

ISSN: 1991-346X (Print)
ISSN: 2518-1726 (Online)

**ACADEMIC JOURNAL
OF PHYSICAL AND CHEMICAL SCIENCES**

№1
2026

ISSN 2518-1483 (Online),
ISSN 2224-5227 (Print)

2026 • 1



**ACADEMIC JOURNAL
OF PHYSICAL AND
CHEMICAL SCIENCES**

PUBLISHED SINCE JANUARY 1944

ALMATY, NAS RK

EDITOR-IN-CHIEF

ZHURINOV Murat Zhurinovich, Doctor of Chemical Sciences, Professor, Academician of IAAS and NAS RK, General Director Oil refining and Petrochemistry Research Institute (Almaty, Kazakhstan), <https://www.scopus.com/authid/detail.uri?authorId=6602177960>, <https://www.webofscience.com/wos/author/record/2017489>

DEPUTY EDITOR-IN-CHIEF:

KALIMOLDAYEV Maksat Nuradilovich, Doctor of Physical and Mathematical Sciences, Professor, Academician of NAS RK (Almaty, Kazakhstan), <https://www.scopus.com/authid/detailuri?authorId=56153126500>, <https://www.webofscience.com/wos/author/record/2428551>

ABILMAGZHANOV Arlan Zainutallaevich, PhD in Chemistry, General Director of JSC "Institute of Fuel, Catalysis and Electrochemistry named after D.V. Sokolsky", (Almaty, Kazakhstan), <https://www.scopus.com/authid/detail.uri?authorId=57197468109>, <https://www.webofscience.com/wos/author/record/2024265>

EDITORIAL BOARD:

ADEKENOV Sergazy Mynzhasarovich, Doctor of Chemical Sciences, Professor, Academician of NAS RK, Director of the JSC "Phytochemistry Research and Production Center", (Karaganda, Kazakhstan), <https://www.scopus.com/authid/detail.uri?authorId=7006153118>, <https://www.webofscience.com/wos/author/record/48648658>

RAMAZANOV Tlekkabul Sabitovich, Doctor of Physical and Mathematical Sciences, Professor, Academician of NAS RK (Almaty, Kazakhstan), <https://www.scopus.com/authid/detail.uri?authorId=6701328029>, <https://www.webofscience.com/wos/author/record/13503476>

ABIEV Rufat, Doctor of Technical Sciences (Biochemistry), Professor, Head of the Department of Optimization of Chemical and Biotechnological Equipment, St. Petersburg State Technological Institute (St. Petersburg, Russia), <https://www.scopus.com/authid/detail.uri?authorId=6602431781>, <https://www.webofscience.com/wos/author/record/1405661>

OLIVIERO Rossi Cesare, PhD (Chemistry), Professor at the University of Calabria (Calabria, Italy), <https://www.scopus.com/authid/detail.uri?authorId=57221375979>, <https://www.webofscience.com/wos/author/record/399768>

TIGINYANU Ion Mihailovich, Doctor of Physical and Mathematical Sciences, Academician, President of the Academy of Sciences of Moldova, Technical University of Moldova (Chisinau, Moldova), <https://www.scopus.com/authid/detail.uri?authorId=7006315935>, <https://www.webofscience.com/wos/author/record/524462>

SANG SU Kwak, PhD (Biochemistry, Agricultural Chemistry), Professor, Chief Scientist, Research Center for Plant Systems Engineering, Korea Research Institute of Bioscience and Biotechnology (KRIBB), (Daecheon, Korea), <https://www.scopus.com/authid/detail.uri?authorId=59286321700>, <https://www.webofscience.com/wos/author/record/30028581>

BERSIMBAYEV Rakhmetkazhi Iskenderovich, Doctor of Biological Sciences, Professor, Academician of NAS RK, L.N. Gumilyov Eurasian National University (Astana, Kazakhstan), <https://www.scopus.com/authid/detail.uri?authorId=7004012398>, <https://www.webofscience.com/wos/author/record/19854255>

CALANDRA Pietro, PhD (Physics), Professor, Institute for the Study of Nanostructured Materials (Rome, Italy), <https://www.scopus.com/authid/detail.uri?authorId=7004303066>, <https://www.webofscience.com/wos/author/record/616360>

BOSHKAEV Kuantai Avgazyevich, PhD, Associate Professor, Department of Theoretical and Nuclear Physics, Al-Farabi Kazakh National University (Almaty, Kazakhstan), <https://www.scopus.com/authid/detail.uri?authorId=54883880400>, <https://www.webofscience.com/wos/author/record/2080231>

BURKITBAEV Mukhambetkali, Doctor of Chemical Sciences, Professor, Academician of NAS RK, (Almaty, Kazakhstan), <https://www.scopus.com/authid/detail.uri?authorId=8513885600>, <https://www.webofscience.com/wos/author/record/29017135>

QUEVEDO Hernando, Professor, National Autonomous University of Mexico (UNAM), Institute of Nuclear Sciences (Mexico City, Mexico), <https://www.scopus.com/authid/detail.uri?authorId=55989741100>, <https://www.webofscience.com/wos/author/record/30353742>

ZHUSUPOV Marat Abzhanovich, Doctor of Physical and Mathematical Sciences, Professor of the Department of Theoretical and Nuclear Physics, Al-Farabi Kazakh National University (Almaty, Kazakhstan), <https://www.scopus.com/authid/detail.uri?authorId=6602166928>, <https://www.webofscience.com/wos/author/record/566>

KOVALEV Alexander Mikhailovich, Doctor of Physical and Mathematical Sciences, Academician of NAS of Ukraine, Institute of Applied Mathematics and Mechanics (Donetsk, Ukraine), <https://www.scopus.com/authid/detail.uri?authorId=7202799321>, <https://www.webofscience.com/wos/author/record/65533963>

TAKIBAEV Nurgali Zhabagaevich, Doctor of Physical and Mathematical Sciences, Professor, Academician of NAS RK, Al-Farabi Kazakh National University (Almaty, Kazakhstan), <https://www.scopus.com/authid/detail.uri?authorId=24077239000>, <https://www.webofscience.com/wos/author/record/1671760>

KHARIN Stanislav Nikolaevich, Doctor of Physical and Mathematical Sciences, Professor, Academician of NAS RK, Kazakh-British Technical University (Almaty, Kazakhstan), <https://www.scopus.com/authid/detail.uri?authorId=6701353063>, <https://www.webofscience.com/wos/author/record/2023295>

ABISHEV Medeu Erzhanovich, Doctor of Physical and Mathematical Sciences, Professor, Corresponding Member of NAS RK, (Almaty, Kazakhstan), <https://www.scopus.com/authid/detail.uri?authorId=26530759900>, <https://www.webofscience.com/wos/author/record/1556025>

ACADEMIC JOURNAL OF PHYSICAL AND CHEMICAL SCIENCES.

ISSN 2518-1483 (Online), ISSN 2224-5227 (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 Social Development of the Republic of Kazakhstan № KZ93VPY00121157 issued 05.06.2025

Thematic scope: *physics and chemistry*.

Periodicity: 4 times a year.

<http://reports-science.kz/index.php/en/archive>

БАС РЕДАКТОР

ЖҰРЫНОВ Мұрат Жұрынулы, химия ғылымдарының докторы, профессор, ХҒАҚ және ҚР ҰҒА академигі, Мұнай өңдеу және мұнай-химиясы ғылыми-зерттеу институтының бас директоры (Алматы, Қазақстан), <https://www.scopus.com/author/detail.uri?authorId=6602177960>, <https://www.webofscience.com/wos/author/record/2017489>

БАС РЕДАКТОРДЫҢ ОРЫНБАСАРЛАРЫ:

КАЛИМОЛДАЕВ Мақсат Нұрәділұлы, физика-математика ғылымдарының докторы, профессор, ҚР ҰҒА академигі (Алматы, Қазақстан), <https://www.scopus.com/author/detail.uri?authorId=56153126500>, <https://www.webofscience.com/wos/author/rec-ord/2428551>

ӘБИЛМАҒЖАНОВ Арлан Зайнуталлайұлы, химия ғылымдарының кандидаты, Д.В. Сокольский атындағы «Жанармай, катализ және электрохимия институты» АҚ Бас директоры (Алматы, Қазақстан), <https://www.scopus.com/author/detail.uri?authorId=57197468109>, <https://www.webofscience.com/wos/author/record/2024265>

РЕДАКЦИЯ АЛҚАСЫ:

ӘДЕКЕНОВ Серғазы Мынжасарұлы, химия ғылымдарының докторы, профессор, ҚР ҰҒА академигі, «Фитохимия» ғылыми-өндірістік орталығы» АҚ директоры (Қарағанды, Қазақстан), <https://www.scopus.com/author/detail.uri?authorId=7006153118>, <https://www.webofscience.com/wos/author/record/48648658>

РАМАЗАНОВ Тілеккабыл Сәбитұлы, физика-математика ғылымдарының докторы, профессор, ҚР ҰҒА академигі (Алматы, Қазақстан), <https://www.scopus.com/author/detail.uri?authorId=6701328029>, <https://www.webofscience.com/wos/author/record/13503476>

ӘБИЕВ Руфат, техника ғылымдарының докторы (биохимия), профессор, Санкт-Петербург мемлекеттік технологиялық институты «Химиялық және биотехнологиялық аппаратураны оңтайландыру» кафедрасының меңгерушісі (Санкт-Петербург, Ресей), <https://www.scopus.com/author/detail.uri?authorId=6602431781>, <https://www.webofscience.com/wos/author/record/1405661>

ОЛИВЬЕРО Росси Сесаре, PhD (химия), Калабрия университетінің профессоры (Калабрия, Италия), <https://www.scopus.com/author/detail.uri?authorId=57221375979>, <https://www.webofscience.com/wos/author/record/399768>

ТИГИНЯНУ Ион Михайлович, физика-математика ғылымдарының докторы, академик, Молдова Ғылым академиясының президенті, Молдова техникалық университеті (Кишинев, Молдова), <https://www.scopus.com/author/detail.uri?authorId=7006315935>, <https://www.webofscience.com/wos/author/record/524462>

САНГ-СУ Квак, PhD (биохимия, агрохимия), профессор, Корей Биоғылым және биотехнология ғылыми-зерттеу институты (KRIBB), өсімдіктердің инженерлік жүйелері ғылыми-зерттеу орталығының бас ғылыми қызметкері (Дэчон, Корея), <https://www.scopus.com/author/detail.uri?authorId=59286321700>, <https://www.webofscience.com/wos/author/record/30028581>

БЕРСІМБАЕВ Рахметқажы Есендірұлы, биология ғылымдарының докторы, профессор, ҚР ҰҒА академигі, Л.Н. Гумилев атындағы Еуразия ұлттық университеті (Астана, Қазақстан), <https://www.scopus.com/author/detail.uri?authorId=7004012398>, <https://www.webofscience.com/wos/author/record/19854255>

КАЛАНДРА Пьетро, PhD (физика), нанокүрылымды материалдарды зерттеу институтының профессоры (Рим, Италия), <https://www.scopus.com/author/detail.uri?authorId=7004303066>, <https://www.webofscience.com/wos/author/record/616360>

БӨШКАЕВ Қуантай Авғазыұлы, PhD теориялық және ядролық физика кафедрасының доценті, әл-Фараби атындағы Қазақ ұлттық университеті (Алматы, Қазақстан), <https://www.scopus.com/author/detail.uri?authorId=54883880400>, <https://www.webofscience.com/wos/author/record/2080231>

БҮРКІТБАЕВ Мұхамбетқали, химия ғылымдарының докторы, профессор, ҚР ҰҒА академигі (Алматы, Қазақстан), <https://www.scopus.com/author/detail.uri?authorId=8513885600>, <https://www.webofscience.com/wos/author/record/29017135>

