Brief information about the program

Program Name	BR18574219 Development of environmentally safe technologies for obtaining innovative products from natural and raw materials of Kazakhstan
Relevance	Kazakhstan possesses significant reserves of rare metals but lacks enterprises specifically for rare metal raw materials. During the Soviet era, several rare metals were produced at Kazakhstan's non-ferrous metallurgy enterprises. The revival of the rare metal industry should become the driving force of the mining and processing industries. The involvement of rare metal deposits, along with industrial products and waste from various productions, into industrial processing will be a breakthrough direction in the technological development of the Republic of Kazakhstan. As is known, modern technologies, which form the foundation of an innovative economy, are based on high product quality, energy and material savings, and environmental safety of processes. Supercritical fluid technologies (SCFT), which are based on simple reagents such as carbon dioxide, water, etc., are large-scale productions covering many industrial sectors. Every year, several million tons of plant raw materials are processed worldwide using CO2. It is CO2 that has found the most widespread use as an extractant in SCFE processes due to its inertness, non-toxicity, and affordability. From 2018 to 2020, the Target Program "Green Technologies Based on Supercritical Media" was successfully implemented at CPCMRA. The current project of the Program is its continuation and provides for the comprehensive processing of raw materials, semi-finished products, and technogenic waste containing valuable components using SCFT; the development of environmentally safe technologies for producing special-purpose metals and alloys.
Goal	Comprehensive processing of raw materials, semi-finished products, and technogenic waste containing valuable components using supercritical fluid technologies (SCFT). Development of environmentally safe technologies for obtaining special-purpose metals and alloys.
Objectives	Develop and certify new methods for analyzing rare and rare-earth metals and their impurities in state authorities; Develop scientific foundations for the technology of obtaining rare-earth metal concentrates; Develop technologies for the associated extraction of rare elements from mother liquors of the technological cycle of mining enterprises of JSC "NAC "KazAtomProm"; Obtain individual metals from collective REE extracts isolated from technogenic waste and natural raw materials using SCFE methods; Develop technologies for obtaining high-purity Hg, Zn, Cu, In; Create a technology for producing precision titanium alloys with ultrafine-grained structures using rare and rare-earth metals; Develop a universal high-efficiency flow reactor with an original catalyst for the production of biodiesel fuel.

Expected and Achieved Results	As a result of the Program's implementation, the following outcomes specified in Technical Specification No. 26 for the competition will be achieved: - New methods for analyzing rare and rare-earth metals and their impurities will be developed and certified in state authorities; - SCF technologies for the comprehensive processing of natural (Kundybay deposit) and technogenic (phosphogypsum dumps of LLP "Kazphosphate") raw materials with the extraction of a number of rare and rare-earth metals will be developed; - A technology for the associated extraction of rare elements from mother liquors of the technological cycle of mining enterprises of JSC "NAC "KazAtomProm" will be developed; - Methods for obtaining high-purity Hg, Zn, Cu, In will be created; - Technologies for producing precision titanium alloys with ultrafine-grained structures using certain rare and rare-earth metals will be developed; - A universal high-efficiency flow reactor with an original catalyst for the production of biodiesel fuel will be developed; - At least 5 (five) articles and/or reviews will be published in peer-reviewed scientific journals in the scientific field of the program, included in the 1st, 2nd, or 3rd quartiles of the Web of Science database and/or with a CiteScore percentile of at least 50 in the Scopus database; as well as 5 (five) articles in journals recommended by SHEQAC; - At least 3 patent applications for utility models and/or inventions will be submitted. **The following results were obtained for 2023–2024:** 1. New methods for analyzing rare and rare-earth metals and their impurities were developed and certified in state authorities. Methods for analyzing pure mercury, indium, and zinc were developed, and standards for the necessary analysis methods were obtained. 2. SCF technologies and technological schemes for the comprehensive processing of natural (Kundybay deposit) and technogenic (phosphogypsum dumps of LLP "Kazphosphate") raw materials with the extraction of rare and rare-earth metals were developed. Optimal modes for extracting REE extracts from natural and technogenic raw materials under SC-CO2 conditions were determined. A concentrate with a Ce content of 80% was obtained by oxidizing Ce (III) to Ce (IV) followed by precipitation. 3. A technology for the associated extraction of rare elements from mother liquors of the technological cycle of mining enterprises of JSC "NAC "KazAtomProm" was developed. The parameters of the extraction concentration of rhenium with trialkylamine modified by decyl alcohol dissolved in a hydrocarbon mixture were studied. The fundamental possibility of obtaining crude ammonium perrhenate by processing rhenium-containing nitrate desorbate through extraction and conducting the process in two stages was established. Crude ammonium perrhenate with a rhenium content of 67.4% was obtained. 4. Methods for obtaining high-purity Hg, Zn, Cu, In were created. An electrolyzer for obtaining pure mercury was designed. A semi-industrial

