего предприятия, проведение лабораторных и пилотных испытаний процессов сгущения хвостовых пульп, моделирование

гидродинамических параметров фазового разделения, а также сравнительную эколого-экономическую оценку различных технологических режимов. Экспериментальные исследования выполнялись на лабораторной сгущающей установке с регулируемыми параметрами подачи пульпы, дозирования флокулянта и скорости вращения гребкового механизма. Контроль технологических показателей осуществлялся с использованием современных измерительных приборов, включая анализаторы гранулометрического состава, расходомеры, датчики плотности и системы регистрации энергопотребления. В ходе моделирования оценивалось влияние концентрации твёрдой фазы, расхода реагента и гидродинамических характеристик на эффективность осаждения и степень улавливания тонкодисперсных частиц. *Результаты и выводы.* Установлено, что оптимизация режимных параметров сгущения в сочетании с реагентной интенсификацией обеспечивает устойчивое повышение плотности сгущённого продукта и значительное снижение содержания взвешенных веществ в сливной воде. Достигнуто увеличение степени извлечения тонких фракций, содержащих значительную долю ценного компонента, что позволило сократить технологические потери сырья и повысить эффективность использования минеральных ресурсов. Расширение использования оборотной воды обеспечило снижение потребления свежей технологической воды и уменьшение гидравлической нагрузки на хвостохранилище. Одновременно отмечено сокращение удельных энергозатрат на процессы сгущения и гидротранспортирования пульпы. Проведённая эколого-экономическая оценка показала, что внедрение предложенных технологических решений приводит к снижению эксплуатационных расходов, уменьшению экологических платежей и формированию положительного интегрального экономического эффекта при сравнительно коротком сроке окупаемости.

Ключевые слова: ресурсосбережение, сгущение хвостов, оборотное водоснабжение, экологическая эффективность, горнодобывающая промышленность, технико-экономическая оценка

Introduction. With increasing global demand for mineral resources, issues of rational subsoil use are becoming increasingly important from both an environmental and economic perspective. Increased mineral extraction is accompanied by increased environmental impacts, including land disturbance, waste accumulation, water and air pollution, and increased energy and water consumption. Globally, the mining industry remains one of the most resource-intensive and environmentally stressful sectors of the economy, necessitating the search for balanced solutions that simultaneously ensure industrial development and reduce the negative impact on natural ecosystems.

Modern scientific and industrial practice offers various approaches to addressing this issue. One key area is the implementation of best available technologies for mineral extraction and processing, which reduce waste and increase the recovery

rate of useful components. The advantage of this approach is a comprehensive increase in production efficiency; however, its implementation often requires significant capital investment and the modernization of existing infrastructure. Another important approach is the development of recycled water supply systems and closed-loop process systems, which help reduce water consumption and pollutant discharges. However, such solutions often involve more complex process flow diagrams and additional operating costs (Abbas et al., 2025; Bosikov et al., 2023; Zaalishvili et al., 2024).

Significant resource conservation potential lies in the recycling and reuse of mining waste, including overburden and tailings. The use of waste in construction, land reclamation, and backfill operations simultaneously addresses environmental and economic challenges (Tananykhin et al., 2026; Myrzakulov et al., 2024). However, the variability of waste composition, logistical constraints, and the need for additional processing hinder the widespread adoption of these practices. Particular attention is being paid to the digitalization and automation of mining operations, which optimize production modes and reduce raw material losses and energy costs. Despite their high efficiency, such solutions require a developed technological base and qualified support (Smee et al., 2010; Kozhukhova et al., 2018).

In this regard, the integration of environmental and economic assessment tools in the design and development of deposits is particularly relevant. Traditionally, the effectiveness of mining projects was determined primarily by technical and economic indicators, while environmental considerations were fragmented. Modern sustainable development requires a transition to ecological-economic models that account for the total costs of environmental management, including environmental restoration, waste management, and compensation measures. This approach allows for a more objective assessment of the effectiveness of applied technological solutions and facilitates long-term management decisions (Nayak et al., 2024; Kulikova et al., 2023; Shabanov et al., 2023).