QUEVEDO Hernando, профессор, Мексика ұлттық автономиялық университеті (UNAM), Ядролық ғылымдар институты (Мехико, Мексика), <https://www.scopus.com/author/detail.uri?authorId=55989741100>, <https://www.webofscience.com/wos/author/record/30353742>

ЖҮСІПОВ Марат Абжанұлы, физика-математика ғылымдарының докторы, теориялық және ядролық физика кафедрасының профессоры, әл-Фараби атындағы Қазақ ұлттық университеті (Алматы, Қазақстан), <https://www.scopus.com/author/detail.uri?authorId=6602166928>, <https://www.webofscience.com/wos/author/record/566>

КОВАЛЕВ Александр Михайлович, физика-математика ғылымдарының докторы, Украина ҰҒА академигі, Қолданбалы математика және механика институты (Донецк, Украина), <https://www.scopus.com/author/detail.uri?authorId=7202799321>, <https://www.webofscience.com/wos/author/record/65533963>

ТАКИБАЕВ Нұрғали Жабағаұлы, физика-математика ғылымдарының докторы, профессор, ҚР ҰҒА академигі, әл-Фараби атындағы Қазақ ұлттық университеті (Алматы, Қазақстан), <https://www.scopus.com/author/detail.uri?authorId=24077239000>, <https://www.webofscience.com/wos/author/record/1671760>

ХАРИН Станислав Николаевич, физика-математика ғылымдарының докторы, профессор, ҚР ҰҒА академигі (Алматы, Қазақстан), <https://www.scopus.com/author/detail.uri?authorId=6701353063>, <https://www.webofscience.com/wos/author/record/2023295>

ӘБИШЕВ Медеу Ержанұлы, физика-математика ғылымдарының докторы, профессор, ҚР ҰҒА академигі, (Алматы, Қазақстан), <https://www.scopus.com/author/detail.uri?authorId=26530759900>, <https://www.webofscience.com/wos/author/record/1556025>

ACADEMIC JOURNAL OF PHYSICAL AND CHEMICAL SCIENCES

ISSN 2518-1483 (Online), ISSN 2224-5227 (Print)

Меншіктеуші: «Орталық Азия академиялық ғылыми орталығы» ЖШС (Алматы қ.).

Ақпарат агенттігінің мерзімді баспасөз басылымын, ақпарат агенттігінің және желілік басылымды қайта есепке қою туралы ҚР Мәдениет және Ақпарат министрлігі «Ақпарат комитеті» Республикалық мемлекеттік мекемесі **05.06.2025 ж.** берген № **KZ93VPY00121157** Куәлік.

Тақырыптық бағыты: *физика, химия.*

Мерзімділігі: жылына 4 рет.

<http://reports-science.kz/index.php/en/archive>

ГЛАВНЫЙ РЕДАКТОР

ЖУРИНОВ Мурат Журинович, доктор химических наук, профессор, академик МАН и НАН РК, Генеральный директор Научно-исследовательского института нефтепереработки и нефтехимии (Алматы, Казахстан), <https://www.scopus.com/authid/detail.uri?authorId=6602177960>, <https://www.webofscience.com/wos/author/record/2017489>

ЗАМЕСТИТЕЛИ ГЛАВНОГО РЕДАКТОРА:

КАЛИМОЛДАЕВ Максат Нурадилович, доктор физико-математических наук, профессор, академик НАН РК (Алматы, Казахстан), <https://www.scopus.com/authid/detail.uri?authorId=56153126500>, <https://www.webofscience.com/wos/author/record/2428551>

АБИЛЬМАГЖАНОВ Арлан Зайнуталлаевич, кандидат химических наук, Генеральный директор АО «Институт топлива, катализа и электрохимии им. Д.В. Сокольского», (Алматы, Казахстан), <https://www.scopus.com/authid/detail.uri?authorId=57197468109>, <https://www.webofscience.com/wos/author/record/2024265>

РЕДАКЦИОННАЯ КОЛЛЕГИЯ:

АДЕКЕНОВ Сергазы Мынжасарович, доктор химических наук, профессор, академик НАН РК, директор АО «Научно-производственного центра «Фитохимия» (Караганда, Казахстан), <https://www.scopus.com/authid/detail.uri?authorId=7006153118>, <https://www.webofscience.com/wos/author/record/48648658>

РАМАЗАНОВ Тлеккабул Сабитович, (заместитель главного редактора), доктор физико-математических наук, профессор, академик НАН РК (Алматы, Казахстан), <https://www.scopus.com/authid/detail.uri?authorId=6701328029>, <https://www.webofscience.com/wos/author/record/13503476>

АБИЕВ Руфат, доктор технических наук (биохимия), профессор, заведующий кафедрой «Оптимизация химической и биотехнологической аппаратуры», Санкт-Петербургский государственный технологический институт (Санкт-Петербург, Россия), <https://www.scopus.com/authid/detail.uri?authorId=6602431781>, <https://www.webofscience.com/wos/author/record/1405661>

ОЛИБЬЕРО Россин Чезаре, доктор философии (PhD, химия), профессор Университета Калабрии (Калабрия, Италия), <https://www.scopus.com/authid/detail.uri?authorId=57221375979>, <https://www.webofscience.com/wos/author/record/399768>

ТИГИНЯНУ Ион Михайлович, доктор физико-математических наук, академик, президент Академии наук Молдовы, Технический университет Молдовы (Кишинев, Молдова), <https://www.scopus.com/authid/detail.uri?authorId=7006315935>, <https://www.webofscience.com/wos/author/record/524462>

САНГ-СУ Квак, доктор философии (PhD, биохимия, агрохимия), профессор, главный научный сотрудник, Научно-исследовательский центр инженерных систем растений, Корейский научно-исследовательский институт бионауки и биотехнологии (KRIBB) (Дэчон, Корея), <https://www.scopus.com/authid/detail.uri?authorId=59286321700>, <https://www.webofscience.com/wos/author/record/30028581>

БЕРСИМБАЕВ Рахметкажи Искендерович, доктор биологических наук, профессор, академик НАН РК, Евразийский национальный университет им. Л.Н. Гумилева (Астана, Казахстан), <https://www.scopus.com/authid/detail.uri?authorId=7004012398>, <https://www.webofscience.com/wos/author/record/19854255>

КАЛАНДРА Пьетро, доктор философии (PhD, физика), профессор Института по изучению наноструктурированных материалов (Рим, Италия), <https://www.scopus.com/authid/detail.uri?authorId=7004303066>, <https://www.webofscience.com/wos/author/record/616360>

БОШКАЕВ Куантай Авгазиевич, PhD, преподаватель, доцент кафедры теоретической и ядерной физики, Казахский национальный университет им. Аль-Фараби (Алматы, Казахстан), <https://www.scopus.com/authid/detail.uri?authorId=54883880400>, <https://www.webofscience.com/wos/author/record/2080231>

БУРКИТБАЕВ Мухамбетали, доктор химических наук, профессор, академик НАН РК, (Алматы, Казахстан), <https://www.scopus.com/authid/detail.uri?authorId=8513885600>, <https://www.webofscience.com/wos/author/record/29017135>

QUEVEDO Hernando, профессор, Национальный автономный университет Мексики (UNAM), Институт ядерных наук (Мехико, Мексика), <https://www.scopus.com/authid/detail.uri?authorId=55989741100>, <https://www.webofscience.com/wos/author/record/30353742>

ЖУСУПОВ Марат Абжанович, доктор физико-математических наук, профессор кафедры теоретической и ядерной физики, Казахский национальный университет имени аль-Фараби (Алматы, Казахстан), <https://www.scopus.com/authid/detail.uri?authorId=6602166928>, <https://www.webofscience.com/wos/author/record/566>

КОВАЛЕВ Александр Михайлович, доктор физико-математических наук, академик НАН Украины, Институт прикладной математики и механики (Донецк, Украина), <https://www.scopus.com/authid/detail.uri?authorId=7202799321>, <https://www.webofscience.com/wos/author/record/65533963>

ТАКИБАЕВ Нурғали Жабағевич, доктор физико-математических наук, профессор, академик НАН РК, Казахский национальный университет им. Аль-Фараби (Алматы, Казахстан), <https://www.scopus.com/authid/detail.uri?authorId=24077239000>, <https://www.webofscience.com/wos/author/record/1671760>

ХАРИН Станислав Николаевич, доктор физико-математических наук, профессор, академик НАН РК (Алматы, Казахстан), <https://www.scopus.com/authid/detail.uri?authorId=6701353063>, <https://www.webofscience.com/wos/author/record/2023295>

АБИШЕВ Мелеу Ержанович, доктор физико-математических наук, профессор, академик НАН РК, (Алматы, Казахстан), <https://www.scopus.com/authid/detail.uri?authorId=26530759900>, <https://www.webofscience.com/wos/author/record/1556025>

ACADEMIC JOURNAL OF PHYSICAL AND CHEMICAL SCIENCES

ISSN 2518-1483 (Online), ISSN 2224-5227 (Print)

Собственник: ТОО «Центрально-азиатский академический научный центр» (г. Алматы).

Свидетельство № KZ93VPY00121157 о повторной регистрации периодического печатного издания информационного агентства, информационного агентства и сетевого издания, выданное Республиканским государственным учреждением «Комитет информации» Министерства культуры и информации Республики Казахстан **05.06.2025**Тематическая направленность: *физика, химия*.

Периодичность: 4 раза в год.

<http://reports-science.kz/index.php/en/archive>

CONTENTS

PHYSICS

Aimaganbetova Z.K., Kulshymbayev Y.A., Zhanturina N.N., Beketova G.K.
First-principles calculation of the electronic properties of the Double Halide Perovskite $\text{Cs}_2\text{Ag}_{0.2}\text{Na}_{0.4}\text{In}_{0.6}\text{Ti}_{0.4}\text{Cl}_6$ based on the quantum ESPRESSO software.....14

Amangeldinova S., Zhuniskhan S., Kalzhigitov N., Kurmangaliyeva V.
Study of the cluster structure of ^5He and ^5Li mirror nuclei in two-cluster approximation.....35

Chokin K., Otunchi Ye., Kozhahmetova A., Kasenova A., Shongalova A.
Development and testing of a laboratory pyrometallurgical installation for recycling lithium-ion batteries.....46

Issayeva A., Beisebayeva A., Madybekova G., Shynazbekova Sh., Issa A.
Comparative analysis of physico-chemical characteristics of drinking, spring and natural water in the South Kazakhstan.....65

Kim V.Yu., Aimuratov Y.K.
Search for transient cosmic events by scanning the sky with wide-field telescopes.....78

Koshtybayev T.B., Tatenov A.M., Aliyeva M.E., Tugelbaeva G.T., Zhanaliyeva G.Zh.
Study of the electromagnetic field based on thermodynamics principles.....89

Mukamedenkyzy V., Akberdiyev B.
Numerical investigation of the effect of inclination angle on the stability of mechanical equilibrium in Ar–N₂ binary gas mixtures.....105

Myasnikova L.N., Uzakbaeva S.S., Shanina Z.K., Bekeshev A.Z.
Kinetic properties of high-density polyethylene filled with chromium spinel powder.....119

Nurbayev B.M., Dmitriyeva E.A., Kemelbekova A.E.
The role of low-dimensional layered structures in enhancing the stability of tin-based perovskite materials.....136

Sattinova Z., Ermakhanova F., Assilbekov B., Taimuratova L.
Influence of various cooling conditions and heat transfer coefficients on solidification during the formation of beryllium ceramic products.....149

Shestakova L.I., Serebryanskiy A.V., Spassyuk R.R., Omarov Ch.T.
Search for gas of comet-meteor origin in the inner Solar System: caii ion emission.....165

Ualikhanova U., Tursynkazy F., Syzdykova A.M., Altayeva G.S., Altaibayeva A.B.
Studying the amplitude of $f(T)$ gravitational waves using Bessel functions.....179