	batch of mercury weighing 18.87 kg with a purity of 99.999% was produced. An electrolyzer for obtaining indium and zinc was manufactured. The process mode was worked out, and indium and zinc with a purity of 99.9999% were obtained. A method for reducing copper (II) ions to elemental ultradispersed copper was developed. The influence of the main electrolysis parameters on the chemical composition and dispersion of copper powders was determined. It was shown that in the presence of titanium (IV) ions and under alternating current polarization, more finely dispersed powders are formed. A method for obtaining copper sulfide was developed, protected by a RK patent for an invention. 5. Technologies for producing precision titanium alloys with ultrafine-grained structures using certain rare and rare-earth metals were developed. The alloy structure after superplastic deformation represents a dispersed mixture of equiaxed grains of alpha and beta phases. The optimal temperature-strain rate modes for 0Zr and 0.5Zr alloys were identified. The results allow for the recommendation of optimal deformation modes ensuring maximum mechanical properties and material stability. 6. A universal high-efficiency flow reactor with an original catalyst for the production of biodiesel fuel was developed. Original catalysts for biodiesel fuel production were created, and the technology for biodiesel fuel production in a continuous-flow supercritical installation was optimized, allowing for biodiesel fuel meeting the EN14214 standard, with a maximum yield of fatty acid esters of ~90–94%. 7. Four articles were published in peer-reviewed scientific journals in the scientific field of the program, included in the 1st, 2nd, or 3rd quartiles of the Web of Science database and/or with a CiteScore percentile of at least 50 in the Scopus database; as well as 7 articles in journals recommended by SHEQAC; 5 patents for utility models and/or inventions were obtained.

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Author ID, Researcher ID, ORCID, if available) and links to relevant profiles	6781-6464 Scopus ID: 6506602038 https://www.scopus.com/authid/detail.uri?authorId=6506602038 2. Tokpayev Rustam Rishatovich, PhD, Corresponding Member of KazNAEN Hirsch Index – 5 (Scopus). Author ID in Scopus – 56998810900 https://www.scopus.com/authid/detail.uri?authorId=56998810900 Researcher ID Web of Science D-3859-2015 https://www.webofscience.com/wos/author/record/440647 ORCID ID 0000-0002-0117-4454 https://orcid.org/0000-0002-0117-4454 3. Galeeva Alina Kulbaevna, PhD, Associate Professor Hirsch Index – 6 (Scopus). ResearcherID Web of Science: A-8292-2015 https://www.webofscience.com/wos/author/record/1099919 ORCID: 0000-0001-9303-5277 https://orcid.org/0000-0001-9303-5277 Scopus ID: 56436524000 https://www.scopus.com/authid/detail.uri?authorId=56436524000 4. Baeshova Azhar Kospanovna, Doctor of Technical Sciences, Professor Hirsch Index – 3 (WoS). ResearcherID Web of Science: A-8794-2015 https://www.webofscience.com/wos/author/record/1749768,5185356,41861088 ORCID: https://orcid.org/0000-0002-9076-8130, Scopus Author ID: 56177619400. https://www.scopus.com/authid/detail.uri?authorId=56177619400 5. Atchabarova Azhar Aidarovna, PhD Hirsch Index – 5 (Scopus). ResearcherID Web of Science: D-3857-2015 https://www.webofscience.com/wos/author/record/1355961,46719493,53537705 ORCID: 0000-0002-4600-2728 https://orcid.org/0000-0002-4600-2728 Scopus ID: 56998822600 https://www.scopus.com/authid/detail.uri?authorId=56998822600 6. Avchukir Khaisa, PhD Hirsch Index – 4 (Scopus). ResearcherID Web of Science: P-5738-2017 https://www.webofscience.com/wos/author/record/1708940,28914729 ORCID: 0000-0001-6612-0775 https://orcid.org/0000-001-6612-0775 Scopus ID: 57207207777 https://www.scopus.com/authid/detail.uri?authorId=57207207777 7. Kishibayev Kanagat Kazhmukhanovich, PhD Hirsch Index – 5 (Scopus). Author ID in Scopus – 56604294100 https://www.scopus.com/authid/detail.uri?authorId=56604294100 Researcher ID Web of Science C-7678-2015 https://www.webofscience.com/wos/author/record/715617,53609035 ORCID ID 0000-0003-1590-5243 https://orcid.org/0000-0003-1590-5243 8. Shapovalov Yuriy Alexandrovich, higher education, Doctor of Technical Sciences, Academician of KazNAEN Hirsch Index – 1 (Scopus). Author ID in Scopus – 57216613061 https://www.scopus.com/authid/detail.uri?authorId=57216613061 Researcher ID Web of Science DYN-3210-2022 https://www.webofscience.com/wos/author/record/16073613 ORCID ID 0000-0002-4107-1636 https://orcid.org/0000-0002-4107-1636 9. Zlobina Elena Viktorovna, Ph.D. Hirsch Index - 1 (Scopus). Scopus ID: 41262845500 https://www.scopus.com/authid/detail.uri?authorId=41262845500 ResearcherID Web of Science: A-5782-2015 https://www.webofscience.com/wos/author/record/1395894 10. Ismailova Akmaral Gazizovna, Ph.D. Hirsch Index - 2 (Scopus). Scopus ID: 57193336562.