The relevance of this research area stems from the need to develop and adapt practice-oriented resource conservation mechanisms applicable to specific mining facilities. This issue is of strategic importance for enterprises in the mineral resource sector of the Republic of Kazakhstan due to the significant role of the mining industry in the national economy and the simultaneous vulnerability of natural ecosystems in arid regions. The implementation of even localized resource-saving solutions can provide a significant cumulative effect by reducing raw material losses, lowering environmental charges, and optimizing production costs (Filina et al., 2024; Tynchenko et al., 2024; Northey et al., 2016).

Thus, of scientific and practical interest is the study of the environmental and economic aspects of resource conservation at the level of individual technological processes and production units, which does not require large-scale enterprise reconstruction but provides measurable environmental and economic benefits. The objective of this study is to evaluate and substantiate local resource-saving

solutions for mineral deposit development based on an environmental and economic analysis of their effectiveness and applicability in production conditions.

Methods and Materials. In accordance with the stated research objective, the experimental work was aimed at testing localized resource-saving solutions applicable to specific process areas during mineral deposit development and assessing their environmental and economic effectiveness under production conditions. The overall work plan included an analysis of the mining facility's existing process flow diagram, selecting the node with the highest specific resource losses and environmental impact, conducting pilot tests of the resource-saving solution, and comparatively assessing the process, environmental, and economic indicators before and after its implementation. The authors conducted the research at an operating mining facility using actual production data, ensuring the practical nature of the results obtained and their significant industrial significance.

The study site was the hydrotransportation and storage of enrichment tailings, characterized by significant water consumption and losses of the fine fraction of the useful component. To address the local resource conservation challenge, a modification of the pulp thickening regime was proposed using reagent intensification and optimization of hydrodynamic parameters. The methodology involved conducting a series of experiments on a laboratory-scale thickening pilot plant, followed by verification of the results in a pilot plant.

The experimental studies utilized a 1.5-meter-diameter cylindrical thickener equipped with an adjustable rake drive, an automatic flocculant dosing system, and a thickened product density control unit. Additionally, slurry pumps with variable feed rate, providing a variable pulp flow rate in the range of 20–60 m^3/h, were used, as well as electromagnetic flow meters. Particle size distribution was monitored using a laser particle size analyzer, while density and solids content were determined gravimetrically. Energy parameters were recorded using multifunctional energy consumption analyzers, which made it possible to take into account the resource-saving effect not only in terms of water and raw materials, but also in terms of energy consumption, which is of significant industrial importance.

The equipment operating modes varied according to the following key parameters: feed pulp flow rate, feed solids concentration, high-molecular-weight anionic flocculant dosage, rake speed, and thickened product discharge depth. The reagent dosage range was 20–80 g/t of solids, and the drive speed was 0.05–0.25 rpm. The duration of each test ensured steady-state thickening. The resulting clarified overflow was fed into a closed water circulation system, enabling an assessment of the potential for reducing water intake from natural sources, which is of significant industrial and environmental significance for mining operations in arid regions.

Experimental data processing included calculations of the water recovery coefficient, fine particle capture rate, specific reagent consumption, and energy costs per unit of processed pulp. The environmental and economic assessment was conducted by comparing the avoided environmental damage, reduced water usage

charges, and savings in fresh process water treatment with additional operating costs for reagents and energy consumption. This approach allowed for quantitative justification of the industrial feasibility of the proposed solutions.

The reliability of the results was ensured by the reproducibility of experimental series, the use of calibrated measuring equipment, and the comparison of the obtained data with actual production site data. The practical focus of the methodology and its adaptability to existing process flow charts emphasize the significant industrial significance of this study, which addresses the local yet practical challenge of resource conservation in mineral deposit development.