Zhexenbayeva G.A., Nasirova D.M., Aimanova G.K., Shomshekova S.A. Photometric study of the symbiotic object V725 Tau.....	194
Zhusupova N.K., Zhadyranova A.A. Bounce cosmology in $f(T, \mathcal{T})$ gravity based on energy condition analysis.....	205
Ziyatbekova G., Abdimanapova P., Sagyntay O., Nurym A., Ilinov R. Using artificial intelligence to predict diseases based on medical data.....	225

CHEMISTRY

Almassov N.Zh., Zhumagaliyeva A.N., Duisenbekov S.E., Zhakiyev N.K. Design and optimization of hybrid renewable energy systems for hydrogen production in Kazakhstan.....	236
Amangeldi B., Zhanikulov N., Taimasov B., Aitureev M.M., Dauletiyarov M. Calculation of the Raw material composition for obtaining white Portland cement clinker.....	251
Baeshov A., Tashenov E.A., Atykhanova S.B., Koshkarbayeva Sh.T. Preparation of cadmium sulfide by electrochemical method using a composite sulfur-graphite electrode.....	267
Baisalova G.Zh., Azhikhanova Zh., Taltenov A.A., Kuzhatova P. Determination of the total phenolic content in perennial herbaceous plants of the flora of Kazakhstan.....	277
Darmenbayeva A.S., Rajasekharan R., Zhussipnazarova G.M., Mukazhanova Zh.B., Begenova B.E. Composites based on chitosan and cellulose: synthesis, properties, and application prospects.....	287
Erkasov R.Sh., Zhamkenova A.S., Sergazina S.M., Nurmukhanbetova N.N., Kassenova N.B. Halide-dependent modulation of hydrogen bonding in Mn(II) complexes with protonated acetamide: a QAIM, NCI, and energy decomposition study.....	304
Kalimoldina L.M., Shaikhova Zh.E., Kaliyeva B.K., Bubish Sh., Askarova Sh.K. The effect of silver nanoparticles on the germination of bean, lemon, tangerine and avocado seeds.....	320
Kurtebayeva A.A., Alvarez-Torrellas S., Gomes H.T., Orynbayev S.A., Kalmakhanova M.S. Activated-carbon-enhanced polymeric membranes for efficient elimination of emerging contaminants.....	334

Massenova A.T., Zhumakanova A.S., Torlopov I.I., Rakhmetova K.S., Abilmagzhanov A.Z. Optimization of the hierarchical zeolite ZSM-5 synthesis process by steam-assisted alkaline modification.....	350
Mutushev A.Zh., Nuraly A.M., Sanat A.S., Shaukharova M.A., Yessimsiitova Z.B. The effect of light-converting films on the accumulation of bioactive compounds and the quality of fruits.....	366
Nefedov A.N., Taikenova A.T. Current state of organic corrosion inhibitor application in oil refining.....	379
Omarov B.T., Altybayev Zh.M., Serikbayeva B.S. Production of biohumus by vermicomposting of organic wastes and study of its agroecological effectiveness.....	399
Rakhman D.M., Kappasuly A., Makhayeva D.N., Kazybayeva D.S., Irmukhametova G.S. Development and investigation of mucoadhesive hydrogels based on gellan–cysteine complexes.....	414
Sabyrzhanova A.E., Bolatkyzy N., Berganaeva G.E., Dyusebaeva M.A. Study of amino acids and fatty acids in the aerial part of <i>Plantago major</i>	428
Satayeva S., Akhmetova F., Urazova A., Aituganova S., Yerniyazova K. The influence of PEPA concentration on the physical, mechanical, and operational properties of ED-20 epoxy adhesives.....	439
Zamanbek A.Zh., Koshkarbayeva Sh.T., Satayev M.S. Methods of Obtaining Silver Nanoparticles and Antibacterial Properties.....	450
Zhortarova A.A., Salkeyeva L.K., Minayeva Ye.V., Ibrayev M.K., Fazylov S.D. New possibilities for the synthesis and phosphorylation of phosphonoacetic acid ester.....	462

МАЗМҰНЫ

ФИЗИКА

Аймағанбетова З.К., Құлшымбаев Е.А., Жантурина Н.Н., Бекетова Г.К. Quantum Espresso бағдарламасы негізінде Cs ₂ Ag _{0.2} Na _{0.4} In _{0.6} Ti _{0.4} Cl ₆ кос галогенді перовскиттің электрондық қасиеттерін бірінші принциптік есептеу.....	14
Амангелдинова С., Жүнісхан С., Калжигитов Н., Курманғалиева В. Екі кластерлік жуықтауда 5Ne және 5Li айналық ядроларының кластерлік құрылымын зерттеу.....	35
Чокин К., Отунчи Е., Кожаметова А., Касенова А., Шонғалова А. Литий-ионды аккумуляторларды қайта өндеуге арналған зертханалық пирометаллургиялық қондырғыны әзірлеу және сынау.....	46
Исаева А.Б., Бейсебаева А.С., Мадыбекова Г.М., Шиназбекова Ш.С., Иса А.Б. Сравнительный анализ физико-химических характеристик питьевой, родниковой и природной воды юга Казахстана.....	65
Ким В.Ю., Аймуратов Е.К. Кең бұрышты телескоптармен аспанды сканерлеу арқылы өтпелі ғарыштық оқиғаларды іздеу.....	78
Коштыбаев Т.Б., Татенов А.М., Алиева М.Е., Тугелбаева Г.Т., Жаналиева Г.Ж. Электромагниттік өрісті термодинамикалық бастамалар тұрғысында зерттеу.....	89
Мукамеденқызы В., Ақбердиев Б. Ar–N ₂ бинарлы газ қоспаларындағы механикалық тепе-теңдік тұрақтылығына қиғаш бұрыштың әсерін сандық зерттеу.....	105
Мясникова Л.Н., Узакбаева С.С., Шанина З.К., Бекешев А.З. Хром-шпинельді ұнтақ қосылған жоғары тығыздықты полиэтиленнің кинетикалық қасиеттері.....	119
Нұрбаев Б.М., Дмитриева Е.А., Кемелбекова А.Е. Қалайы негізіндегі перовскитті материалдардың тұрақтылығын арттырудағы төменөлшемді қабатты құрылымдардың рөлі.....	136
Саттинова З., Ермаханова Ф., Асылбеков Б., Таймуратова Л. Бериллий керамикалық бұйымдарын қалыптастыру кезінде әр түрлі салқындату жағдайлары мен жылу беру коэффициенттерінің қатаюға әсері.....	149
Шестакова Л.И., Серебрянский А.В., Спасюк Р.Р., Омаров Ш.Т. Күн жүйесінің ішкі аймағындағы комета-метеорлық тектегі газды іздеу: CaII иондарының жарқырауы.....	165

Уалиханова У.А., Тұрсынқазы Ф., Сыздықова А.М., Алтаева Г.С., Алтайбаева А.Б.
Бессель функцияларын пайдаланып $f(T)$ гравитациялық толқындардың
амплитудасын зерттеу.....179

Жексенбаева Г.А., Насирова Д.М., Айманова Г.К., Шомшекова С.А
V725 Тау симбиотикалық объектiсiн фотометрлiк зерттеу.....194

Жусупова Н.К., Жадыранова А.А.
Энергия шарттарын талдауға негiзделген $f(T, T)$ серпiлiс космологиясы.....205

Зиятбекова Г.З., Абдиманапова П.Б., Сағынтай О.А., Нұрым А.А., Ильинов Р.А.
Жасанды интеллект көмегiмен медициналық деректер бойынша
ауруларды болжау.....225

ХИМИЯ

Алмассов Н.Ж., Жумагалиева А.Н., Дүйсенбеков С.Е., Жакиев Н.К.
Қазақстанда сутегi өндiруге арналған гибрирдiк жаңартылатын энергия жүйелерiн
жобалау және оңтайландыру.....236

Амангелдi Б., Жаникулов Н., Таймасов Б., Айтуреев М., Даулетияров М.
Ақ портландцемент клинкерiн алу үшiн шикiзат шихта құрамын есептеу.....251

Баешов А., Ташенов Е.А., Атыханова С.Б., Кошкарбаева Ш.Т.
Композициялы күкiрт-графит электродын қолдану арқылы кадмий
сульфидiн электрохимиялық әдiспен алу.....267

Байсалова Г.Ж., Ажиханова Ж., Талтенов А.А., Құжатова П.
Қазақстан флорасындағы көпжылдық шөптесiн өсiмдiктердiң фенолдық
қосылыстарының жиынтық мөлшерiн анықтау.....277

**Дарменбаева А.С., Rajasekharan R., Жусипназарова Г.М., Мукажанова Ж.Б.,
Бегенова Б.Е.**
Хитозан және целлюлоза негiзiндегi композиттер: синтез, қасиеттерi және қолдану
перспективалары.....287

**Еркасов Р.Ш., Жамкенова А.С., Сергазина С.М., Нурмуханбетова Н.Н.,
Касенова Н.Б.**
Mn (II) кешендерiндегi сутектiк байланыстардың энергиясы мен табиғатына
галогеннiң әсерi: QТАІМ, NCI және энергия декомпозициясы.....304

Калимолдина Л.М., Шаихова Ж.Е., Калиева Б.К., Бубиш Ш., Аскарова Ш.К.
Күмiс нанобөлшектерiнiң бұршақ, лимон, мандарин, авокадо тұқымдарының
өнуiне әсерi.....320

Қуртебаева А.А., Álvarez-Torrellas S., Gomes Н.Т., Орынбаев С.Ә., Калмаханова М.С. Алаңдаушылық тудыратын ластаушы заттарды тиімді жою үшін белсендірілген көмір полимерлі мембраналар.....	334
Масенова А.Т., Жұмақанова А.С., Торлопов И.И., Рахметова К.С., Абильмагжанов А.З. ZSM-5 иерархиялық цеолитін бумен сілтілі модификациялау арқылы алу процесін онтайландыру.....	350
Мутушев А.Ж., Нұралы Ә.М., Санат А.С., Шаукарова М.А., Есимситова З.Б. Жарық түрлендіретін пленкалардың биоактивті қосылыстардың жинақталуына және жеміс сапасына әсері.....	366
Нефедов А.Н., Тайекенова А.Т. Мұнай өңдеу өнеркәсібінде органикалық коррозия ингибиторларын қолданудың қазіргі жағдайы.....	379
Омаров Б.Т., Алтыбаев Ж.М., Серикбаева Б.С. Органикалық қалдықтарды вермикомпостинг арқылы биогумус өндіру және оның агроэкологиялық тиімділігін зерттеу.....	399
Рахман Д.М., Қаппасұлы Ә., Махаева Д.Н., Қазыбаева Д.С., Ирмухаметова Ғ.С. Геллан–цистеин кешендері негізінде мукоадгезиялық гидрогельдерді әзірлеу және зерттеу.....	414
Сабыржанова А.Е., Болатқызы Н., Берганаева Г.Е., Дюсебаева М.А. Plantago Major жер үсті бөлігінің құрамындағы амин қышқылдары мен май қышқылдарын зерттеу.....	428
Сатаева С., Ахметова Ф., Уразова А., Айтуганова С., Ерниязова К. ЭД-20 эпоксидті желімдерінің физика-механикалық және эксплуатациялық қасиеттеріне ПЭПА концентрациясының ықпалы.....	439
Заманбек А.Ж., Кошкарбаева Ш.Т., Сатаев М.С. Күміс нанобөлшектерінің алыну әдістері мен антибактериалдық қасиеттері.....	450
Жоргарова А.А., Салькева Л.К., Минаева Е.В., Ибраев М.К., Фазылов С.Д. Фосфоносірке қышқылының эфирін синтездеу мен фосфорландырудың жаңа мүмкіндіктері.....	462

