

ISSN 2518-1491 (Online),
ISSN 2224-5286 (Print)



«ҚАЗАҚСТАН РЕСПУБЛИКАСЫ
ҰЛТТЫҚ ҒЫЛЫМ
АКАДЕМИЯСЫ» РҚБ

«ҚАЗАҚСТАН РЕСПУБЛИКАСЫ
ҰЛТТЫҚ ҒЫЛЫМ АКАДЕМИЯСЫ» РҚБ

Х А Б А Р Л А Р Ы

ИЗВЕСТИЯ

РОО «НАЦИОНАЛЬНОЙ
АКАДЕМИИ НАУК РЕСПУБЛИКИ
КАЗАХСТАН»

N E W S

OF THE ACADEMY OF SCIENCES
OF THE REPUBLIC OF
KAZAKHSTAN

SERIES
CHEMISTRY AND TECHNOLOGY

3 (460)

JULY – SEPTEMBER 2024

PUBLISHED SINCE JANUARY 1947

PUBLISHED 4 TIMES A YEAR

ALMATY, NAS RK

Бас редактор:

ЖҰРЫНОВ Мұрат Жұрынұлы, химия ғылымдарының докторы, профессор, ҚР ҰҒА академигі, Қазақстан Республикасы Ұлттық ғылым академиясының президенті, АҚ «Д.В. Сокольский атындағы отын, катализ және электрохимия институтының» бас директоры (Алматы, Қазақстан) Н = 4

Редакция алқасы:

ӘДЕКЕНОВ Серғазы Мынжасарұлы (бас редактордың орынбасары), химия ғылымдарының докторы, профессор, ҚР ҰҒА академигі, «Фитохимия» Халықаралық ғылыми-өндірістік холдингінің директоры (Қарағанды, Қазақстан) Н = 11

АГАБЕКОВ Владимир Енокович (бас редактордың орынбасары), химия ғылымдарының докторы, профессор, Беларусь ҰҒА академигі, Жаңа материалдар химиясы институтының құрметті директоры (Минск, Беларусь) Н = 13

СТРНАД Мирослав, профессор, Чехия ғылым академиясының Эксперименттік ботаника институтының зертхана меңгерушісі (Оломоуц, Чехия) Н = 66

БҮРКІТБАЕВ Мұхамбетқали, химия ғылымдарының докторы, профессор, ҚР ҰҒА академигі, әл-Фараби атындағы ҚазҰУ-дың бірінші проректоры (Алматы, Қазақстан) Н = 11

ХОХМАНН Джудит, Сегед университетінің Фармацевтика факультетінің Фармакогнозия кафедрасының меңгерушісі, Жаратылыстану ғылымдарының пәнаралық орталығының директоры (Сегед, Венгрия) Н = 38

РОСС Самир, PhD докторы, Миссисипи университетінің Өсімдік өнімдерін ғылыми зерттеу ұлттық орталығы, Фармация мектебінің профессоры (Оксфорд, АҚШ) Н = 35

ХУТОРЯНСКИЙ Виталий, философия докторы (PhD, фармацевт), Рединг университетінің профессоры (Рединг, Англия) Н = 40

ТЕЛТАЕВ Бағдат Бұрханбайұлы, техника ғылымдарының докторы, профессор, ҚР ҰҒА корреспондент-мүшесі, Қазақстан Республикасы Индустрия және инфрақұрылымдық даму министрлігі (Алматы, Қазақстан) Н = 13

ФАРУК Асана Дар, Хамдар аль-Маджида Шығыс медицина колледжінің профессоры, Хамдард университетінің Шығыс медицина факультеті (Карачи, Пәкістан) Н = 21

ФАЗЫЛОВ Серік Драхметұлы, химия ғылымдарының докторы, профессор, ҚР ҰҒА академигі, Органикалық синтез және көмір химиясы институты директорының ғылыми жұмыстар жөніндегі орынбасары (Қарағанды, Қазақстан) Н = 6

ЖОРОБЕКОВА Шарипа Жоробекқызы, химия ғылымдарының докторы, профессор, Қырғызстан ҰҒА академигі, ҚР ҰҒА Химия және химиялық технология институты (Бішкек, Қырғызстан) Н = 4

ХАЛИКОВ Джурабай Халикович, химия ғылымдарының докторы, профессор, Тәжікстан ҒА академигі, В.И. Никитин атындағы Химия институты (Душанбе, Тәжікстан) Н = 6

ФАРЗАЛИЕВ Вагиф Меджидоглы, химия ғылымдарының докторы, профессор, ҰҒА академигі (Баку, Әзірбайжан) Н = 13

ГАРЕЛИК Хемда, философия докторы (PhD, химия), Халықаралық таза және қолданбалы химия одағының Химия және қоршаған орта бөлімінің президенті (Лондон, Англия) Н = 15

«ҚР ҰҒА Хабарлары. Химия және технология сериясы»

ISSN 2518-1491 (Online),

ISSN 2224-5286 (Print)

Меншіктенуші: «Қазақстан Республикасының Ұлттық ғылым академиясы» РҚБ (Алматы қ.). Қазақстан Республикасының Ақпарат және қоғамдық даму министрлігінің Ақпарат комитетінде 29.07.2020 ж. берілген № **KZ66VPY00025419** мерзімдік басылым тіркеуіне қойылу туралы куәлік.