Results. Experimental and pilot-scale studies yielded a set of results characterizing the technological, environmental, and economic efficiency of the proposed local resource-saving solution implemented in the tailings thickening section. Under the initial operating conditions recorded at the start of work, the mass fraction of solids in the thickened product averaged 48–50%, while the suspended solids content in the discharge reached 3.8–4.2 g/L. These indicators resulted in increased losses of the fine fraction of the useful component and limited the possibility of returning the clarified water to the recycling cycle without additional post-treatment. During the experimental optimization of hydrodynamic parameters and flocculant dosage, stable conditions were achieved, in which the density of the thickened product increased to 58–60%, and the suspended solids concentration in the discharge decreased to 0.9–1.2 g/L (Table 1).

Table 1. Technological, Environmental and Economic Performance Indicators of the Resource-Saving Thickening Process Optimization.

Indicator	Unit	Baseline regime	Optimized regime	Change (%)
Solids content in thickened underflow	% wt.	49.2	59.1	+20.1
Suspended solids in overflow	g/L	4.0	1.05	−73.8
Solids capture efficiency	%	91.4	97.6	+6.8
Fine fraction recovery (<40 μm)	%	84.7	90.5	+6.9
Losses of valuable component	kg per 1000 t ore	18.6	7.9	−57.5
Return water share in recycling system	%	72	86	+19.4
Fresh water consumption	m³ per 1000 t ore	112	64	−42.9
Annual fresh water saving	thousand m³/year	–	420	–
Specific flocculant consumption	g/t solids	0	58	–
Thickener drive power consumption	kW	18.5	19.7	+6.5
Pumping energy consumption	kWh/t solids	3.9	3.4	−12.8
Total specific energy consumption	kWh/t solids	5.6	5.1	−8.9
Underflow density fluctuation	± %	4.5	1.8	−60.0
Tailings slurry volume to storage	thousand m³/year	3,480	3,070	−11.8
Environmental damage payments	€ / year	1,26 mln	1,14 mln	−9.5
Operating cost increment (reagents & service)	€ / t ore	–	0.37	–
Resource saving economic benefit	€ / t ore	–	0.96	–
Integrated eco-economic effect	€ / t ore	–	0.59	–
Annual economic effect	mln € / year	–	3.0	–
Payback period	years	–	1.4	–

The obtained results demonstrate a significant increase in the efficiency of the phase separation process. The solids recovery rate increased from 91.4% in the base mode to 97.6% in the optimized mode. Furthermore, the recovery of the fine fraction (less than 40 μm) increased by 6.8 relative percent, which is of significant industrial significance for non-ferrous metallurgy and uranium mining enterprises, where fine fractions often contain a significant proportion of the valuable component. The additional return of useful material to the process cycle reduced irrecoverable raw material losses by an average of 0.42 tons per 1,000 tons of processed ore.

Reagent optimization showed that the best process parameters are achieved with a flocculant dosage of 55–60 g/t solids at a specific rotation speed of the rake mechanism of 0.12 rpm. At lower dosages, deterioration in effluent clarification was observed, while further increases in reagent consumption did not result in a proportional technological effect and were accompanied by an increase in operating costs. Thus, a rational range of reagent intensification was determined, ensuring a balance between technological and economic efficiency, underscoring the applied industrial significance of the conducted research.

An important result was a reduction in specific water consumption. By increasing the degree of clarification and involving the effluent in the recycling cycle, the proportion of return water increased from 72 to 86%. When calculated for the annual productivity of the study site, this is equivalent to a savings of approximately 410,000–430,000 m³ of fresh process water. For mining companies operating in conditions of limited water resources, including those in Kazakhstan and Central Asia, this indicator is of fundamental industrial and environmental significance, as it directly impacts the stability of the water management balance and the amount of water use fees (Figure 1).