СОДЕРЖАНИЕ

ФИЗИКА

Аймаганбетова З.К., Кулшымбаев Е.А., Жантурина Н.Н., Бекетова Г.К. Расчет по первому принципу электронных свойств двойного галогенидного перовскита Cs ₂ Ag _{0.2} Na _{0.4} In _{0.6} Ti _{0.4} Cl ₆ на основе программы Quantum Espresso.....	14
Амангелдинова С., Жүнісхан С., Калжигитов Н., Курмангалиева В. Исследование кластерной структуры зеркальных ядер ⁵ He и ⁵ Li в двухкластерном приближении.....	35
Чокин К., Отунчи Е., Кожаметова А., Касенова А., Шонгалова А. Разработка и испытания лабораторной пирометаллургической установки для переработки литий-ионных аккумуляторов.....	46
Исаева А.Б., Бейсебаева А.С., Мадыбекова Г.М., Шиназбекова Ш.С., Иса А.Б. Сравнительный анализ физико-химических характеристик питьевой, родниковой и природной воды юга Казахстана.....	65
Ким В.Ю., Аймуратов Е.К. Поиск транзиентных космических событий методом сканирования неба широкоугольными телескопами.....	78
Коштыбаев Т.Б., Татенов А.М., Алиева М.Е., Тугелбаева Г.Т., Жаналиева Г.Ж. Исследование электромагнитного поля на основе термодинамических принципов.....	89
Мукамеденкызы В., Акбердиев Б. Численное исследование влияния угла наклона на устойчивость механического равновесия в бинарной газовой смеси Ar–N ₂	105
Мясникова Л.Н., Узакбаева С.С., Шанина З.К., Бекешев А.З. Кинетические свойства высокоплотного полиэтилена с добавлением хром-шпинельного порошка.....	119
Нурбаев Б.М., Дмитриева Е.А., Кемелбекова А.Е. Роль низкоразмерных слоистых структур в повышении стабильности перовскитных материалов на основе олова.....	136
Саттинова З., Ермаханова Ф., Асылбеков Б., Таймуратова Л. Влияние различных условий охлаждения и коэффициентов теплопередачи на затвердевание при формировании бериллиевых керамических изделий.....	149

Шестакова Л.И., Серебрянский А.В., Спасюк Р.Р., Омаров Ш.Т. Поиск газа кометно-метеорного происхождения во внутренней области Солнечной Системы: Свечение ионов СаII.....	165
Уалиханова У.А., Турсынказы Ф., Сыздыкова А.М., Алтаева Г.С., Алтайбаева А.Б. Изучение амплитуды $f(T)$ гравитационных волн с использованием функций Бесселя.....	179
Жексенбаева Г.А., Насирова Д.М., Айманова Г.К., Шомшекеева С.А. Фотометрическое исследование симбиотического объекта V725 Tau.....	194
Жусупова Н.К., Жадыранова А.А. Космология отскока в $f(T, \mathcal{J})$ гравитации на основе анализа энергетических условий.....	205
Зиятбекова Г.З., Абдимананова П.Б., Сағынтай О.А., Нұрым А.А., Ильинов Р.А. Использование искусственного интеллекта для прогнозирования заболеваний на основе медицинских данных.....	225

ХИМИЯ

Алмассов Н.Ж., Жумагалиева А.Н., Дуйсенбеков С.Е., Жакиев Н.К. Проектирование и оптимизация гибридных возобновляемых источников энергии для производства водорода в Казахстане.....	236
Амангелді Б., Жаникулов Н., Таймасов Б., Айтуреев М., Даулетияров М. Расчёт состава сырьевой шихты для получения белого порландцементного клинкера.....	251
Башов А., Ташенов Е.А., Атыханова С.Б., Кошкарбаева Ш.Т. Получение сульфида кадмия электрохимическим методом с использованием композитного сера-графитового электрода.....	267
Байсалова Г.Ж., Ажиханова Ж., Талтенов А.А., Кужатова П. Определение суммы фенольных соединений в многолетних травянистых растениях флоры Казахстана.....	277
Дарменбаева А.С., Rajasekharan R., Жусиппазарова Г.М., Мукажанова Ж.Б., Бегенова Б.Е. Композиты на основе хитозана и целлюлозы: синтез, свойства и перспективы применения.....	287
Еркасов Р.Ш., Жамкенова А.С., Сергазина С.М., Нурмуханбетова Н.Н., Касенова Н.Б. Влияние галогена на энергетику и природу водородных связей в Mn(II): QTAIM, NCI и энергодекомпозиция.....	304

Калимолдина Л.М., Шаихова Ж.Е., Калиева Б.К., Бубиш Ш., Аскарова Ш.К. Влияние наночастиц серебра на прорастание семян фасоли, лимона, мандарина, авокадо.....	320
Куртебаева А.А., Álvarez-Torrellas S., Gomes Н.Т., Орынбаев С.А., Калмаханова М.С. Полимерные мембраны с активированным углем для эффективного удаления загрязняющих веществ вызывающих обеспокоенность.....	334
Масенова А.Т., Жұмақанова А.С., Торлопов И.И., Рахметова К.С., Абильмагжанов А.З. Оптимизация процесса получения иерархического цеолита ZSM-5 паровой щелочной модификацией.....	350
Мутушев А.Ж., Нуралы А.М., Санат А.С., Шаукарова М.А., Есимсиитова З.Б. Влияние светопреобразующих плёнок на накопление биоактивных соединений и качество плодов.....	366
Нефедов А.Н., Тайекенова А.Т. Современное состояние применения органических ингибиторов коррозии в нефтепереработке.....	379
Омаров Б.Т., Алтыбаев Ж.М., Серикбаева Б.С. Получение биогумуса путем вермикомпостирования органических отходов и исследование его агроэкологической эффективности.....	399
Рахман Д.М., Қаппасұлы Ә., Махаева Д.Н., Казыбаева Д.С., Ирмухаметова Г.С. Разработка и исследование мукоадгезивных гидрогелей на основе комплексов геллан–цистеин.....	414
Сабыржанова А.Е., Болаткызы Н., Берганаева Г.Е., Дюсебаева М.А. Исследование аминокислот и жирных кислот в составе надземной части <i>Plantago Major</i>	428
Сатаева С., Ахметова Ф., Уразова А., Айтуганова С., Ерниязова К. Влияние концентрации ПЭПА на физические, механические и эксплуатационные свойства эпоксидных клеев ЭД-20.....	439
Заманбек А.Ж., Кошкарбаева Ш.Т., Сатаев М.С. Методы получения наночастиц серебра и антибактериальные свойства.....	450
Жоргарова А.А., Салькева Л.К., Минаева Е.В., Ибраев М.К., Фазылов С.Д. Новые возможности синтеза и фосфорилирования фосфонуксусного эфира.....	462

ACADEMIC JOURNAL
OF PHYSICAL AND CHEMICAL SCIENCES
ISSN 2224-5227
Volume 1.
Number 357 (2026), 334–349

<https://doi.org/10.32014/2026.2518-1483.424>

UDC: 628.16:66.095.26:541.183

IRSTI: 31.15.37

©Kurtebayeva A.A.¹, Álvarez-Torrellas S.², Gomes H.T.³, Orynbayev S.A.¹,
Kalmakhanova M.S.^{1*}, 2026.

¹M.Kh. Dulaty Taraz University, Taraz, Kazakhstan;

²Complutense University, Madrid, Spain;

³CIMO, LA SusTEC, Instituto Politécnico de Bragança, Bragança, Portugal.

*E-mail: marjanseitovna@mail.ru

ACTIVATED-CARBON-ENHANCED POLYMERIC MEMBRANES FOR EFFICIENT ELIMINATION OF EMERGING CONTAMINANTS

Kurtebayeva Assel — PhD student, M.Kh. Dulaty Taraz University, Taraz, Kazakhstan,

E-mail: d.a.kurtebayeva@dulaty.kz, <https://orcid.org/0000-0002-1975-0755>;

Álvarez-Torrellas Silvia — PhD, Associate Professor, Complutense University, Madrid, Spain,

E-mail: satorrellas@ucm.es, <https://orcid.org/0000-0003-0916-6122>;

Helder Teixeira Gomes — PhD, Associate Professor, CIMO, LA SusTEC, Instituto Politécnico de Bragança, Bragança, Portugal,

E-mail: htgomes@ipb.pt, <https://orcid.org/0000-0001-6898-2408>;

Orynbayev Seitzhan — PhD, L.N. M.Kh. Dulaty Taraz University, Taraz, Kazakhstan,

E-mail: sa.orynbayev@dulaty.kz, <https://orcid.org/0000-0002-5077-7219>;

Kalmakhanova Marzhan — PhD, Associate Professor, M.Kh. Dulaty Taraz University, Taraz, Kazakhstan,

E-mail: marjanseitovna@mail.ru, <https://orcid.org/0000-0002-8635-463X>.

Abstract. The removal of contaminants of emerging concern (CECs) from wastewater remains one of the key challenges in water treatment, especially in countries with limited water resources and partially outdated infrastructure, including Kazakhstan. This study investigates polymeric membranes based on polyvinylidene fluoride (PVDF) modified with activated carbon of plant origin (AC-CN) to assess their structural characteristics and potential for further use in the removal of organic pollutants. AC-CN activated carbon was characterized by BET, SEM and FT-IR methods, which showed a developed microporous structure ($S_{\text{BET}} = 462 \text{ m}^2 \cdot \text{g}^{-1}$) and the presence of oxygen-containing functional groups. The membranes were formed by phase inversion using distilled water and a 70/30 ratio of distilled water and isopropanol, respectively, as a coagulation bath. Under continuous-flow conditions ($C_0 = 10 \text{ mg/L}$, flow 0.5 mL/min, pH - 6.8), PVDF membranes loaded with AC-CN showed markedly different performance depending on the coagulation bath: the water-coagulated AC-CN membrane removed 13.8% of paracetamol and 40.9% of 4-nitrophenol, whereas the H₂O/IPA (70:30)-coagulated AC-



CN-IPA membrane achieved substantially higher paracetamol removal (60–64% at 60 min) and an initial 4-nitrophenol removal of 37.7% with sustained retention of 33.0% to 21.7% over 20–60 min. All measurements were performed in triplicate ($n = 3$) and are reported as mean; the relative standard deviation did not exceed 1%, indicating good repeatability of the analytical method. These findings indicate that coagulation bath composition critically controls membrane morphology and access to AC-CN sorption sites, supporting further optimization of these materials for sustainable wastewater treatment.

Keywords: membranes, activated carbons, adsorption; paracetamol, 4-nitrophenol

Financing. *This research has been supported by the Funding Program of the Republic of Kazakhstan by the Ministry of Higher Education and Science (grant BR24992867) and by Base Funding of CIMO (UIDB/00690/2020) through FEDER under Program PT2020. Also, the Spanish MICINN has funded this work through CATAD3.0 (PID2020-116478RB-100) and QUATerval (PID2023-150365OB-100) research projects.*

For citations: Kurtebayeva A.A., Alvarez-Torrellas S., Gomes H.T., Orynbayev S.A., Kalmakhanova M.S. *Activated-Carbon-Enhanced Polymeric Membranes for Efficient Elimination of Emerging Contaminants. Academic Journal of Physical and Chemical Sciences.* 2026. No.1. Pp. 334–349. DOI: <https://doi.org/10.32014/2026.2518-1483.424>

©Куртебаева А.А.¹, Álvarez-Torrellas S.², Gomes H.T.³, Орынбаев С.Ә.¹,
Калмаханова М.С.^{1*}, 2026.

¹М.Х. Дулати атындағы Тараз университеті, Тараз, Қазақстан;

²Комплутенсе Мадрид университеті, Мадрид, Испания;

³СИМО, Браганса политехникалық институты, Браганса, Португалия.