Тақырыптық бағыты: *органикалық химия, бейорганикалық химия, катализ, электрохимия және коррозия, фармацевтикалық химия және технологиялар.*

Мерзімділігі: жылына 4 рет.

Тиражы: 300 дана.

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

<http://chemistry-technology.kz/index.php/en/arhiv>

© Қазақстан Республикасының Ұлттық ғылым академиясы РҚБ, 2024

Редакцияның мекенжайы: 050100, Алматы қ., Қонаев к-сі, 142, «Д.В. Сокольский атындағы отын, катализ және электрохимия институты» АҚ, каб. 310, тел. 291-62-80, факс 291-57-22, e-mail: orgcat@nursat.kz

Главный редактор:

ЖУРИНОВ Мурат Журинович, доктор химических наук, профессор, академик НАН РК, президент Национальной академии наук Республики Казахстан, генеральный директор АО «Институт топлива, катализа и электрохимии им. Д.В. Сокольского» (Алматы, Казахстан) Н = 4

Редакционная коллегия:

АДЕКЕНОВ Сергазы Мынжасарович (заместитель главного редактора), доктор химических наук, профессор, академик НАН РК, директор Международного научно-производственного холдинга «Фитохимия» (Караганда, Казахстан) Н = 11

АГАБЕКОВ В ладимир Енокович (заместитель главного редактора), доктор химических наук, профессор, академик НАН Беларуси, почетный директор Института химии новых материалов (Минск, Беларусь) Н = 13

СТРНАД Мирослав, профессор, заведующий лабораторией института Экспериментальной ботаники Чешской академии наук (Оломоуц, Чехия) Н = 66

БУРКИТБАЕВ Мухамбеткали, доктор химических наук, профессор, академик НАН РК, Первый проректор КазНУ имени аль-Фараби (Алматы, Казахстан) Н = 11

ХОХМАНН Джудит, заведующий кафедрой Фармакогнозии Фармацевтического факультета Университета Сегеда, директор Междисциплинарного центра естественных наук (Сегед, Венгрия) Н = 38

РОСС Самир, доктор PhD, профессор Школы Фармации национального центра научных исследований растительных продуктов Университета Миссисипи (Оксфорд, США) Н = 35

ХУТОРЯНСКИЙ Виталий, доктор философии (Ph.D, фармацевт), профессор Университета Рединга (Рединг, Англия) Н = 40

ТЕЛЬГАЕВ Багдат Бурханбайулы, доктор технических наук, профессор, член-корреспондент НАН РК, Министерство Индустрии и инфраструктурного развития Республики Казахстан (Алматы, Казахстан) Н = 13

ФАРУК Асана Дар, профессор колледжа Восточной медицины Хамдарда аль-Маджида, факультет Восточной медицины университета Хамдарда (Карачи, Пакистан) Н = 21

ФАЗЫЛОВ Серик Драхметович, доктор химических наук, профессор, академик НАН РК, заместитель директора по научной работе Института органического синтеза и углехимии (Караганда, Казахстан) Н = 6

ЖОРОБЕКОВА Шарипа Жоробековна, доктор химических наук, профессор, академик НАН Кыргызстана, Институт химии и химической технологии НАН КР (Бишкек, Кыргызстан) Н = 4

ХАЛИКОВ Джурабай Халикович, доктор химических наук, профессор, академик АН Таджикистана, Институт химии имени В.И. Никитина АН РТ (Душанбе, Таджикистан) Н = 6

ФАРЗАЛИЕВ Вагиф Меджид оглы, доктор химических наук, профессор, академик НАНА (Баку, Азербайджан) Н = 13

ГАРЕЛИК Хемда, доктор философии (Ph.D, химия), президент Отдела химии и окружающей среды Международного союза чистой и прикладной химии (Лондон, Англия) Н = 15

«Известия НАН РК. Серия химии и технологий».

ISSN 2518-1491 (Online),

ISSN 2224-5286 (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 № KZ66VPY00025419, выданное 29.07.2020 г.

Тематическая направленность: *органическая химия, неорганическая химия, катализ, электрохимия и коррозия, фармацевтическая химия и технологии.*

Периодичность: 4 раз в год.

Тираж: 300 экземпляров.

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

<http://chemistry-technology.kz/index.php/en/archiv>

© РОО Национальная академия наук Республики Казахстан, 2024

Адрес редакции: 050100, г. Алматы, ул. Кунаева, 142, АО «Институт топлива, катализа и электрохимии им. Д.В. Сокольского», каб. 310, тел. 291-62-80, факс 291-57-22, e-mail: orgcat@nursat.kz

Editor in chief:

ZHURINOV Murat Zhurinovich, doctor of chemistry, professor, academician of NAS RK, president of NAS RK, general director of JSC "Institute of fuel, catalysis and electrochemistry named after D.V. Sokolsky (Almaty, Kazakhstan) H = 4

Editorial board:

ADEKENOV Sergazy Mynzhasarovich (deputy editor-in-chief) doctor of chemical sciences, professor, academician of NAS RK, director of the international Scientific and production holding «Phytochemistry» (Karaganda, Kazakhstan) H = 11

AGABEKOV Vladimir Enokovich (deputy editor-in-chief), doctor of chemistry, professor, academician of NAS of Belarus, honorary director of the Institute of Chemistry of new materials (Minsk, Belarus) H = 13

STRNAD Miroslav, head of the laboratory of the institute of Experimental Botany of the Czech academy of sciences, professor (Olomouc, Czech Republic) H = 66

