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MINING INDUSTRY IN THE COMMONWEALTH OF INDEPENDENT STATES (CIS) COUNTRIES

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DEVELOPMENT OF THE ZANGEZUR COPPER–MOLYBDENUM COMBINE AS A LEADING SEGMENT OF THE MINING INDUSTRY IN ARMENIA

Introduction

Zangezur Copper–Molybdenum Combine (ZCMC) established in 1951 is a backbone of the mining industry in Armenia. Primarily intended to supply the domestic industry with raw materials, it plays a key role in export and economic growth of the country [1]. For many decades, the Company makes a great contribution to the national economy by production of copper and molybdenum which are in high demand both on internal and external markets. The long-term production activities of the Company resulted in accumulation of unique and extensive resources and experience to comprehend various technical and economic aspects of resource management [2–4].

At the present time, the Company uses both conventional ore resources and mine waste accumulated within decades of production. The overall reserves are estimated as 45 Mt of ore with copper content of 0.45% and molybdenum content 0.025%. The annual production output is 35 thousand tons of copper and 1.2 thousand tons of

This research aims at the analysis of economic value of the mineral processing industry in Armenia, with spotlight on the Zangezur Copper–Molybdenum Combine (ZCMC). The analysis integrates economic and ecological aspects, and the strategic role of the mining industry in the national development of Armenia.

The article offers a structural and technological review of activities of ZCMC, including production stages of copper and molybdenum concentrates, mineral processing methods, and volumes of production. Emphasis is laid on contribution made by ZCMC to industrial production (10–15%) and export (25–30%) of Armenia owing to sales of mineral concentrates.

In addition, the socio-economic effects of activities of ZCMC are discussed, including job creation, infrastructure development and integration of local communities.

Keywords: Armenia, mining industry, copper–molybdenum combine, economic effect, sustainability, resource management

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molybdenum, which highlights the value of the Company in the commercial production in Armenia [5]. The introduction of advanced technologies and optimization of resource management allows the Company to increase productivity, decrease expenses and enhance profitability.

The scope of this study also encompasses the international experience, in particular, performance of the Erdenet Mining Corporation in Mongolia, where resources of low-grade ore and mine waste are widely and effectively utilized to prolong service life of mines and improve industrial sustainability [6]. Adaptation of such practices can enable the Zangezur Combine both to build-up production output and solve ecological issues, including management of tailings storages and recycling of water [3, 7].

Literature review

Mineral processing is commonly considered as a key factor of economic sustainability and growth in the countries rich with mineral resources. The world literature emphasizes that focus on high-value-added production rather than on export of raw materials allows economies to gain from long-term economic benefits and to weaken reliance on volatility of global prices [3, 8]. According to Sachs and Warner [9], effective policy in the field of mineral processing contributes to industrial diversification and employment growth. Another important factor of long-term advancement is development of cognitive skills and human capital assets in countries with low and average proceeds for creating a framework for the industrial upgrading [10].

The ecological sustainability yet remains a critical issue. Kumar and Singh [11] highlight that water resources management and utilization of mine tailings are the obligatory conditions of eco-risk reduction. The international organizations, including the World Bank [12] and the European Bank of Reconstruction and Development [13], emphasize that introduction of advanced practices of management improves operational efficiency.

Mining industry plays a pivot role in the context of Armenia. Governmental reports and international financial institutions prove that the leading mining companies are of crucial value for the external commerce and regional growth [14, 15]. The level of economic freedom and regulatory settings also have a direct influence on investment attractiveness of this industrial sector [16]. The social and economic influence of the industry runs far beyond job creation and encompasses local infrastructure, education and public health services, which is proved by implementation of the Extractive Industries Transparency Initiative in Armenia [17].

Methodology

The methodological framework of this research integrates the qualitative and quantitative approaches of comprehensive evaluation of mineral processing practices in Armenia. This research involves a case-study of the Zangezur Copper–Molybdenum Combine as the best representative of the mining sector in the country.

The data were collected from the official publications of the Statistical Committee of the Republic of Armenia [5], corporate reports of ZCMC [1], and from the analysis of the Index of Economic Freedom and macroeconomic indicators of IMF [15, 16].