*E-mail: marjanseitovna@mail.ru

АЛАНДАУШЫЛЫҚ ТУДЫРАТЫН ЛАСТАУШЫ ЗАТТАРДЫ ТИІМДІ ЖОЮ ҮШІН БЕЛСЕНДІРІЛГЕН КӨМІР ПОЛИМЕРЛІ МЕМБРАНАЛАР

Куртебаева Асель — PhD докторант, М.Х. Дулати атындағы Тараз университеті, Тараз, Қазақстан,
E-mail: d.a.kurtebayeva@dulaty.kz, <https://orcid.org/0000-0002-1975-0755>;

Álvarez-Torrellas Silvia — PhD, қауымдастырылған профессор, Комплутенсе Мадрид университеті,
Мадрид, Испания,

E-mail: satorrellas@ucm.es, <https://orcid.org/0000-0003-0916-6122>;

Helder Teixeira Gomes — PhD, қауымдастырылған профессор, Браганса политехникалық институты,
Браганса, Португалия,

E-mail: htgomes@ipb.pt, <https://orcid.org/0000-0001-6898-2408>;

Орынбаев Сейтжан — PhD, М.Х. Дулати атындағы Тараз университеті, Тараз, Қазақстан,

E-mail: sa.orynbayev@dulaty.kz, <https://orcid.org/0000-0002-5077-7219>;

Калмаханова Маржан — PhD, қауымдастырылған профессор, М.Х. Дулати атындағы Тараз университеті, Тараз, Қазақстан,

E-mail: marjanseitovna@mail.ru, <https://orcid.org/0000-0002-8635-463X>.

Аннотация. Ағынды сулардан ерекше алаңдаушылық тудыратын ластанушы заттарды (CECs) шығару, әсіресе су ресурстары шектеулі және ішінара ескірген инфрақұрылымы бар елдерде, соның ішінде Қазақстанда суды тазарту саласындағы негізгі міндеттердің бірі болып қала береді. Бұл зерттеу олардың құрылымдық сипаттамаларын және органикалық ластанушы заттарды жоюда одан әрі пайдалану әлеуетін бағалау мақсатында өсімдік тектес белсендірілген көмірмен (AC-CN) толтырылған поливинилиденфторид (PVDF) негізіндегі полимерлі мембраналарды зерттейді. Белсендірілген AC-CN көмірі BET, SEM және FT-IR әдістерімен сипатталды, олар дамыған микро-кеуекті құрылымды ($S_{\text{BET}}=462\text{ м}^2\cdot\text{г}^{-1}$) және құрамында оттегі бар функционалды топтардың болуын көрсетті. Мембраналар дистилденген суды және коагуляциялық ванна ретінде 70/30 дистилденген су мен изопропанол қоспасын пайдаланып фазалық инверсия арқылы түзілді. Үздіксіз ағын жағдайында ($c = 10$ мг/л, ағын жылдамдығы 0,5 мл/мин, pH - 6,8) AC-CN жүктелген PVDF мембраналары коагуляциялық ваннаға байланысты айтарлықтай әртүрлі сипаттамаларды көрсетті: сумен коагуляцияланған AC-CN мембранасы 13,8% парацетамолды және 40,9% 4-нитрофенол, ал $\text{H}_2\text{O}/\text{IPA}$ (70:30) коагуляцияланған AC-CN мембранасы парацетамолды (60 минут ішінде 60-64%) және 37,7% 4-нитрофенолды 20-60 минут ішінде тұрақты ұстаумен 33,0% -дан 21,7% дейін жойып тастады. Барлық өлшемдер үш рет орындалды ($n = 3$) және орташа мәндер ретінде ұсынылды; салыстырмалы стандартты ауытқу 1% - дан аспады, бұл аналитикалық әдістің жақсы қайталануын көрсетеді. Бұл нәтижелер коагуляциялық ваннаның құрамы мембрананың морфологиясына және AC-CN сорбциялық орындарына қол жеткізуге сыни әсер ететінін көрсетеді, бұл ағынды суларды тұрақты тазарту үшін осы материалдарды одан әрі оңтайландырудың орындылығын растайды.

Түйін сөздер: мембраналар, белсендірілген көмір, адсорбция, парацетамол, 4-нитрофенол

©Куртебаева А.А.¹, Álvarez-Torrellas S.², Gomes Н.Т.³, Орынбаев С.А.¹,
Калмаханова М.С.^{1*}, 2026.

¹Таразский университет имени М.Х. Дулати, Тараз, Казахстан;

²Мадридский университет Комплутенсе, Мадрид, Испания;

³Политехнический институт Браганса, Браганса, Португалия.

*E-mail: marjanseitovna@mail.ru

ПОЛИМЕРНЫЕ МЕМБРАНЫ С АКТИВИРОВАННЫМ УГЛЕМ ДЛЯ ЭФФЕКТИВНОГО УДАЛЕНИЯ ЗАГРЯЗНЯЮЩИХ ВЕЩЕСТВ ВЫЗЫВАЮЩИХ ОБЕСПОКЕННОСТЬ

Куртебаева Асель — PhD студент, Таразский университет имени М.Х. Дулати, Тараз, Казахстан,
E-mail: d.a.kurtebayeva@dulaty.kz, <https://orcid.org/0000-0002-1975-0755>;

Álvarez-Torrellas Silvia — PhD, ассоциированный профессор, Мадридский университет
Комплутенсе, Мадрид, Испания,

E-mail: satorrellas@ucm.es, <https://orcid.org/0000-0003-0916-6122>;



Helder Teixeira Gomes — PhD, ассоциированный профессор, Политехнический институт Браганса, Браганса, Португалия,

E-mail: htgomes@ipb.pt, <https://orcid.org/0000-0001-6898-2408>;

Орынбаев Сейтжан — PhD, Таразский университет имени М.Х. Дулати, Тараз, Казахстан,

E-mail: sa.orynbayev@dulaty.kz, <https://orcid.org/0000-0002-5077-7219>;

Калмаханова Маржан — PhD, ассоциированный профессор, Таразский университет имени М.Х. Дулати, Тараз, Казахстан,

E-mail: marjanseitovna@mail.ru, <https://orcid.org/0000-0002-8635-463X>.

Аннотация. Удаление загрязняющих веществ, вызывающих особую озабоченность (СЕС), из сточных вод остается одной из ключевых задач в области водоочистки, особенно в странах с ограниченными водными ресурсами и частично устаревшей инфраструктурой, включая Казахстан. В данном исследовании рассматриваются полимерные мембраны на основе поливинилиденфторида (PVDF), модифицированные активированным углем растительного происхождения (АС-CN), с целью оценки их структурных характеристик и потенциала для последующего применения при удалении органических загрязняющих веществ. Активированный уголь АС-CN был охарактеризован методами BET, SEM и FT-IR, которые показали развитую микропористую структуру ($S_{\text{BET}} = 462 \text{ м}^2/\text{г}$) и наличие кислородсодержащих функциональных групп. Мембраны формировали методом фазовой инверсии с использованием в качестве коагуляционной ванны дистиллированной воды, а также смеси дистиллированной воды и изопропанола в соотношении 70/30. В условиях непрерывного потока ($C_0 = 10 \text{ мг/л}$, расход 0,5 мл/мин, $\text{pH} \approx 6,8$) мембраны из PVDF, модифицированные АС-CN, продемонстрировали заметные различия в характеристиках в зависимости от состава коагуляционной ванны. Так, мембрана АС-CN, коагулированная в воде, обеспечила удаление 13,8 % парацетамола и 40,9 % 4-нитрофенола, тогда как мембрана АС-CN, коагулированная в системе $\text{H}_2\text{O}/\text{IPA}$ (70:30), показала значительно более высокую степень удаления парацетамола (60–64 % за 60 мин) и 37,7 % 4-нитрофенола при устойчивом удерживании в диапазоне от 33,0 до 21,7 % в течение 20–60 мин. Все измерения были выполнены в трех повторностях ($n = 3$) и представлены в виде средних значений; относительное стандартное отклонение не превышало 1 %, что свидетельствует о хорошей воспроизводимости аналитического метода. Полученные результаты указывают на то, что состав коагуляционной ванны оказывает критическое влияние на морфологию мембраны и доступность сорбционных центров АС-CN, что подтверждает целесообразность дальнейшей оптимизации данных материалов для устойчивой очистки сточных вод.

Ключевые слова: мембраны, активированный уголь, адсорбция, парацетамол, 4-нитрофенол

Introduction. Wastewater treatment is a critical environmental and public health issue, drawing increasing attention to advanced technologies for removing contaminants of concern (CECs). Like many countries, Kazakhstan faces the need to modernise its wastewater treatment networks and implement innovative solutions due

to outdated infrastructure and growing requirements for the quality of discharged water (Kalmakhanova et al., 2025).

Currently, Kazakhstan mainly relies on traditional wastewater treatment methods, such as mechanical and biological processes (e.g. activated sludge systems and sedimentation tanks). Many of these facilities were built decades ago and are experiencing problems related to equipment wear and tear, changes in the composition and volume of incoming wastewater, and a lack of investment in modernisation. These factors lead to reduced treatment efficiency and increased environmental risks, particularly in large cities such as Almaty (Ospanov et al., 2022). More modern solutions are also being adopted in practice, such as the use of electrical discharges to neutralise and remove heavy metals at industrial sites, and sedimentation and suspension bioreactors for small treatment plants (Abdykadyrov et al., 2025). However, large-scale implementation of these innovations is limited by economic and infrastructural barriers (Bekenova et al., 2024).

Literature review. There has been a global shift towards advanced and hybrid technological solutions to combat water scarcity, recover resources and remove persistent pollutants. Membrane-based processes such as ultrafiltration, nanofiltration and reverse osmosis, combined with adsorption, are becoming increasingly popular due to their high efficiency and selectivity, and their potential for water reuse (Álvarez-Torrellas S. et al., 2016). Patent analysis indicates a trend away from individual technological units towards integrated systems that combine physical, chemical and biological approaches, emphasising automation and energy efficiency (Mao et al., 2021). Combinations of membrane bioreactors, advanced oxidation processes and adsorption are recognised as being particularly effective in removing CEC (Ahmed et al., 2022).

Polymeric membranes modified with activated carbon (AC) show great promise for the comprehensive removal of organic and inorganic pollutants. Incorporating AC into the polymer membrane matrix enhances hydrophilicity, sorption capacity and selectivity towards micro- and nano-pollutants, while reducing pore clogging and facilitating flow recovery (Arabloo and Javadpour, 2025; Moraes et al., 2023). These hybrid structures have been shown to perform well in the removal of heavy metals, phenolic compounds and CECs, with some studies reporting removal efficiencies of over 90% for individual compounds (Sherugar et al., 2022; Moraes et al., 2023).

Combined systems that use membrane filtration alongside activated carbon adsorption and other methods, such as ultrasound and photocatalysis, can achieve almost complete removal of pharmaceutical compounds and other persistent CECs (Secondes et al., 2014). Activated carbon is still one of the most effective adsorbents thanks to its large surface area and the fact that it can be modified; using adsorbents derived from agricultural waste makes solutions more sustainable and cost-effective (Ntone et al., 2025).

This study presents a novel approach to developing polymeric membranes for efficient contaminant removal by incorporating biomass-derived activated carbon (AC-CN). The scientific novelty lies in:

- Investigating the critical role of coagulation bath composition (distilled water

vs. H₂O/IPA mixture) in controlling the membrane's porous structure and surface properties, directly impacting the accessibility of activated carbon's sorption sites.

- Establishing a direct link between membrane fabrication parameters, resulting morphology, and adsorption performance for model emerging contaminants (paracetamol and 4-nitrophenol).

- Demonstrating significantly improved and sustained removal efficiencies for paracetamol and 4-nitrophenol using AC-CN-modified PVDF membranes coagulated in an H₂O/IPA bath, showcasing their potential for advanced wastewater treatment applications.

- This research differentiates itself by not only synthesizing and characterizing AC-CN but also by systematically evaluating the influence of the membrane formation process on overall contaminant removal efficiency, offering a more holistic understanding for designing advanced filtration materials.