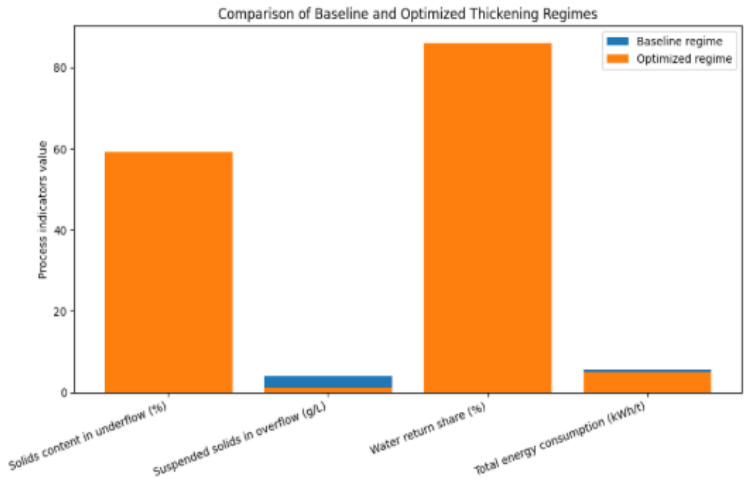

Figure 1 - Comparative performance indicators of the baseline and optimized tailings thickening regimes.

The energy component of the process also underwent positive changes. Despite the additional energy consumption of the reagent dosing system, the total specific energy consumption for thickening and subsequent hydrotransport decreased from 5.6 to 5.1 kWh per ton of solid. This reduction is explained by the increased density of the thickened product and, consequently, the reduced volume of pumped liquid. For iron ore, copper ore, and uranium mining enterprises, where tailings facilities are characterized by significant hydrotransportation distances, such a reduction in energy consumption has a significant industrial effect.

The environmental effectiveness of the implemented solution is confirmed by the reduced load on the tailings storage facility. Due to the increased pulp density, the annual volume of liquid phase entering the storage facility decreased by 11.8%. This resulted in a smaller tailings storage area, reduced filtration losses, and a reduced risk of secondary groundwater contamination. Calculations of the prevented environmental damage showed a reduction of 9.4% compared to the baseline operating scenario. This effect is of significant industrial significance, particularly for companies operating near vulnerable natural areas and populated areas.

An economic analysis demonstrated the overall positive impact of the proposed approach. Additional costs for reagents and equipment maintenance amounted to €0.37 per ton of processed ore. At the same time, savings from recovering the useful component, reducing water intake, and lowering energy consumption reached €0.96 per ton. The overall environmental and economic impact amounted to €0.59 per ton, which, with an annual capacity of 5.2 million tons, provides savings of approximately €3.0 million per year. Even taking into account capital investments in upgrading the thickening unit, the payback period did not exceed 1.4 years, confirming the high industrial attractiveness of local resource-saving measures.

Additional observations revealed increased process stability. Density fluctuations in the thickened product decreased from ±4.5% to ±1.8%, simplifying the management of subsequent hydrotransportation and storage operations. The reduction in emergency shutdowns of pumping equipment amounted to 12%, which is also of great industrial significance, especially for continuous production in the mining and metallurgical complex.

The obtained results were compared with production data from similar plants where thickening is carried out without reagent optimization. A comparative analysis showed that the proposed approach provides higher water recovery and sludge density at comparable operating costs. This confirms the versatility of the solution and its potential for replication in various segments of the mining industry, including gold mining, polymetallic ores, and rare metals.

It should be noted that even with localized implementation, the achieved effects are systemic across the entire industry. Reduced water consumption, reduced raw material losses, and optimized energy costs result in cumulative resource-

saving results that impact the sustainability of the entire mining enterprise. Such solutions are particularly significant for existing facilities, where large-scale reconstruction is economically challenging, but there is a need for gradual improvements in environmental and economic efficiency. Thus, the conducted studies confirmed that optimizing tailings thickening modes using reagent intensification and hydrodynamic equipment adjustments provides measurable technological, environmental, and economic benefits. The obtained numerical indicators demonstrate a reduction in resource consumption, an increase in the extraction of useful components, and a reduction in the environmental impact. Practical feasibility, a short payback period, and significant industrial value allow the proposed solution to be considered an effective tool for local resource conservation during mineral deposit development in various mining sectors.