The analysis integrates three basic areas:

1. Economic evaluation (based on [1, 5]);
2. Technology and production analysis (based on [3, 8]);
3. Socio-ecological evaluation and regulatory policy (based on [14, 17]).

Table 1. Contribution of ZCMC to economy of Armenia (2020–2024) [1, 5]

Indicator	2020	2021	2022	2023	2024
Index of industrial production, %	10–15	10–15	10–15	10–15	10–15
Export index, %	25–30	25–30	25–30	25–30	25–30
Number of employees, people	>4000	>4000	>4000	>4000	>4000
Key export regions	Europe, Asia	Europe, Asia	Europe, Asia	Europe, Asia	Europe, Asia

*Source: compiled by the authors based on annual report of Zangezur Copper–Molybdenum Combine reports in 2022–2023 [17]

Table 2. Economic effectiveness indicators of ZCMC

Indicator	Current	Optimized	Potential change, %
Income, million USD	120	160	+33
Cost, USD/t	4 200	3 800	–10
Profitability, %	18	25	+7
Average labor content, t/man	45	55	+22

Integration of these areas allows displaying the strategic value of the mineral processing industry for the economic development of Armenia with simultaneous disclosure of the current problems and potential paths of sustainable growth.

Results and discussion

The results of the research enable a multi-sided vision of the strategic role of the mineral processing industry in the national economy of Armenia, with focus on the Zangezur Copper–Molybdenum Combine (ZCMC).

Contribution to industry and export. One of the most significant results is the validation of the sustainable role of ZCMC in the industrial system of the country. For the last five years, ZCMC provided 10–15% of the overall commercial production and around 25–30% of the export revenues. The main macroeconomic indicators of the Company’s performance over the period of 2020–2024 are systematized in **Table 1**. It is found that the Company’s contribution acquires a critical value at the times of external economic shocks, when export of the mining industry products becomes the key source of currency supply [15]. On the other hand, the high percentage of raw concentrates in the export structure is reflective of vulnerability of the national economy due to price volatility in the world [1].

Potential to improve efficiency. Preliminary data prove a sufficient resource available at the Company to improve its production efficiency. Owing to introduction of innovative processing technologies and to recycling of mine waste, it is predicted that revenues and profit can grow. The comparative analysis of the current and optimized indicators of efficiency is given in **Table 2**. The use of ore mill tailings can enable an increment in production output by 5–10% without additional expenditures connected with mining operations, and with reduction of ecosystem load [3]. The forecasted benefits of introduction of technological upgrading in mineral processing, improved labor efficiency and recycling of manmade resources include:

Table 3. Environmental challenges of ZCMC [1]

Ecological issue	Description	Potential problems
Water pollution	Discharge of tailings and process water in rivers	Pollution of potable water, damage of water ecosystems
Land degradation	Large-scale mining using opencast method and accumulation of mine waste	Loss of plough land, reduction of biodiversity, aesthetic pollution
Air emission	Dust and particulates during blasting and haulage	Deterioration of air quality, respiratory risks
Waste	Accumulation of tailings at tailings dams	Long-term soil pollution and accident risk at dams

*Source: compiled by the authors based on annual report of Zangezur Copper–Molybdenum Combine reports in 2022–2023 [17]

- an increase in annual receipts from 120 to 160 million USD;
- a decrease in production cost by 10%;
- a rise in profitability from 18 to 25%;
- an increase in productivity of labor by more than 20%, which provides larger production output at the unchanged labor content.

The most promising trend is recycling of manmade resources. Recycling of processing tailings can help increase production without extra spending on mining operations and ensure an increment in production output by 5–10%, which creates an additional economic value and reduces the environmental burden at the same time.

An illustration of efficient handling of such problems is the Erdenet Mining Corporation in Mongolia. Utilization of low-grade ore reserves and mine waste allowed Erdenet to extend the life of the field, to cut expenditures and to ensure production sustainability. Adaptation of such strategies to the conditions of ZCMC opens the way toward sustainable production, improved performance and successive achievement of environmental objectives.

Table 2 illustrates effect of optimized utilization of resources and introduction of advanced technologies on the key economic indicators at ZCMC [1].