Materials and methods. *Materials.* Paracetamol, also known as acetaminophen (PCM, $\geq 99\%$), and acetonitrile (HPLC grading, $\geq 99.9\%$) were purchased from Sigma-Aldrich (Merck KGaA, Germany) and used without further purification. Polyvinylpyrrolidone (PVP; MW: 40,000 g mol⁻¹), 1-methyl-2-pyrrolidone (NMP; 99.5 wt.%) and poly(vinylidene fluoride) (PVDF; MW: 275,000 g mol⁻¹), from Sigma-Aldrich, were used for membrane fabrication.

All chemicals were of analytical or chromatographic purity and were used directly in working solutions.

Methods for obtaining activated carbon as a filler for polymeric membranes. The synthesis of the activated carbons was adapted from the work of F. Bibi et al. (2023), as described elsewhere. In this study, agro-industrial waste such as corn cobs was used as the raw material. To obtain activated carbon, the raw material was thoroughly washed with ultrapure water and then pre-carbonised at 450 °C in a vertical furnace under a nitrogen flow of 0.2 mL/min. The material was pre-washed with a diluted HCl solution to remove residual non-carbon impurities. It was then activated by impregnation with an acid solution (HNO₃) of a specified concentration. Finally, the material was washed with ultrapure water until a neutral pH was achieved in the washing water. The carbonisation process was then carried out at 600°C under the same N₂ flow rate (0.2 ml/min) as during pre-carbonisation. (See Figure 1.) The material was labelled AC-CN: the first letter denotes the precursor. C: *corn cob*; and the second letter indicates the activating agent used: N: *HNO₃*.



Figure 1 - Scheme of the procedure of the activated carbons preparation

(I - Biomass (corn cob), II - Pre-carbonization in a nitrogen atmosphere (oven) at 450 °C, III - Acid wash (HCl) with heating,

IV - Activation step (impregnation/activation using a shaker), V - Rinse with ultrapure water, VI - Drying, VII - Final activated carbon material obtained)

Methods for preparing polymeric membranes. To prepare the membranes, 1.3 g of PVP, 11.5 mL of NMP and 2.5 g of activated carbon (AC-CN) were sequentially added to the solution and dispersed in an ultrasonic bath for 3 hours until a homogeneous suspension was obtained. Then, 1.25 g of PVDC was added and stirred on a magnetic stirrer at 40°C and 200 rpm for 48 hours. After that, the solution was left overnight at room temperature without external influence for degassing and stabilization. The prepared solution was applied to a glass substrate and spread with a precision applicator with a blade thickness of 300 µm, after which the membrane was subjected to coagulation (Ribeiro R.S. et al, 2022). In the first variant, coagulation was carried out in ultrapure water, and the resulting sample was designated as AC-CN_membrane. In the second variant, a coagulation bath containing a mixture of ultrapure water and isopropanol in a ratio of 70/30 was used; after exposure for 20 minutes, the membrane was transferred to fresh ultrapure water and left overnight. This sample was designated AC-CN_IPA and further stored in ultrapure water at 3 °C (Wang Y., et al., 2020). Figure 2 shows the membrane preparation process in detail.

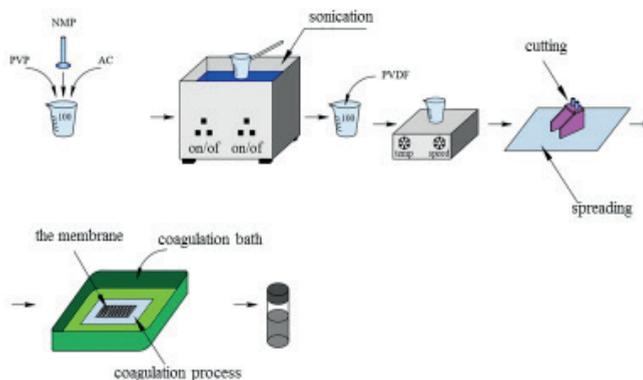


Figure 2 - Scheme of the membrane preparation process

Polymeric mixed matrix membranes in a continuous system. To evaluate the effectiveness of the obtained membrane in removing contaminants, a reactor containing the membranes (AC-CN_membrane and AC-CN_IPA) was connected to a peristaltic pump to create a continuous system. The following conditions were used to conduct the experiment: The contaminant (paracetamol) at a concentration of 10 mg/L was connected to the pump at a flow rate of 0.5 mL/min. This fed the contaminant through the reactor inlet, passing it through the polymeric membrane installed in the reactor (see Figure 3). Samples (2 ml) were taken at 0, 3, 6, 10, 20, 30, 40, 50, 60, 70, 80, 90, 100, 110 and 120 minutes during filtration. All measurements were performed in triplicate ($n = 3$) and reported as mean standard deviation. The filtered samples were analysed by HPLC and UV spectrophotometry. The samples were then centrifuged and filtered through 0.45 µm nylon membrane filters before being analysed using a JASCO High-Performance Liquid Chromatograph equipped with a UV-4575 detector. Separation was performed using an Inertsil ODS-3 column (250 × 4.6 mm, 5 µm). The mobile phase

consisted of acetonitrile and ultrapure water (45:55 v/v) adjusted to pH 2.5. The flow rate was maintained at 1.0 mL/min and detection was carried out at 254 nm.

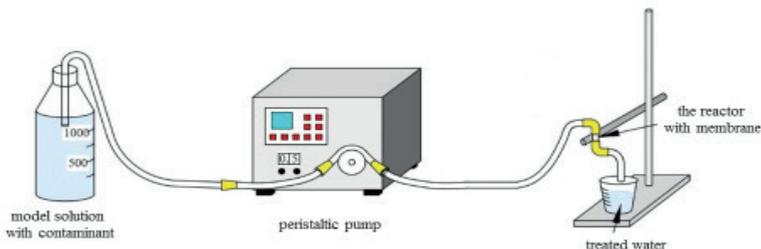


Figure 3 - Experimental set-up for adsorption tests using membrane materials

Equations (1) and (2) were used to process the results.

$$residue\% = \frac{C_{in} \cdot 100\%}{C_{exp}} \tag{1}$$

$$purified\% = 100\% - residue\% \tag{2}$$

where, residue% - is the unadsorbed residue in the solution; purified% - is the purified result, C_{in} - is the initial concentration of the model solution, C_{exp} - is the experimental data of the model solution during the experiments.

Results and discussions. *Material characteristics.* Of the synthesised carbons, the AC-CN membrane matrix showed the most promising characteristics, combining the highest specific surface area (according to BET analysis) with the best adsorption capacity for PCM (20.26 mg/g). Consequently, it was chosen for membrane fabrication.

Table 1 - Textural properties of the synthesized activated carbons.

Material	S_{BET} (m ² /g)	V_{Total} (cm ³ /g)	V_{micro} (cm ³ /g)	V_{meso} (cm ³ /g)	V_{micro}/V_{Total}	d_{pore} (Å)
AC-CN	462	0.224	0.182	0.042	0.81	19.4

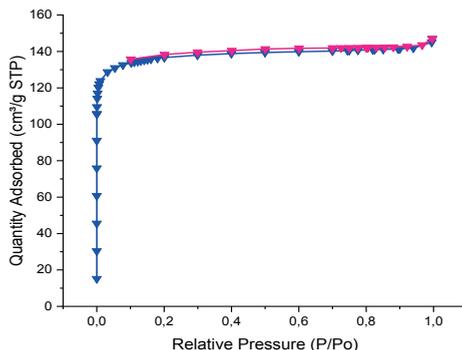


Figure 4 - N₂ adsorption-desorption isotherms at 77K of the activated carbon obtained from corncob (AC-CN).

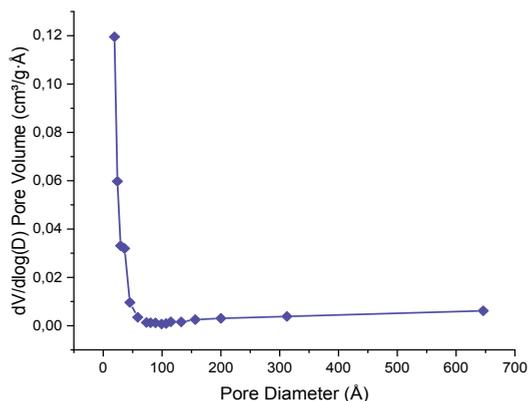


Figure 5 - Pores size distributions of the activated carbon obtained from corncob (AC-CN).

AC-CN exhibits a clearly pronounced microporous structure with a high specific surface area. SBET is approximately $462\ 462\ \text{m}^2\cdot\text{g}^{-1}$ and the total pore volume is approximately $0.224\ \text{cm}^3\cdot\text{g}^{-1}$. The micropore volume is approximately $0.182\ \text{cm}^3\cdot\text{g}^{-1}$, corresponding to a microporosity fraction is approximately $0,182\ \text{cm}^3\cdot\text{g}^{-1}$, of the total pore volume. The average effective pore size is calculated to be $\approx 19.4\ \text{\AA}$ ($\approx 1.94\ \text{nm}$). These parameters indicate the predominance of micropores and the presence of a narrow mesopore contribution (see Figures 4 and 5). The adsorption isotherm in Figure 4 is of Type I, which is characteristic of microporous solids. However, because the theoretical assumptions underlying the Brunauer–Emmett–Teller (BET) model are not fully met for strictly microporous materials, the reported BET surface area must be considered an apparent value. Rigorous assessment of microporosity and pore size distribution therefore requires complementary analyses. Chemical activation (KOH , H_3PO_4 , ZnCl_2) and process parameters (temperature, time and impregnation coefficient) play a key role in forming textural characteristics (Sousa et al., 2022; Bedane et al., 2023). The composition of the starting precursor (e.g. cellulose, hemicellulose, lignin and ash content) also significantly influences the development of the porous structure and the final properties of the activated carbon (AC) (Santos et al., 2020).

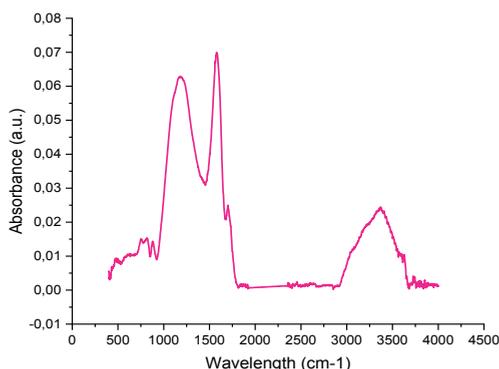


Figure 6 - FT-IR spectra of the synthesized activated carbon prepared from corncob (AC-CN).

The FT-IR spectrum of AC-CN shows the presence of several key functional groups that form the surface chemistry of activated carbon: a broad band in the region of $\sim 3400\text{ cm}^{-1}$, corresponding to $\nu(\text{O-H})$ (hydroxyl/adsorbed water molecules); bands in the region of $\sim 1700\text{--}1650\text{ cm}^{-1}$, associated with carbonyl $\nu(\text{C=O})$; bands $\sim 1200\text{--}1000\text{ cm}^{-1}$, indicating $\nu(\text{C-O})$ of ether/phenolic groups; as well as characteristic bands of aromatic C=C in the region of $\sim 1600\text{ cm}^{-1}$ (Figure 6). This combination of oxygen-containing functional groups and aromatic structure is typical for chemically activated biochar and determines a polar, slightly acidic surface with the possibility of multiple types of intermolecular interactions (Țucureanu et al., 2016).