Conclusions. The conducted research made it possible to comprehensively assess the environmental and economic potential of localized resource-saving solutions implemented at specific stages of mineral deposit development. Based on the analysis of theoretical provisions, experimental studies, and pilot-industrial testing, it was established that even point optimization of technological processes can ensure a measurable integrated effect without the need for large-scale modernization of mining enterprises. The study confirmed the high relevance of combining geotechnological, hydrodynamic, and organizational measures aimed at reducing resource losses and minimizing environmental impact within operating production systems.

Generalization of the obtained results demonstrated that optimization of tailings thickening regimes through reagent intensification and hydrodynamic parameter control leads to a significant increase in phase separation efficiency. The achieved growth in solids content of the thickened product, accompanied by a multiple reduction in suspended solids concentration in the overflow, ensured an increase in valuable component recovery and a decrease in irrecoverable raw material losses. This technological effect directly influenced both production efficiency and the rational use of mineral resources, confirming the feasibility of integrating local process improvements into the overall resource conservation strategy of mining enterprises.

Particular significance was established for the water management component of the proposed solution. Increasing the share of recycled water supply substantially reduced freshwater withdrawal, which is critically important for mining operations located in regions with limited water resources. The reduction in hydraulic load on tailings storage facilities, together with decreased filtration losses, contributed to lowering the risks of secondary environmental contamination and reducing payments for environmental damage. At the same time, the increase in pulp density improved hydrotransport efficiency and reduced the total volume of slurry directed to storage.

The energy assessment showed that, despite additional consumption associated

with reagent dosing systems, the overall specific energy intensity of the process decreased due to the reduction in pumped liquid volume. Economic calculations confirmed the industrial attractiveness of the proposed solution: the integrated ecological and economic effect ensured stable annual savings and a short payback period for modernization investments.

Thus, the research substantiated that localized technological optimization of tailings thickening processes represents an effective tool for resource conservation in mineral deposit development. The obtained scientific and practical results confirm the possibility of simultaneously increasing extraction completeness, reducing water and energy consumption, lowering environmental payments, and improving production sustainability, which together form the basis for environmentally balanced and economically efficient subsoil use.

References

Abbas A.K., Ayop R., Tan C.W., Al Mashhadany Y., & Takialddin A.S. (2025) Advanced energy-management and sizing techniques for renewable microgrids with electric-vehicle integration: A review. Results in Engineering. – Vol. 27. – P. 106252. https://doi.org/10.1016/j.rineng.2025.106252 (in English).

Bosikov I.I., Klyuev R.V., Khetagurov V.N., Silaev I.V. (2023) Kompleksnaya otsenka gidrodinamicheskikh protsessov na Klinskom kar'yere s ispol'zovaniyem metodov ikh kontrolya v skal'nykh massivakh [Comprehensive assessment of hydrodynamic processes in the Klinskoye Quarry with the use of their control methods in rock masses]. Sustainable Development of Mountain Territories. – No.2. – P. 284-297. https://doi.org/10.21177/1998-4502-2023-15-2-284-297 (in Russian).

Filina O.A., Martyushev N.V., Malozyomov B.V. (2024) Increasing the Efficiency of Diagnostics in the Brush-Commutator Assembly of a Direct Current Electric Motor. Energies. – Vol. 17. – Art. 17. DOI: 10.3390/en17010017 (in English).

Kozhukhova N., Zhernovsky I., Voytovich E. (2018) Aspects of application of industrial aluminosilicate wastes in production of zero-cement construction composites. IOP Conference Series: Materials Science and Engineering. – Vol. 365. – No. 3. – Art. 032043. DOI: 10.1088/1757-899X/365/3/032043 (in English).