BURKITBAYEV Mukhambetkali, doctor of chemistry, professor, academician of NAS RK, first vice-rector of al-Farabi KazNU (Almaty, Kazakhstan) H = 11

HOHMANN Judith, head of the department of pharmacognosy, faculty of Pharmacy, university of Szeged, director of the interdisciplinary center for Life sciences (Szeged, Hungary) H = 38

ROSS Samir, Ph.D., professor, school of Pharmacy, national center for scientific research of Herbal Products, University of Mississippi (Oxford, USA) H = 35

KHUTORYANSKY Vitaly, Ph.D., pharmacist, professor at the University of Reading (Reading, England) H = 40

TELTAYEV Bagdat Burkhanbayuly, doctor of technical sciences, professor, corresponding member of NAS RK, ministry of Industry and infrastructure development of the Republic of Kazakhstan (Almaty, Kazakhstan) H = 13

PHARUK Asana Dar, professor at Hamdard al-Majid college of Oriental medicine. faculty of Oriental medicine, Hamdard university (Karachi, Pakistan) H = 21

FAZYLOV Serik Drakhmetovich, doctor of chemistry, professor, academician of NAS RK, deputy director for institute of Organic synthesis and coal chemistry (Karaganda, Kazakhstan) H = 6

ZHOROBEKOVA Sharipa Zhorobekovna, doctor of chemistry, professor, academician of NAS of Kyrgyzstan, Institute of Chemistry and chemical technology of NAS KR (Bishkek, Kyrgyzstan) H = 4

KHALIKOV Jurabay Khalikovich, doctor of chemistry, professor, academician of the academy of sciences of Tajikistan, institute of Chemistry named after V.I. Nikitin AS RT (Tajikistan) H = 6

FARZALIEV Vagif Medzhid ogly, doctor of chemistry, professor, academician of NAS of Azerbaijan (Azerbaijan) H = 13

GARELIK Hemda, PhD in chemistry, president of the department of Chemistry and Environment of the International Union of Pure and Applied Chemistry (London, England) H = 15

News of the National Academy of Sciences of the Republic of Kazakhstan. Series of chemistry and technology.

ISSN 2518-1491 (Online),

ISSN 2224-5286 (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. **KZ66VPY00025419**, issued 29.07.2020.

Thematic scope: *organic chemistry, inorganic chemistry, catalysis, electrochemistry and corrosion, pharmaceutical chemistry and technology.*

Periodicity: 4 times a year.

Circulation: 300 copies.

Editorial address: 28, Shevchenko str., of. 219, Almaty, 050010, tel. 272-13-19

<http://chemistry-technology.kz/index.php/en/arhiv>

© National Academy of Sciences of the Republic of Kazakhstan, 2024

Editorial address: JSC «D.V. Sokolsky institute of fuel, catalysis and electrochemistry», 142, Kunayev str., of. 310, Almaty, 050100, tel. 291-62-80, fax 291-57-22, e-mail: orgcat@nursat.kz

NEWS

OF THE NATIONAL ACADEMY OF SCIENCES OF THE REPUBLIC OF KAZAKHSTAN
SERIES CHEMISTRY AND TECHNOLOGY

ISSN 2224-5286

Volume 3. Number 460 (2024), 124–136

<https://doi.org/10.32014/2024.2518-1491.240>

UDC 669.2

**B.K. Kenzhalyiev¹, A.K. Koizhanova¹, T. A. Chepushtanova²,
A.O. Mukangaliyeva^{1,*}, D.R. Magomedov¹, 2024.**

¹Satbayev University, the JSC “Institute of Metallurgy and Ore Beneficiation”,
Almaty, Kazakhstan;

²Satbayev University, Almaty, Kazakhstan.

*E-mail: 000316650668-D@stud.satbayev.university

INNOVATIVE METHODS FOR PROCESSING COPPER ORES IN KAZAKHSTAN: A COMPREHENSIVE APPROACH TO ENHANCING THE EFFICIENCY OF VALUABLE COMPONENT EXTRACTION

B. K. Kenzhalyiev – doctor of technical sciences, professor, General Director in the “Institute of Metallurgy and Ore Beneficiation”, Kazakhstan, Almaty, Shevchenko str., 29/133, E-mail: bagdaulet_k@satbayev.university, <https://orcid.org/0000-0003-1474-8354>;

A.K. Koizhanova – candidate of technical sciences, head of the laboratory of special methods of hydrometallurgy. Satbayev University, the JSC “Institute of Metallurgy and Ore Beneficiation”, Kazakhstan, Almaty, Shevchenko str., 29/133, E-mail: a.koizhanova@satbayev.university, <https://orcid.org/0000-0001-9358-3193>;

T. A. Chepushtanova –Ph.D., candidate of Technical Sciences, Associate Professor. Satbayev University, Head of the Department of Metallurgical Processes, Heat Engineering and Technology of Special Materials, Kazakhstan, Almaty, Satpayev str., 22a, Email: t.chepushtanova@satbayev.university, <https://orcid.org/0000-0002-6526-0044>;

A.O. Mukangaliyeva – engineer, master of sciences, Satbayev University, the JSC “Institute of Metallurgy and Ore Beneficiation”, Kazakhstan, Almaty, Shevchenko str., 29/133, E-mail: 000316650668-D@stud.satbayev.university, <https://orcid.org/0000-0001-7032-1764>;

D.R. Magomedov – researcher, master of sciences, Satbayev University, the JSC “Institute of Metallurgy and Ore Beneficiation”, Kazakhstan, Almaty, Shevchenko str., 29/133, E-mail: d.magomedov@satbayev.university, <https://orcid.org/0000-0001-7216-2349>.