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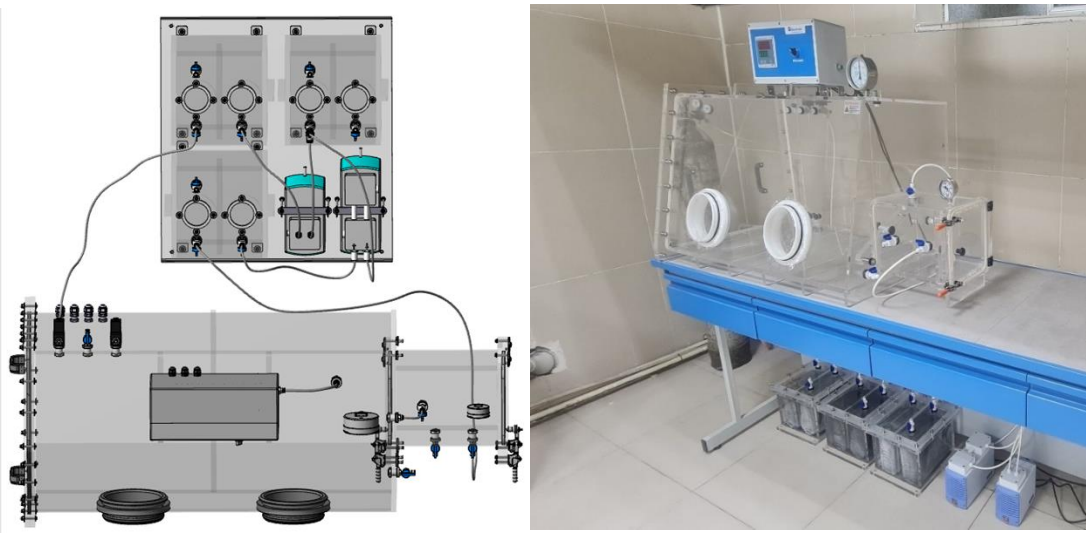

Figure 1 - Developed scheme and installation of hermetic box with purification and regeneration system for obtaining extremely pure Hg, Zn, Cu, In;

Figure 2 - Obtained purified white carbon black (technology of obtaining rare and rare-earth metals and white carbon black from the weathering crust ores of the Kundybay deposit)

Figure 3 - Appearance of the alloy in the cast state (technology for producing precision titanium alloys of ultrafine-grained structure using some rare and rare-earth metals)