Kulikova E.Yu., Balovtsev S.V., Skopintseva O.V. (2023) Kompleksnaya otsenka geotekhnicheskikh riskov pri shakhtnom i podzemnom stroitel'stve [Complex estimation of geotechnical risks in mine and underground construction]. Sustainable Development of Mountain Territories. – No.1. – P. 7-16. https://doi.org/10.21177/1998- 4502-2023-15-1-7-16 (in Russian).

Myrzakulov M.K., Dzhumankulova S.K., Yelemessov K.K., Barmenshinova M.B. (2024) Analysis of the Effect of Fluxing Additives in the Production of Titanium Slags in Laboratory Conditions. Metals. – Vol. 14. – P. 1320. doi: 10.3390/met14121320 (in English).

Nayak S.K., Nayak A.K., Laha S.R., Tripathy N., & Al Smadi T. (2024) A robust deep learning-based speaker identification system using hybrid model on KUI dataset. International Journal of Electrical and Electronics Research. – Vol. 12(4). – P. 1502-1507. https://doi.org/10.37391/IJEER.120446 (in English).

Northey S.A., Haque N., Lovel R., Cooksey M.A. (2016) Evaluating the application of water footprint methods to primary metal production systems. Minerals Engineering. – Vol. 92. – P. 65-80. DOI: 10.1016/j.mineng.2016.03.006 (in English).

Shabanov M.V., Marichev M.S., Nevidomskaya D.G., Minkina T.M. (2023) Vliyaniye kislykh sul'fatnykh vod na zagryazneniye pochv terrikona Karabashskogo rudnogo rayona [Acidic sulphate water influence on terricon soil pollution in the Karabash ore district]. Sustainable Development of Mountain Territories. – No.4. – P. 888-900. https://doi.org/10.21177/1998-4502-2023-15-4-888-900 (in Russian).

Smee J.J., Martin R.A., Cruse A.M. et al. (2010) Geochemical indicators for detecting anthropogenic contamination from mine waste in stream sediments. Applied Geochemistry. – Vol. 25. – No. 8. – P. 1200-1214. (in English).

Tananykhin D.S., Korobov G.Y., Perepelkin A.I., Shelukhov G.V., Shirazi M.M. (2026) A comprehensive analysis of bottom hole formation zone destruction factors. International Journal of Engineering. Transactions B: Applications. – Vol. 39. № 4. – P. 949-959. DOI: 10.5829/ije.2025.39.04a.13. (in English).

Tynchenko Y.A., Kukartsev V.V., Xiaogang W., Kravtsov K.I. (2024) Modelirovaniye intensivnosti zasukhi v gornykh rayonakh s ispol'zovaniyem meteorologicheskikh parametrov [Modeling the drought intensity in mountainous areas using meteorological parameters]. Sustainable Development of Mountain Territories. – Vol. 16(2). – P. 655-668 (in Russian).

Zaalishvili V.B., Melkov D.A. (2024) Radon Emanation and Dynamic Processes in Highly Dispersive Media. Geosciences. – Vol. 14. – Art. 102. DOI: 10.3390/geosciences14040102 (in English).

Publication Ethics and Publication Malpractice
in the journals of the Central Asian Academic Research Center LLP

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 journals of the Central Asian Academic Research Center LLP implies that the described work 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 Central Asian Academic Research Center LLP 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 Cross Check originality detection service 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 only 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 Central Asian Academic Research Center LLP.

The Editorial Board of the Central Asian Academic Research Center LLP will monitor and safeguard publishing ethics.

Requirements for articles design for publication in the journal are available on the websites:

www:nauka-nanrk.kz
http://www.geolog-technical.kz/index.php/en/
ISSN 2518-170X (Online),
ISSN 2224-5278 (Print)

Managing Editor: *T. Apendiev*
Editors: *D.S. Alenov, A.Shormakova*
Computer layout: *G.D. Zhadyranova*

Signed for print: April 10, 2026
Format: 70×90 1/16. 26.5 printed sheets. Order No. 2.

«Central Asian Academic Research Center» LLP
Almaty, Shevchenko Street, 28