Abstract. This article presents an innovative approach to processing copper ore from one of the deposits in Kazakhstan, aimed at enhancing the efficiency of copper extraction from materials with a complex mineral composition. The described methodology includes several key stages: comprehensive analysis of the ore’s material composition, gravity and flotation beneficiation, as well as hydrometallurgical processes. During the study, the ores underwent preliminary preparation, including crushing and grinding to the required fineness. Experiments on gravity and flotation beneficiation demonstrated that optimizing the parameters of these processes significantly increases the yield of copper concentrate. Additionally, sulfuric acid leaching conducted showed high efficiency in extracting copper from the ground ore. The research results confirm that a

comprehensive approach to copper ore processing ensures high efficiency in extracting valuable components and opens up prospects for the sustainable and economically viable utilization of complex copper ores.

Keywords: copper-containing raw materials, ore-beneficiation; gravity; flotation; leaching.

This study was conducted with the financial support of the Ministry of Science and Higher Education of the Republic of Kazakhstan within the framework of program-targeted financing (grant BR21882140).

**Б.К. Кенжалиев¹, А.К. Койжанова¹, Т.А.Чепуштанова², А.Ө. Мұқанғалиева^{1,*},
Д.Р. Магомедов¹**

¹Satbayev University, «Металлургия және кен байыту институты» АҚ.,
Алматы, Қазақстан;

² Қ.И. Сәтбаев атындағы Қазақ ұлттық техникалық зерттеу университеті,
Алматы, Қазақстан.

*E-mail: 000316650668-D@stud.satbayev.university

ҚАЗАҚСТАНДАҒЫ МЫС КЕНДЕРІН ӨНДЕУДІҢ ИННОВАЦИЯЛЫҚ ӘДІСТЕРІ: ҚҰНДЫ КОМПОНЕНТТЕРДІ АЛУДЫҢ ТИІМДІЛІГІН АРТТЫРУҒА КЕШЕНДІ КӨЗҚАРАС

Кенжалиев Б.К. – техника ғылымдарының докторы, профессор. Бас директор «Металлургия және кен байыту институты» АҚ., Қазақстан, Алматы, Шевченко к-сі, 29/133, E-mail: bagdaulet_k@satbayev.university, <https://orcid.org/0000-0003-1474-8354>;

Койжанова А.К. – техника ғылымдарының кандидаты, гидрометаллургияның арнайы әдістері зертханасының меңгерушісі. Satbayev University, «Металлургия және кен байыту институты» АҚ., Қазақстан, Алматы, Шевченко к-сі, 29/133, E-mail: a.koizhanova@satbayev.university, <https://orcid.org/0000-0001-9358-3193>;

Т.А. Чепуштанова – Ph.D. доктор, техника ғылымдарының кандидаты, доцент. Satbayev University, Metallurgy processes, heat treatment technology and special materials technology department, Kazakhstan, Almaty, ul. Satpaeva, 22a, E-mail: t.chepushtanova@satbayev.university, <https://orcid.org/0000-0002-6526-0044>;

Мұқанғалиева А.Ө. – инженер, магистр. Satbayev University, «Металлургия және кен байыту институты» АҚ., Қазақстан, Алматы, Шевченко к-сі, 29/133, E-mail: 000316650668-D@stud.satbayev.university, <https://orcid.org/0000-0001-7032-1764>;

Магомедов Д.Р. – ғылыми қызметкер, магистр. Satbayev University, «Металлургия және кен байыту институты» АҚ., Қазақстан, Алматы, Шевченко к-сі, 29/133, E-mail: d.magomedov@satbayev.university, <https://orcid.org/0000-0001-7216-2349>.

Аннотация. Бұл мақалада Қазақстанның бір кен орнынан алынған мыс рудасын өндеудің инновациялық тәсілі ұсынылған, ол күрделі минералды құрамдағы материалдардан мыс алу тиімділігін арттыруға бағытталған. Сипатталған әдістеме бірнеше негізгі кезеңдерді қамтиды: руданың материалдық құрамын жан-жақты талдау, гравитациялық және флотациялық байыту, сондай-ақ гидрометаллургиялық процестер. Зерттеу барысында рудалар қажетті ұсақтыққа дейін ұсақтау және майдалау сияқты алдын ала дайындықтан өтті. Гравитациялық және флотациялық

байыту бойынша жүргізілген эксперименттер бұл процестердің параметрлерін оңтайландыру мыс концентратын шығымын айтарлықтай арттыратынын көрсетті. Сонымен қатар, күкірт қышқылымен шаймалау ұсақталған рудалардан мыс алудың жоғары тиімділігін көрсетті. Зерттеу нәтижелері мыс рудаларын кешенді өңдеуге жүйелі көзқарас құнды компоненттерді алудың жоғары тиімділігін қамтамасыз ететінін және күрделі мыс рудаларын тұрақты және экономикалық тиімді пайдаланудың келешегін ашатынын растайды.

Түйін сөздер: мыс құрамындағы шикізат, руда байыту, гравитация, флотация; шаймалау.