Socio-economic effects and technology analysis. ZCMC is the largest employer giving employment to more than 4000 people. The Company’s presence in Kajaran stimulated development of the regional infrastructure [17]. The technology analysis shows that export mainly involves semi-products. The comparison with international standards [7, 8] points at the necessity of investment in high-added-value production.

Technology and production analysis. The technology analysis shows that production process at ZCMC is focused on extraction and processing of ore, and on export of semi-products (copper and molybdenum concentrates). Though the Company demonstrates high efficiency in large-scale production, its current engineering capabilities are limited in terms of innovation, automation and, which is critical, high-added-value production.

The comparison with international standards points at the gap in introduction of advanced mineral processing technologies in Armenia. This weakens the country’s capabilities to obtain high added value in the production chain, and restrains competitiveness of mineral export on global markets. Avoidance of these deficiencies requires target investment in technological innovation and in bringing production processes in line with the world standards of industrial sustainability.

Environmental challenges. The ecological issues remain a sensitive aspect. This research points at such problems as water pollution and land degradation. The main environmental challenges and their aftereffects are generalized in **Table 3**. Although 65% of used water undergoes recycling, the introduction of dry stacking of tailings and closed water use cycles is a top-priority objective for reaching sustainability [1, 5].

Value-added industrialization

Shifting from raw concentrate exports toward refined and semi-finished products to capture higher returns and reduce vulnerability to global price fluctuation

Environmental sustainability

Adopting international best practices and technologies to mitigate ecological damage and ensure compliance with modern environmental standards

Regional and community development

Reinvesting mining revenues into infrastructure, education, and social programs to reduce dependency and strengthen long-term regional resilience

Three trends of strategic development for Armenia

dependence of the regional economy on the business environment of one economy sector.

At the same type, the high share of raw concentrates in the structure of exports implies vulnerability of the national economy because of volatility of world prices.

The obtained data prove that environmental costs can inadequately exceed benefits of mining if no provisions are made for the cost reduction (**Figure**). The key point is the requirement of successive upgrading using advanced technologies, which can enable transformation of the existing model of development into more balanced and sustainable growth.

Conclusions

The implemented research shows that the mineral processing industry represented by the Zangezur Copper–Molybdenum Combine is a strategic pillar of the national economy in Armenia. The Company makes a considerable contribution to industrial production (10–15%) and export (25–30%) [1, 5]. Beside economic effect, ZCMC takes an important part in socio-economic development by job creation for 4000 people and by supporting local infrastructure in the Syunik region [17].

At the same time, the research identifies grave structural and environmental challenges. The long-term dependence on export of raw concentrates leads to global price vulnerability and restrains transition to high-added-value production [8, 15]. Ecological issues, including water pollution and land degradation, highlight the need of introduction of sound mining practices [7, 11].

In view of the aforesaid, the following recommendations are offered:

1. **Increase of high-value-added production.** Armenia should prioritize technological upgrading to convert copper and molybdenum to semi-products or finished products, which can improve competitiveness of the country on the world market.

2. **Strengthening of environmental sustainability.** Investment in clean technologies such as dry tailings stacking and closed water use cycles are necessary for reduction of ecological risks and international standards compliance.

3. **Stimulation of regional development.** Mining revenues should be re-invested in education, public health service and infrastructure in the Syunik region for mitigating economic dependence of the region on a single company, and to ensure its long-term sustainability.

4. **Improvement of institutional and political background.** Government should heighten control over mining activities, create transparent environmental monitoring systems and stimulate introduction of sustainable practices to improve manageability and answerability of this industrial sector.

For the sustainable growth, it is recommended to perform: production upgrading, investment in clean technologies (dry tailings stacking), re-investment of revenues in social capital assets in the region of operation, and improvement of institutional control [14, 16].

To sum up, ZCMC demonstrates both strong sides and limitations of the mining industry in Armenia. The economic value of mining is unquestionable, but without diversification, technological upgrading and heightened ecological standards, the industry runs a risk of becoming a source of long-term vulnerability. Adjustment of mineral processing in accordance with goals of sustainable development can help making natural wealth of Armenia a reliable foundation for economic growth, social prosperity and balanced regional progress.

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