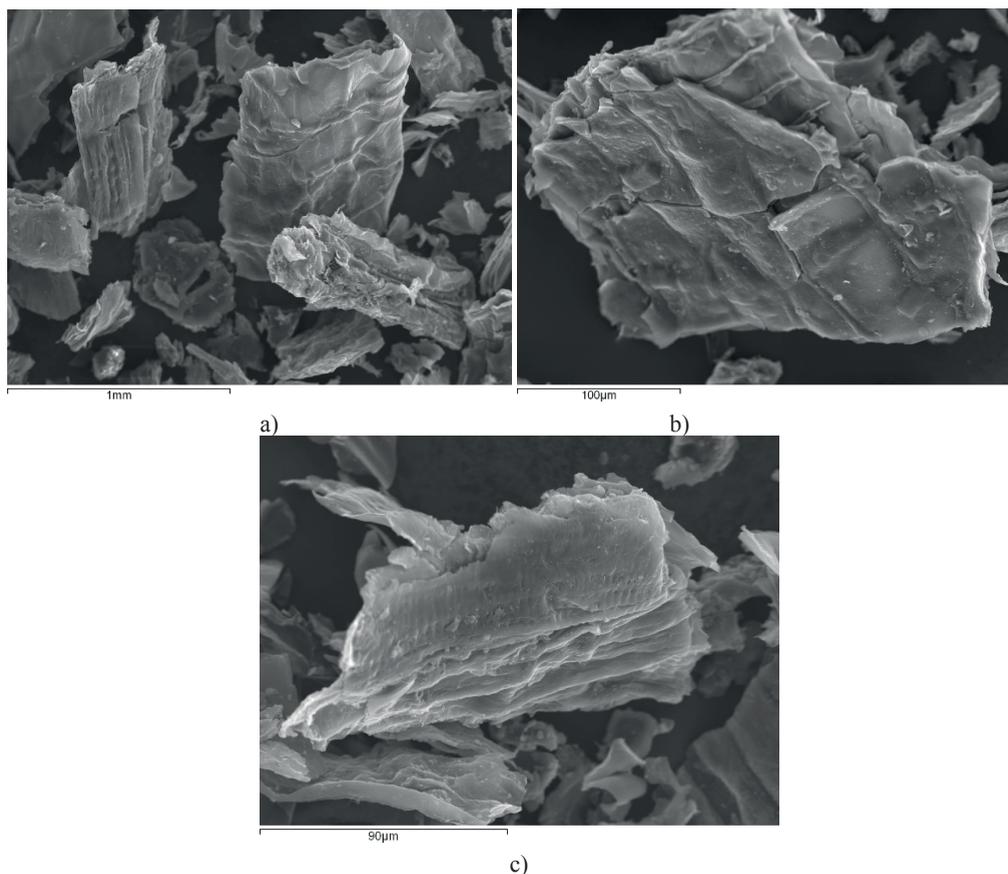


Figure 7 - SEM micrographs of the synthesized activated carbons from corncob (AC-CN) a) x250, b) x370 c) x600.

SEM images of AC-CN powder show a rough, highly textured particle surface: irregularities, cellular structures and local depressions/cracks are visible. Such a surface is typical for activated materials with pronounced microporosity and enlarged external irregularities, which provide additional external surface area. The images (Figure 7) also show thin 'plates' and microcracks, which can occur during carbonization/activation and indicate the layered nature of the original precursor (Portillo E., et al, 2025).

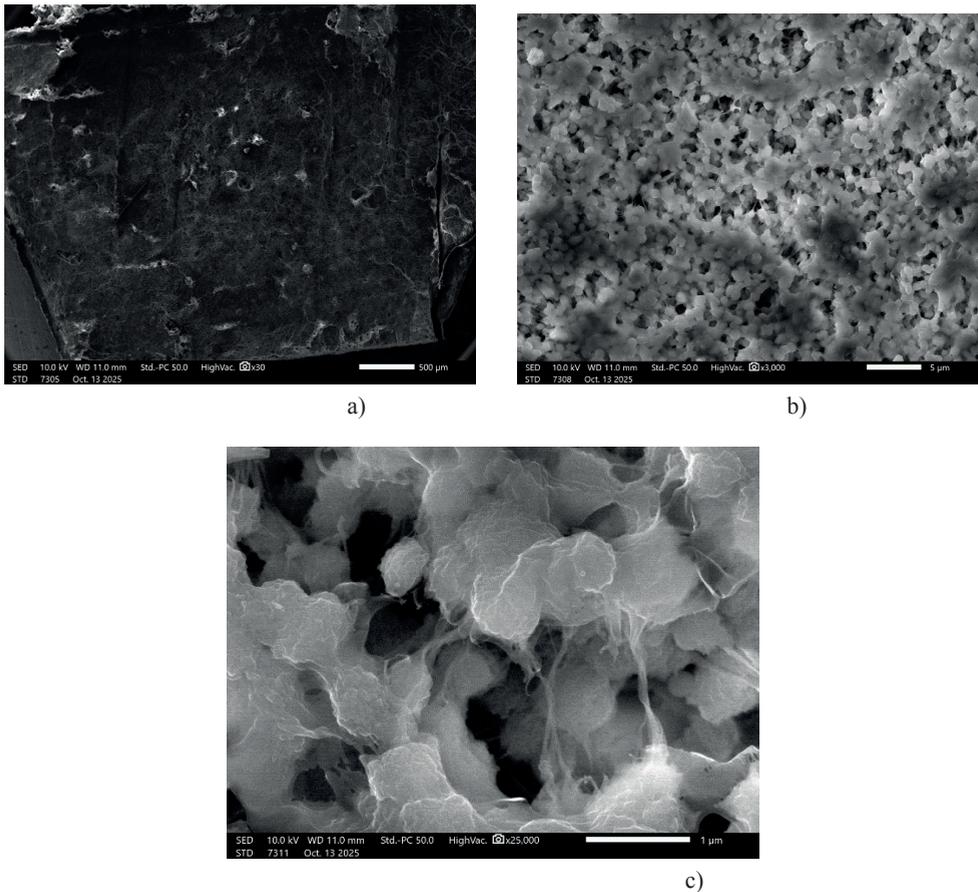


Figure 8 - SEM micrographs of the synthesized membranes with AC matrix (AC-CN_membrane) a) x30, b) x3000 c) x2500.

Scanning electron microscope (SEM) images of the water-coagulated membrane demonstrate the typical morphology of rapid phase separation: a dense 'skin crust' on the surface and a more porous sub-threshold layer. The surface is relatively smooth with isolated irregularities and rare protrusions, indicating the onset of surface sealing during coagulation. Cross-sections clearly show the contrast between the thin, dense surface film and the porous sub-layer. The pores under the crust are often narrow and partially closed, which indicates limited connectivity of the pore network on the surface (Ribeiro R. S. et al., 2022; Y. Wang et al., 2020).

The distribution of AC-CN particles in the matrix is heterogeneous; both uniformly encapsulated particles in close contact with the polymer and local agglomerates are present. At low magnification (Figure 8a), the textured outer surface can be seen, which is caused by the irregular external surfaces of the carbon particles and the peculiarities of phase inversion. At higher magnifications (Figures 8b and 8c), fine cracks and micron-sized depressions typical of carbon particles after heat treatment and the carbonisation of the raw material are visible.

Polymeric mixed matrix membranes in a continuous system. The synthesised AC-CN filler demonstrated a high specific surface area ($S_{\text{BET}} \approx 462 \text{ m}^2/\text{g}$) and significant adsorption capacities in powder form ($\text{PCM} \approx 20.26 \text{ mg/g}$), which justified its selection for the preparation of mixed membrane matrices. However, the transfer of the powder's adsorption properties to the membrane structure was limited — when testing a circular section of the membrane (area 2.10 cm^2), the total percentage removal of paracetamol was low ($\approx 13.8\%$), which indicates the limited availability of activated carbon mass in the section involved in the experiment. The results for adsorption of paracetamol and 4-nitrophenol with the AC-CN membrane are presented in Figures 9 and 10.

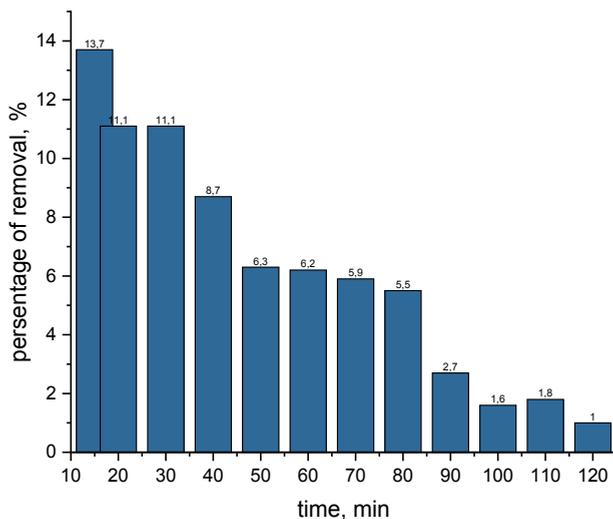


Figure 9 - Continuous experiments with AC-CN membrane for paracetamol adsorption
Conditions: $C_0 = 10 \text{ mg/L}$, flow = 0.5 mL/min , pH = 6.8, T= room temperature.

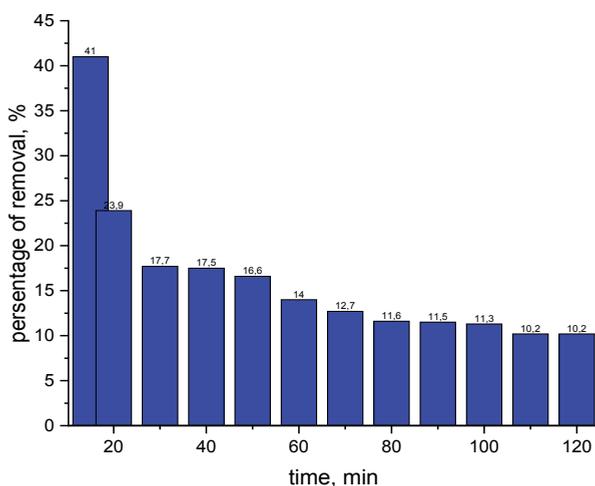


Figure 10 - Continuous experiments with AC-CN membrane for 4-nitrophenol adsorption
Conditions: $C_0 = 10 \text{ mg/L}$, flow = 0.5 mL/min , pH = 6.8, T= room temperature.

The results for adsorption paracetamol and 4-nitrophenol with AC-CN_IPA are presented in Figures 11 and 12.

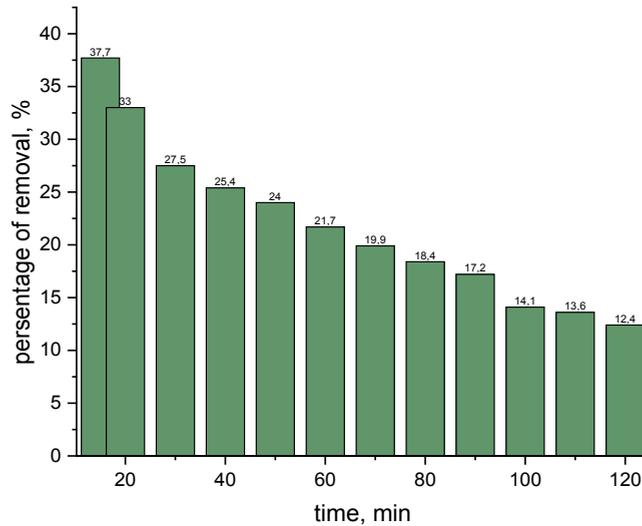


Figure 11 - Continuous experiments with AC-CN_IPA for 4-nitrophenol adsorption
Conditions: $C_0 = 10$ mg/L, flow = 0.5 mL/min, pH = 6.8, T= room temperature.