**Б.К. Кенжалиев¹, А.К. Койжанова¹, Т.А.Чепуштанова², А.О. Муканғалиева^{1,*},
Д.Р. Магомедов¹**

¹ Satbayev University, АО «Институт металлургии и обогащения»,
Алматы, Казахстан;

² Казахский национальный исследовательский технический университет имени
К.И. Сатпаева, Алматы, Казахстан.

*E-mail: 000316650668-D@stud.satbayev.university

ИННОВАЦИОННЫЕ МЕТОДЫ ПЕРЕРАБОТКИ МЕДНЫХ РУД В КАЗАХСТАНЕ: КОМПЛЕКСНЫЙ ПОДХОД К ПОВЫШЕНИЮ ЭФФЕКТИВНОСТИ ИЗВЛЕЧЕНИЯ ЦЕННЫХ КОМПОНЕНТОВ

Б.К. Кенжалиев – доктор технических наук, профессор. Генеральный директор АО «Институт металлургии и обогащения», Казахстан, Алматы, ул. Шевченко, 29/133, E-mail: bagdaulet_k@satbayev.university, <https://orcid.org/0000-0003-1474-8354>;

А.К. Койжанова – кандидат технических наук, заведующая лабораторией специальных методов гидрометаллургии. Satbayev University, АО «Институт металлургии и обогащения», Казахстан, Алматы, ул. Шевченко, 29/133, E-mail: a.koizhanova@satbayev.university, <https://orcid.org/0000-0001-9358-3193>;

Т.А. Чепуштанова – Ph.D., кандидат технических наук, доцент. Satbayev University, заведующая кафедрой металлургических процессов, теплотехники и технологии специальных материалов, Казахстан, Алматы, ул. Сатпаева, 22а, E-mail: t.chepushtanova@satbayev.university, <https://orcid.org/0000-0002-6526-0044>;

А.О. Муканғалиева – инженер, магистр. Satbayev University, АО «Институт металлургии и обогащения», Казахстан, Алматы, ул. Шевченко, 29/133, E-mail: 000316650668-D@stud.satbayev.university, <https://orcid.org/0000-0001-7032-1764>;

Д.Р. Магомедов – научный сотрудник, магистр. Satbayev University, АО «Институт металлургии и обогащения», Казахстан, Алматы, ул. Шевченко, 29/133, E-mail: d.magomedov@satbayev.university, <https://orcid.org/0000-0001-7216-2349>.

Аннотация. В данной статье представлен инновационный подход к переработке медной руды одного из месторождений Казахстана, направленный на повышение эффективности извлечения меди из материалов с сложным минеральным составом. Описанная методология включает несколько ключевых этапов: всесторонний анализ вещественного состава руды, гравитационное и флотационное обогащение, а также гидрометаллургические процессы. В ходе исследования руды прошли предварительную подготовку, включая дробление

и измельчение до необходимой тонкости. Эксперименты по гравитационному и флотационному обогащению показали, что оптимизация параметров этих процессов значительно увеличивает выход медного концентрата. Дополнительно, сернокислотное выщелачивание показало высокую эффективность в извлечении меди из измельченной руды. Результаты исследования подтверждают, что комплексный подход к переработке медной руды обеспечивает высокую эффективность извлечения ценных компонентов и открывают перспективы для устойчивого и экономически выгодного использования сложных медных руд.

Ключевые слова: медьсодержащее сырьё, обогащение руд, гравитация, флотация, выщелачивание

Introduction

The use of copper, the red metal with remarkable properties, is of paramount importance in the field of clean energy and renewable technologies (2023: 54268). The unique characteristics of copper, such as high electrical conductivity, ductility, efficiency, and recyclability, make it indispensable for various applications in renewable energy systems, including solar and wind technologies (2023: 07.01.04). The significant role of copper in energy storage devices, such as flow batteries, lithium-ion batteries, and sodium batteries, underscores its crucial importance in the production of electric vehicles.

Copper's electrical conductivity is among the highest of all metals, making it an ideal material for the efficient transmission of electricity from renewable sources. Copper's ductility allows for the production of thin wires necessary for complex electrical components in solar panels and wind turbines. Copper's efficiency in energy conversion and its ability to be recycled without losing its properties enhance its environmental sustainability.

The energy storage sector, which ensures balance amidst interruptions in renewable energy sources, also heavily relies on copper. Lithium-ion batteries, widely used in electric vehicles and grid storage, require approximately 44 pounds of copper per megawatt of energy storage (Silpa et al., 2022: 12050545).

Technologies for using renewable energy sources, particularly solar and wind systems, require significantly more copper than traditional fossil fuel-based power generation. For instance, solar systems need approximately 5.5 tons of copper per megawatt of electricity, while 3 MW wind turbines require around 4.7 tons. This is due to the extensive wiring, power transformers, and inverters critical to the functioning of renewable energy systems (Keming and Druffel, 2021: 9519105).

The International Copper Association (ICA) emphasizes that no other metal can match copper's versatility and efficiency in these areas. Copper's exceptional properties make it a cornerstone in the development of clean energy and technologies based on renewable sources. Its indispensable role in solar and wind energy systems, energy storage solutions, and electric vehicle production highlights its significance for transitioning to a sustainable and low-carbon future.

