

Brief information about the project

Name of the project	IRN AP25794605 “Removal of mercury ions from wastewater using a composite membrane based on MXene and nanocellulose”
Relevance	The proposed study presents a synergistic approach that simultaneously addresses solid waste management and wastewater treatment, contributing to economic sustainability and circular economy principles. The scientific innovation lies in utilizing rice husk as a cellulose-rich source for the fabrication of an advanced composite membrane. The membrane, consisting of a nanocellulose-based matrix and a 2D MXene phase as a diffusion component, is designed for the efficient removal of mercury ions (Hg^{2+}) from contaminated water.
Purpose	The aim of the research project is to design and develop an advanced composite membrane for the highly efficient removal of mercury ions from contaminated water sources. The project focuses on two key aspects: the extraction of nanocellulose from rice husk as an agricultural by-product serving as a sustainable membrane matrix, and the strategic integration of MXene materials to enhance the structural and adsorption properties of the membrane.
Objectives	Within the research project, the following objectives are defined to ensure a comprehensive understanding of the synthesis, characterization, and optimization of MXene–nanocellulose composite membranes for efficient mercury ion removal during water treatment: - Extraction of nanocellulose from rice husk: - Investigation of various experimental conditions for obtaining nanocellulose from rice husk, including acid hydrolysis and enzymatic processes. - Optimization of parameters such as temperature, reaction time, and reagent concentration to enhance yield and quality of nanocellulose. - Synthesis of MXene from MAX phase: - Investigation of MXene synthesis from MAX phases based on transition metal carbides or nitrides. - Study of etching conditions, including etchant selection, etching time, and temperature, to achieve optimal MXene properties. - Integration of nanocellulose and MXene for composite membrane fabrication: - Development of a methodology for integrating nanocellulose and MXene to form a composite membrane. - Optimization of the nanocellulose-to-MXene ratio to achieve a balance between structural integrity and adsorption capacity. - Water purification experiments for mercury ion removal: - Conducting water treatment experiments using MXene/nanocellulose composite membranes, focusing on mercury ion concentrations in the range of 5–50 mg/L.

	- Investigation of separation conditions, including pressure, pH, membrane thickness, and MXene loading (0.5–2 wt%), and their influence on mercury removal efficiency. 5. Optimization of experimental parameters: - Systematic optimization of experimental parameters based on membrane performance in mercury ion removal. - Evaluation and adjustment of conditions such as pressure, pH, and MXene loading to enhance membrane efficiency. 6. Reusability cycles of the optimized composite membrane: - Evaluation of the stability and reusability of the optimized membrane over multiple water treatment cycles. - Investigation of flux stability, structural integrity, and adsorption capacity to ensure long-term operational performance.
Expected and achieved results	These studies are aimed at obtaining fundamental data and demonstrating the exceptional adsorption capacity of MXene toward hazardous mercury ions in aqueous environments. The project also focuses on developing an optimized method for fabricating MXene–nanocellulose composite membranes through detailed investigation of membrane thickness and MXene nanosheet loading ratios. The proposed cost-effective and efficient method for mercury ion removal, serving as an alternative to existing technologies, has significant potential for patent applications. - The synthesized material is of considerable importance across various industries, from metallurgical chemistry to pharmaceuticals, where effective removal of mercury and other heavy metals from wastewater is essential for process optimization and sustainability. - The research results are expected to be widely applied in Kazakhstan for wastewater treatment and water purification, contributing to environmental remediation and the valorization of large volumes of rice husk. - The socio-economic impact will be twofold: firstly, contributing to the general goal of preventing/reducing wastewater pollution and enhancing the value of industrial waste; secondly, creating new opportunities for the modernization of rice husk processing and wastewater treatment sectors in Kazakhstan. Publications in peer-reviewed international scientific journals During the project implementation, publications are planned in peer-reviewed international and domestic journals recommended by the Science Committee of the Ministry of Science and Higher Education of the Republic of Kazakhstan. The required number of publications will be determined by the конкурсная documentation. Each

	publication will include the project identification number (IRN) and acknowledgment of the grant funding source. Target journals include: • <i>Science of the Total Environment</i> (Elsevier, Q1, percentile 95) • <i>Journal of Environmental Management</i> (Elsevier, Q1, percentile 96) • <i>Journal of Cleaner Production</i> (Elsevier, Q1, percentile 99) • <i>Molecules</i> (MDPI, Q1, percentile 78) • <i>International Journal of Molecular Sciences</i> (MDPI, Q1, percentile 87) • <i>Journal of Molecular Liquids</i> (Elsevier, Q1, percentile 92) as well as other journals meeting the competition requirements: • at least 2 publications and/or review papers in peer-reviewed journals ranked within the top 3 quartiles in <i>Web of Science</i> and/or with a CiteScore percentile of at least 50 in <i>Scopus</i>.
Research team members with their identifiers (Scopus Author ID, Researcher ID, ORCID, if available) and links to relevant profiles	Madina Suleimenova Master of Chemical Technology, PhD H-index: 0 ORCID: https://orcid.org/0000-0001-9113-1687 Scopus Author ID: 58235548000
Usage	The research results are intended for application in wastewater treatment, particularly for the efficient adsorption of heavy metal ions (Hg^{2+}) and organic dyes (methylene blue). The proposed nanocomposite membranes are suitable for use in environmentally friendly water purification technologies.
Priority compared to real-world alternatives	The proposed MXene–nanocellulose-based composite membranes exhibit several advantages over conventional adsorbents and membrane materials. In particular, they demonstrate high adsorption capacity, especially for the efficient removal of heavy metal ions (Hg^{2+}) and organic dyes (methylene blue). In addition, the membranes show excellent mechanical strength, chemical stability, and reusability. The synergistic interaction between MXene and nanocellulose enhances the permeability and selectivity of the material. Therefore, the proposed materials outperform current state-of-the-art analogues in water purification in terms of efficiency and offer strong potential for practical applications.
List of publications with links to them	1. Suleimenova M, Zharylkan S. Mekenova M, Mutushev A. Azat S, Tolepova A, Baimenov A, Satayeva A, Tauanov Z. Fusion-assisted Hydrothermal Synthesis of Technogenic Waste Derived Zeolites and Nanocomposites: Synthesis, Characterization, and Mercury (II) Adsorption. Sustainability MDPI journal. <i>Engineered Science</i> Accepted https://doi.org/10.3390/ijms241411317

	2. Zharylkan S., Sultakhan S., Suleimenova M., Azat S., Sailaukhanuly Y., Tulepov M., Tauanov Z. Enhanced Adsorption of Mercury and Methylene Blue Using Silver and Surface Modified Zeolite-NaX derived from Rice Husk. <i>Engineered Science</i> (accepted for publication 2024) https://doi.org/10.30919/es1241 3. Сулейменова М., Жарылкан С., Мекенова М., Толепова А., Мутушев А., Азат С., Тауанов Ж. «Получение синтетического цеолита и нанокompозита из рисовой шелухи для удаления ионов ртути из воды». Химический бюллетень Вестник КазНУ, рекомендуемый КОКСНВО МОН РК, 2023. Издательство 2-3, том 109. https://doi.org/10.15328/cb1323 4. Suleimenova M., Tabynbayeva A., Toshtay K., Tauanov Zh. Composite Membranes Based on MXene and Nanocellulose for Water Purification: Structure, Efficiency, and Future Prospects // <i>Membranes</i>. – 2025. – Vol. 15, Issue 10, Article 293. DOI: https://doi.org/10.3390/membranes15100293
Patents	-