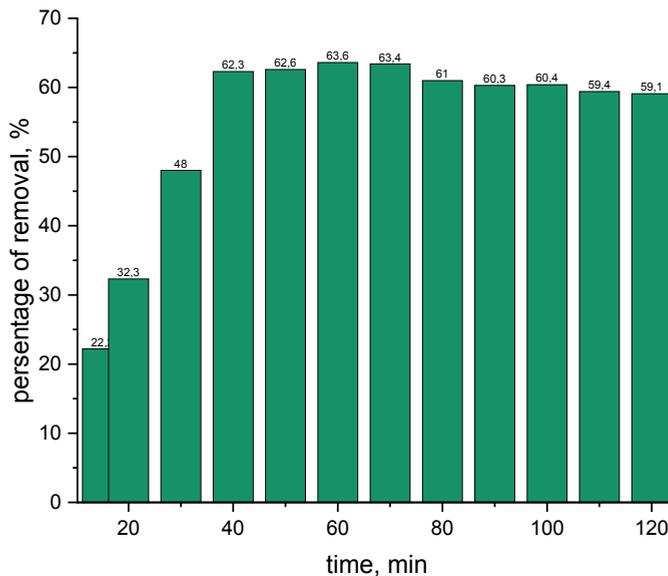


Figure 12 - Continuous experiments with AC-CN_IPA for paracetamol adsorption
Conditions: $C_0 = 10$ mg/L, flow = 0.5 mL/min, pH = 6.8, T= room temperature

A comparison of the two coagulation modes revealed a significant influence of the bath composition on the adsorption kinetics. Figures 10 and 11 show that in the first 15 minutes, the sample coagulated in water (AC-CN_membrane) showed a slightly

higher initial removal ‘spike’ ($\approx 40.9\%$ vs. 37.7% for AC-CN_IPA), while in the 20–60 min interval, the membrane formed in H₂O/IPA (70:30) showed a stable advantage in contaminant retention (approximately $33.0 \rightarrow 21.7\%$), whereas the values for water coagulation fell faster ($\approx 23.8 \rightarrow 14.0\%$) (Moraes E., et al., 2023). A similar trend was observed for paracetamol adsorption (Figures 9 and 12): although the membrane coagulated in water (Figure 9) exhibited a limited overall removal ($\approx 13.8\%$), the AC-CN-IPA membrane (Figure 12) showed a markedly improved and more stable performance, with a rapid increase in removal efficiency during the first 40–60 minutes and a plateau around 60–64% under continuous-flow conditions. This behaviour indicates that the presence of IPA in the coagulation bath enhances the effective utilisation of the carbon filler within the polymeric matrix, promoting sustained access to sorption sites even for a less strongly interacting compound such as paracetamol. This dynamic is consistent with the fact that the composition of the coagulation bath determines the morphology and pore structure of the membrane: an IPA-containing bath likely forms a more porous and open network or improves the exposure of the active centres of the carbon filler, increasing the long-term availability of sorption sites, whereas rapid coagulation in water can lead to the formation of a dense surface crust with limited internal diffusion (Wang Y. et al., 2020).

The relative standard deviation (RSD) of measurements did not exceed $\approx 1\%$ and varied within approximately 0.6–1.0%, indicating good repeatability of the analytical method.

The difference in behaviour towards paracetamol and 4-nitrophenol highlights the role of the chemical nature of the contaminant: 4-nitrophenol, containing a hydroxyl group, exhibits more favourable interactions with the activated carbon surface (hydrogen bonds, π - π interactions), which explains the observed differences in adsorption between the two pollutant models.

Conclusion. This work successfully synthesised PVDF polymeric membranes modified with AC-CN activated carbon. The validated textural characteristics of these membranes ($S_{\text{BET}} = 462 \text{ m}^2 \cdot \text{g}^{-1}$, $V_{\text{micro}} = 0.182 \text{ cm}^3 \cdot \text{g}^{-1}$, micropore fraction = 81%) confirm their substantial sorption potential. The phase inversion process employing distinct coagulation baths yielded membranes with different morphologies: coagulation in distilled water produced a denser surface that limited contaminant access, whereas the H₂O/IPA (70:30) system fostered greater porosity and permeability. These structural differences directly impacted sorption efficiencies. Notably, the water-coagulated membrane exhibited minimal paracetamol removal (approximately 13.8%), whereas the AC-CN-IPA membrane achieved significantly higher and more stable paracetamol capture (approximately 60–64% within 60 minutes), suggesting improved pore accessibility. For 4-nitrophenol, the initial removal differences (40.9% vs 37.7%) were less pronounced than the sustained retention observed for the AC-CN_IPA membrane (33.0% to 21.7% over 20–60 minutes), indicating a more robust interaction. These results definitively demonstrate that the composition of the coagulation baths plays a critical role in controlling membrane morphology and consequently the accessibility of AC-CN sorption sites. Furthermore, the chemical nature of the contaminant plays

a differential role: 4-nitrophenol appears to engage in more favourable specific interactions with carbon fillers, whereas paracetamol removal is more sensitive to pore access. This study confirms the influence of coagulation bath composition on membrane structure–property relationships and validates the potential of PVDF/AC-CN composite membranes for effectively removing diverse organic pollutants, offering a promising approach to sustainable water treatment. Future research should focus on optimising these parameters further and exploring their efficacy against a broader spectrum of CECs.

References

- Abdykadyrov A., Abdullayev S., Kuttybayeva A., Marxuly S., Izbaïrova A., Altayeva Z. & Ermanova D. (2025). Wastewater treatment technologies using electrical discharge after processing of mineral raw materials. *Mining of Mineral Deposits*. <https://doi.org/10.33271/mining19.02.121> (in Eng.).
- Adetunji A., & Olaniran A. (2021). Treatment of industrial oily wastewater by advanced technologies: a review. *Applied Water Science*, 11. <https://doi.org/10.1007/s13201-021-01430-4> (in Eng.).
- Ahmed M., Mavukkandy M., Giwa A., Elektorowicz M., Katsou E., Khelifi O., Naddeo V., & Hasan S. (2022). Recent developments in hazardous pollutants removal from wastewater and water reuse within a circular economy. *npj Clean Water*, 5. <https://doi.org/10.1038/s41545-022-00154-5> (in Eng.).
- Álvarez-Torrellas S., Rodríguez A., Ovejero G., García J. Comparative adsorption performance of ibuprofen and tetracycline from aqueous solution by carbonaceous materials. *Chemical Engineering Journal*. – № 283 (2016). – P. 936–947. <http://dx.doi.org/10.1016/j.cej.2015.08.023> (in Eng.).
- Arabloo F. and Javadpour S. (2025). Optimization of PES-based Hollow fiber membranes incorporating MgO-modified activated carbon via response surface methodology for enhanced pure water permeability. *Scientific reports*, 151, 30044. <https://doi.org/10.1038/s41598-025-15140-3> (in Eng.).
- Bedane A., Guo T., Shirani B., and Xiao H. (2023). Textural characteristics of activated carbons prepared from agricultural residues – review. *The Canadian Journal of Chemical Engineering*. <https://doi.org/10.1002/cjce.24960> (in Eng.).
- Bekenova L., Shtykova I. and Kuzmina N. (2024). Application of innovative technologies in the field of wastewater treatment: foreign and kazakhstani experience. *Statistika, učet i audit*. <https://doi.org/10.51579/1563-2415.2024.-3.14>. (in Eng.).
- Bibi F., Hussain R., Iqbal N., Saeed S., Waseem M., Elkaeed E.B., Al-Anazy M.M., Haq S., Chemical activation and magnetization of onion waste derived carbon for arsenic removal, *Arab. J. Chem.* – № 16 (2023). – P. 105118. <https://doi.org/10.1016/j.arabj.2023.105118> (in Eng.).
- Kalmakhanova M.S., Kurtebayeva A.A., Tleuova Z.T., Satybaldiev B., Orynbayev S.A., Malakar A., Gomes H.T., Snow D.D. Environmental Impact of Wastewater on Surface and Groundwater in Central Asia. *Sustainability 2025*. – № 17. – P. 5370. <https://doi.org/10.3390/su17125370> (in Eng.).
- Mao G., Han Y., Liu X., Crittenden J., Huang N., and Ahmad U. (2021). Technology status and trends of industrial wastewater treatment: A patent analysis. *Chemosphere*, 132483. <https://doi.org/10.1016/j.chemosphere.2021.132483> (in Eng.).
- Moraes E., Da Silva A., De Tuesta J., Silva A., Orssatto F., and Gomes H. (2023). Production of Polymeric Membranes Based on Activated Carbons for Wastewater Treatment. *The 4th International Electronic Conference on Applied Sciences*. <https://doi.org/10.3390/asec2023-16874> (in Eng.).
- Ntone E., Samah R., Wahab M., Alsahy Q. and Rahman S. (2025). Review of PPCPs remediation in Asia: the role of agricultural waste in adsorption-membrane hybrid technology. *Chemical Engineering Communications*, 212. – P. 1132 - 1166. <https://doi.org/10.1080/00986445.2024.2447843> (in Eng.).
- Ospanov K., Kuldeyev E., Kenzhaliyev B. and Korotunov A. (2022). Wastewater Treatment Methods and Sewage Treatment Facilities in Almaty, Kazakhstan. *Journal of Ecological Engineering*. <https://doi.org/10.12911/22998993/143939> (in Eng.).
- Portillo E., Flores S., Carrizosa R., Álvarez-Torrellas S., Carbajo J., Águeda V.I., García J., Sustainable adsorbents from sewage sludge: Efficient removal of cytostatic compounds in single and complex aqueous matrices, *J. Environ. Chem. Eng.* – № 13 (2025). – P. 116927. <https://doi.org/10.1016/j.jece.2025.116927> (in Eng.).

Rui S. Ribeiro, Octavia Vieira, Rita Fernandes, Fernanda F. Roman, Jose L. Diaz de Tuesta, Adrian M.T. Silva, Helder T. Gomes. Synthesis of low-density polyethylene derived carbon nanotubes for activation of persulfate and degradation of water organic micropollutants in continuous mode. *Journal of Environmental Management*. – № 308 (2022). – P. 114622. <https://doi.org/10.1016/j.jenvman.2022.114622> (in Eng.).

Santos M., Silva J., Fontan R., Bonomo R., Santos L. and Veloso C. (2020). New insight about the relationship between the main characteristics of precursor materials and activated carbon properties using multivariate analysis. *Canadian Journal of Chemical Engineering*, 98. – P. 1501-1511. <https://doi.org/10.1002/cjce.23721> (in Eng.).

Secondes M., Naddeo V., Belgiorno V. and Ballesteros F. (2014). Removal of emerging contaminants by simultaneous application of membrane ultrafiltration, activated carbon adsorption, and ultrasound irradiation. *Journal of hazardous materials*, 264. – P. 342-349. <https://doi.org/10.1016/j.jhazmat.2013.11.039> (in Eng.).

Sousa É., Otero M., Rocha L., Gil M., Ferreira P., Esteves V. and Calisto V. (2022). Multivariable optimization of activated carbon production from microwave pyrolysis of brewery wastes - Application in the removal of antibiotics from water. *Journal of hazardous materials*, 431, 128556. <https://doi.org/10.1016/j.jhazmat.2022.128556> (in Eng.).

Țucureanu V., Matei A., Avram A.M., FTIR Spectroscopy for Carbon Family Study, *Crit. Rev. Anal. Chem.* 46 (2016). – P. 502-520. <https://doi.org/10.1080/10408347.2016.1157013> (in Eng.).

Yang Wanga, Gui-E Chena, Hai-Ling Wua, Zhen-Liang Xub, Jia-Jun Wana, Lian-Jing Liua, Sun-Jie Xub, Ya-Fang Konga, Qiong Wua, Jun Mina, Hai-Fang Maoa. Fabrication of GO-Ag/PVDF/F127 modified membrane IPA coagulation bath for catalytic reduction of 4-nitrophenol. *Separation and Purification Technology*. – № 235 (2020). – P. 116143. <https://doi.org/10.1016/j.seppur.2019.116143> (in Eng.).

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.

Правила оформления статьи для публикации в журнале смотреть на сайте:

www.nauka-nanrk.kz

ISSN 2518-1483 (Online), ISSN 2224-5227 (Print)

<http://reports-science.kz/index.php/en/archive>

Ответственный редактор *А. Ботанқызы*

Редакторы: *Д.С. Аленов, Т. Апендиев*

Верстка на компьютере *Г.Д. Жадырановой*

Подписано в печать 16.03.2026.

Формат 60x88¹/₈.

18,0 п.л. Заказ 1.