The complete dematerialization of high-grade copper ore and the continuously

growing demand necessitate the processing of low-grade resources to sustain industrial growth and development (Zhumashev et al., 2021). Copper deposits worldwide are predominantly of the porphyry type, comprising 50–60% of global copper production. They consist of copper sulfide minerals such as chalcopyrite (CuFeS_2), chalcocite (Cu_2S), and bornite (Cu_5FeS_4). About 90% of copper is extracted from sulfide deposits, with chalcopyrite accounting for roughly half of the copper production. Besides sulfide minerals, copper also occurs in oxide forms such as cuprite (Cu_2O), malachite ($\text{CuCO}_3 \cdot \text{Cu}(\text{OH})_2$), azurite ($2\text{CuCO}_3 \cdot \text{Cu}(\text{OH})_2$), chrysocolla ($\text{CuSiO}_3 \cdot 2\text{H}_2\text{O}$), and mixed ores containing both oxidized and sulfide minerals.

Copper, a major non-ferrous metal, is present in the Earth's crust at a concentration of 50 parts per million (ppm). In mining operations, the copper content in open-pit mines is around 0.4%, while in underground mines it ranges from 1% to 2%, along with other valuable minerals and gangue materials. The geological distribution and chemical properties of copper require advanced extraction and processing technologies to maximize yield and efficiency (Gerardo et al., 2020: 04255-9).

Kazakhstan produces about 4% of the world's copper volume and 50% of the CIS production (Zhang et al., 2019: 5137852). The country's copper consumption is 8% of total production, with 22% exported to neighboring countries and 70% to distant markets. Kazakhstan ranks high in the global non-ferrous metals market in terms of reserves, mining, and refined copper production: 7th in refined copper production, 9th in copper reserves, and 11th in mining. Copper from Zhezkazgan and Balkhash is registered as a benchmark on the London Metal Exchange (LME). The observed rise in copper prices on the LME underscores the viability and potential for further investment in the copper industry in the Republic of Kazakhstan (Figure 1). The current price on the London Metal Exchange is \$9,489.50 per ton (<https://www.lme.com/Metals/Non-ferrous/LME-Copper/Summary>).

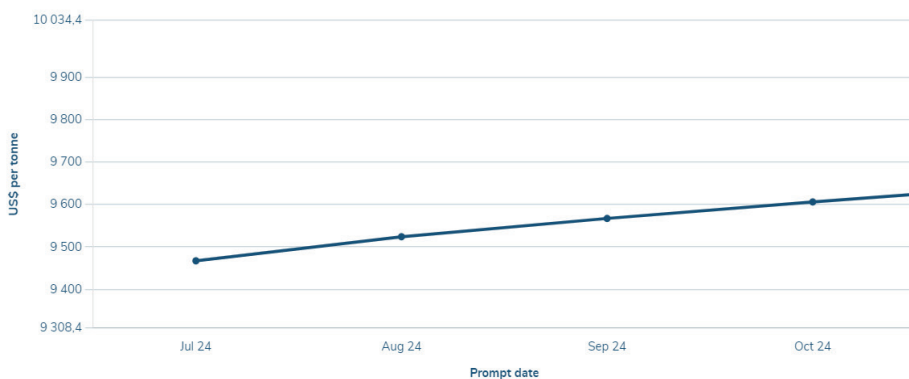


Figure 1 - Dynamics of Copper Prices in US Dollars (USD) per Ton for 2024

In Kazakhstan, the main copper deposits are copper sandstones, copper porphyry, and pyrite-polymetallic types. In 2017, copper ore extraction amounted to nearly 78.5 million

tons, of which 26 million tons were mined in the Karaganda region, 28.5 million tons in the Pavlodar region, and 18.3 million tons in the East Kazakhstan region. A total of 10.5 million tons of copper concentrate and 408,435 tons of refined copper were produced. According to UBS Global Research, global demand for refined copper is increasing, reaching 24.4 million tons in 2017. The global population growth and urbanization demand significant investments in infrastructure, for which copper remains a primary raw material. The rising copper prices on the London Metal Exchange highlight the viability of investments in the development of the copper industry in Kazakhstan.

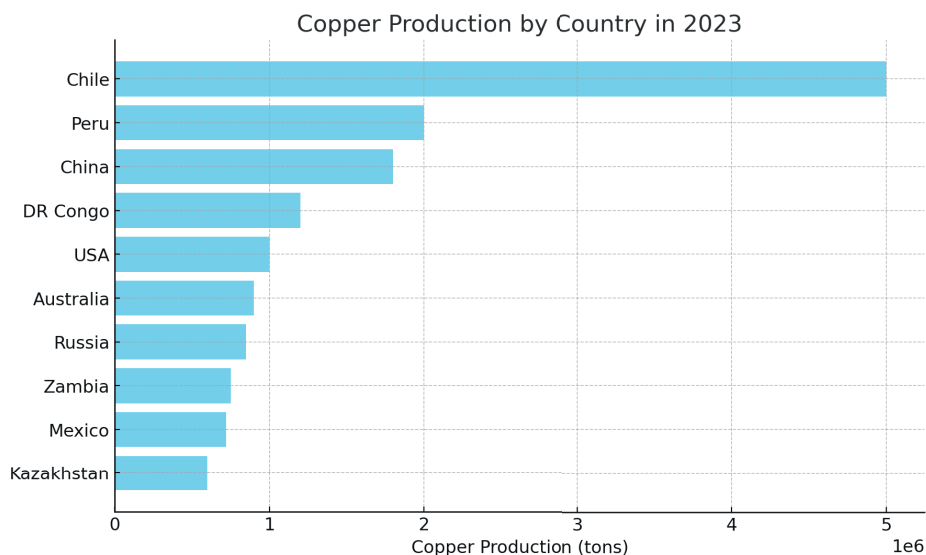


Figure 2 – Copper Production by Country in 2023

The main balance reserves of copper are concentrated in Eastern and Central Kazakhstan, predominantly in low-grade copper porphyry deposits (Chepushtanova et al., 2023: 11–19). Additional reserves include pyrite-polymetallic deposits in the eastern part of the republic (Artemyevskoye, Kosmurun, Akbastau, etc.). In the Karaganda region, the Kenshocky deposit in the Shetsky district and the Nurkazgan copper porphyry deposit with high-grade ores in Central Kazakhstan have been prepared for exploitation. In Southern Kazakhstan, the Shatyrgol copper deposit, and in the Zhezkazgan mining region, one of the largest deposits, Zhaman-Aibat, are notable. Copper porphyry deposits such as Aktogay, Aidarli, Koksay, and Bozshakol also possess significant potential (Koizhanova et al., 2023: 54; Nyamdelger et al., 2023: 26).

The modern copper mining sector faces several fundamental challenges. The depletion of high-grade deposits forces the transition to the development of ores with lower copper content, increasing processing volumes and, consequently, the costs of mining and beneficiation. Additionally, the need to develop deep-seated mines further escalates expenses. The technical complexities of processing such ores require the use of more advanced and costly technologies, leading to higher production costs for

copper. This process is also associated with the necessity of impurity removal, requiring additional processing stages.

The primary objective of this research is to analyze the technological parameters and patterns that determine the efficient processing of copper ore from one of the deposits in Kazakhstan. Particular attention is given to studying the material composition of the ore, conducting comprehensive mineralogical and chemical analyses, and developing and optimizing beneficiation methods such as gravity and flotation. The research aims to obtain new data on the structural changes in copper ores during processing and to develop effective technological solutions for extracting valuable components, thereby enhancing the profitability and environmental sustainability of the copper ore processing process.

Object of study

The research object is copper ore from one of the deposits in Kazakhstan, located in the Karaganda region. The aim of this study is to develop an efficient technology for processing copper ore that contains both oxidized and sulfide copper minerals, as well as other associated components. The primary focus is on studying the material composition of the ore, conducting mineralogical and chemical analyses, and optimizing beneficiation and leaching methods to enhance the copper extraction rate.

The experimental part includes comprehensive laboratory studies such as X-ray fluorescence and X-ray phase analyses, gravity and flotation beneficiation, as well as sulfuric acid leaching. Various technological samples representing different parts of the deposit were selected for analysis: rocks with high malachite content, quartz-sulfide ores, and skarn types.

Experimental Section

Before initiating the research on processing copper ore from one of the deposits in Kazakhstan, the main parameters for gravity and flotation beneficiation, as well as sulfuric acid leaching, were established. A three-inch Knelson KC-MD 3 centrifugal concentrator with continuous discharge was used for gravity beneficiation, under conditions including a cone diameter of 7.5 cm, a water flow rate of 3.5 l/min, a pressure of 25 kPa, and a gravitational acceleration of 60 G.

Sample preparation involved grinding the ores to a fineness of 98% passing -0.071 mm. The samples prepared for the studies were subjected to X-ray fluorescence and X-ray phase analysis to determine their material composition. The loading of ore material samples into the concentrator was performed in averaged mass ratios.

For flotation beneficiation, a laboratory flotation machine of the “Mekhanobr” type with a chamber volume of 3.0 liters was used. Flotation was carried out at a pulp solid particles ratio of 33% in two stages, yielding primary and control concentrates, as well as final tailings. The reagent regime included butyl xanthate and frother C7 at pH 9.0

For sulfuric acid leaching, a sample ground to 80% passing -0.071 mm was used. Leaching was carried out with a 2.5% sulfuric acid solution at a solid-to-liquid ratio of 1:4 for 8 hours. The elemental composition of the initial ore from one of the deposits in Kazakhstan, presented in Table 1, was determined using fluorescence analysis, which allows for the detection of element spectra from oxygen to uranium.

Table 1 – Results of X-ray Fluorescence Analysis of Ore Samples from One of the Deposits in Kazakhstan

Element	Content, %	Element	Content, %	Element	Content, %	Element	Content, %
O	45.782	P	0.412	Mn	0.157	Mo	0.008
F	0.261	S	0.269	Fe	3.417	Ag	0.034
Mg	0.807	Cl	0.125	Cu	5.626	Ba	0.082
Al	3.113	K	0.722	Zn	0.541	Pb	8.557
Si	21.491	Ca	0.726	As	0.033		
Ti	0.116	Cr	0.025	Sr	0.012		

X-ray phase analysis determined the primary composition of the rock-forming components. The measurements were conducted using a D8 Advance (Bruker) apparatus, α -Cu, with a tube voltage of 40 kV and a current of 40 mA. The processing of the obtained diffractogram data and calculation of interplanar distances were performed using EVA software. Sample interpretation and phase identification were conducted using the Search/match program with the PDF-2 powder diffraction database. The results of the X-ray phase analysis are presented in Figure 3 and Table 2.

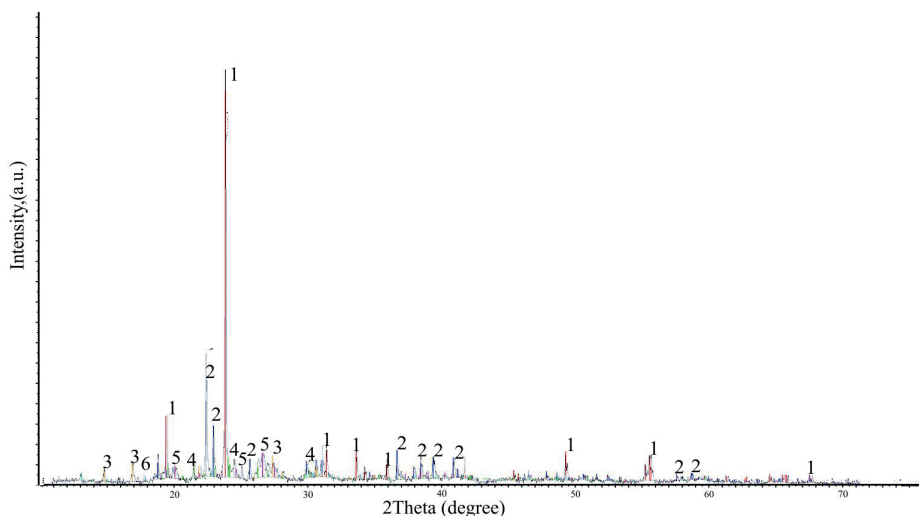


Figure 3 – Diffractogram of the Sample from One of the Deposits in Kazakhstan

Table 2 – Results of X-ray Phase Analysis of the Initial Sample from One of the Deposits in Kazakhstan

№	Compound Name	Formula	Content. rel. %
1	Quartz	SiO ₂	63.3%
2	Cerussite	PbCO ₃	19.3%
3	Malachite	CH ₂ Cu ₂ O ₅	6.2%
4	Orthoclase	KSi ₃ AlO ₈	4.9%
5	Lead Phosphate	Pb ₃ (PO ₄) ₂	4.8%
6	Clinocllore	Al-Fe-SiO ₂ -OH	1.5%

A sample of ore from one of the deposits in Kazakhstan was studied using mineralogical analysis in reflected light with an OLIMPUS-BX 51 microscope. The main mass of the briquettes consists of non-metallic minerals, predominantly quartz. Among the rock-forming minerals, malachite was identified (Figure 4a). Cerussite appears gray in reflected light with low reflectivity, exhibiting strong bireflection and anisotropy. The internal reflections are bright and colorless. Cerussite is observed as irregular segregations with intricate contours, composed of anhedral grains ranging from a few hundredths to 0.05 mm in size (Figure 4b). Iron hydroxides and carbonaceous material are also present.

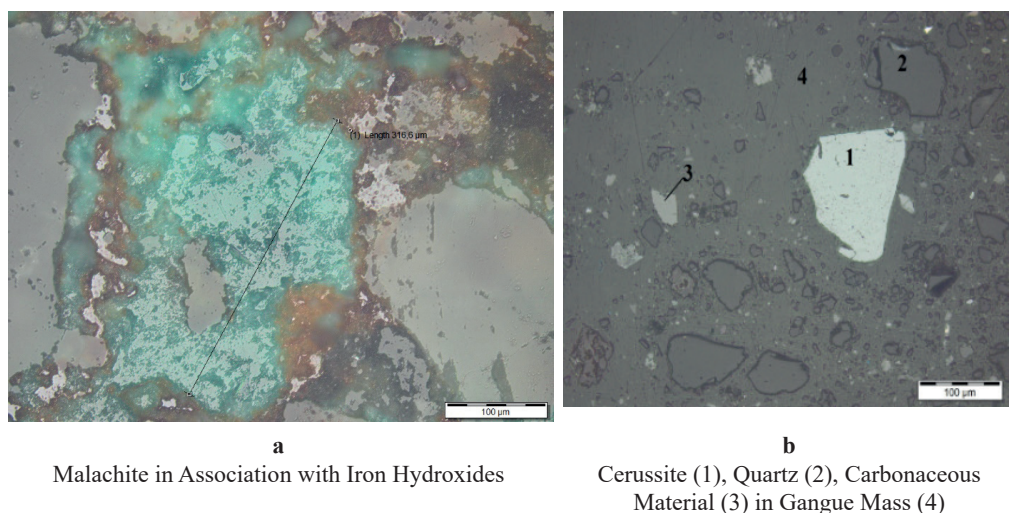


Figure 4 – Mineralogical Analysis of the Sample at 400x Magnification

Phase analysis of the initial sample revealed the content of various forms of copper, lead, and other elements. The copper content in free oxidized minerals was 4.394%, in bound oxidized minerals—0.07%, in secondary sulfides—0.32%, and in primary sulfides—0.0095%, resulting in a total of 4.79%. The main copper minerals include malachite, azurite, tenorite, and cuprite, as well as bornite, chalcopyrite, and chalcocite (Table 3).

Table 3 – Phase Analysis of the Initial Sample from One of the Deposits in Kazakhstan

Mass fraction of determined elements, %					
Cu free oxidized mineral	Cu bound oxidized mineral	Cu secondary sulfides	Cu primary sulfides	ΣCu	Cu _{total}
4.394	0.07	0.32	0.0095	4.79	4.79
malachite, azurite, tenorite, cuprite	malachite, azurite, tenorite, cuprite	bornite, chalcopyrite, chalcocite	chalcopyrite, cubanit		

The sample from one of the deposits in Kazakhstan primarily consists of camallite, halite, and sylvite, which together constitute more than 86% of the total composition.

