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The Ways of Recovery in Economy of the Depressed Mining Enterprises of the Russian Caucasus

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Abstract: In improving economy of the depressed regions of mining and processing ores the problem of using technogenic deposits and off-balance mineral raw materials is important. In terms of using tailings of ore production and concentration in underground winning, it proves that the use technogenic resources forms economic basis for radical modernization of technology that allows to raise production capacity of enterprise and sufficiency of using mineral resources and cover the costs on waste processing. On development of technogenic deposits the earlier lost reserves are engaged into exploitation. In the presence of power reserve, it is effective the development of safe pillars, the involvement of metalliferous stowage and off-balance reserves into the process of mining as they are uncovered and prepared and the costs on their prospecting and mining and development work have already discarded for mining the main stocks. In comparing technologies with various fullness of production from the depths the estimate of loss must be fulfilled on the basis of the lost value of minerals on a threshold price of the sector that allows to use the common criterion gain with consideration for damage from the loss of the mineral resource. Production of metals from mineral raw resources increases when using the technology of leaching out in disintegrator, providing production of metals to the norms of MPC per time less by a factor of two in comparison with agitation leaching. By producing metals from tailings the coproducts are being created: metals and nonmetals as salts and oxides, the tails of secondary processing with safe content of ingredients, desalted water, chlorine, hydrogen and oxygen improving economy. Using the tails of primary processing forms economic basis for radical modernization of technology, raises production capacity of the enterprise and fullness of using minerals and allows to warrant tail processing costs on certain conditions. Inclusion into exploitation of tailings of the first stages of deposit development that have not had commercial value before, considerably impacts on the amount of outputs and metal content in extracted ore mass. It reduces exploitation costs and improves performances of using capital investments and production assets.

Key words: Mineral resources, metal, economy, resource-saving, deposit, sub-surface, model, utilization, rejects, profit, ecology, region, technology, leaching, reserves

INTRODUCTION

Indices of mining industry are very different: developed countries in relation of mining, the population of which accounts for 16%, manufacture about 35% of the world mineral products and consume more 50%. In the developing countries, it is manufactured 35% and consumed about 20% of mineral products. To the rest of the countries, the population of which constitutes 35%, it is fallen 30% of manufacture and 30% of resource consuming (Yastrebinsky, 2014).

In Russia, in the period from 1981-1990, the volume of output and remanufacture of mineral raw materials of mineral resource industry increased from 54- 62 mln. tons. With the change of political map of the Eastern Europe after 1990, the geography of mineral-raw basis of Russia changed as many deposits of mineral resources turned out to be outside the Russian Federation.

Despite these changes, the position of Russia in the world mineral-raw market has remained rather stable. According to geological reserves of gas, ferrous metals zinc, nickel, tin, titanium, tantalum Russia takes the leading position in the world; of oil, wolfram ores, niobium, gold and platinoid, the second place; of coal, ores, copper, lead, molybdenum, rare metals and phosphate, the third place (Fomenko, 2013).

The confirmed reserves of, for example, lead in Russia constitute 10% and zinc 14% of the world reserves, though finished lead and zinc are manufactured less than consumed.

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Economy of Russia is oriented to metal export. About 70% of its export in money terms constitute mineral resources that threatens rapid exhaustion of mineral raw basis.

According to the structure of export and mineral raw material consuming per head Russia has dropped to the level of the developing countries. So the reserves of lead will decrease by 70-80% in the near future.

The development of raw material basis in Russia is characterized by distinctive features. Abroad the government takes place in financing programs, particularly, prospecting works. In the first place, it concerns strategically important and scarce mineral resources, the quantity of which for example in the USA, exceeds 40.

Japan invest in mining projects 75-80%, the USA 50-70%, Canada 38-40%, Australia 30-40%, Great Britain 33-35% of money for their realization.

In Russia, the hopes for improvement of economy are associated with adoption of conversion resource-saving methods of reserve development being less capital-intensive in comparison with traditional (Hint, 1981).

The factor of the level of efficiency of innovation technology and functioning of mining enterprise that applies these technologies, characterizes possibility of obtaining positive results of his activity with regard to costs that provided this effect.

The sum of costs and economic results of activity is "firm price" of an innovation mining enterprise as the summand of price characterizes cost value (costs on reconstruction connected with transfer to innovation technology) and the addend estimated outcome (profit). The fixed "price" reflects opportunity of realizing principles of commercial calculation of cost recovery and benefit.

The production of strategic raw metals such as lead, zinc, wolfram, molybdenum, tin is in critical state. Unsatisfactory state of economy of mining and processing enterprises causes tension in social sphere as these enterprises are enterprises forming a company town.

The state of economy is complicated by low level of renewal of basic production funds. The wear coefficient of the funds accounts for about 70% and half of technological equipment has been used >20 years. The volumes of mining and fundamental works have been rapidly reduced. But, a special rise to anxiety is given by reduction of uncovered and developed proved reserves of ore.

In improving the economy of the depressed regions of extracting and processing ores, it is important to intensify attention to the problem of using technogenic deposits and off-balance reserves of scarce minerals, costs on processing of which for example, tailings is 2-3 times less than on processing of natural raw materials.

The reserves of such raw materials in Russia are great. Only in the Urals, it has been accumulated >180 mln. tons of copper and copper-nickel tailings of concentrating mills. Such situation is also characteristic for Norilsk, Magnitogorsk and others.

It relates to greater extent to the current depressed regions of mining of the North Caucasus, where in former times the leaders of non-ferrous metallurgy flourished in the territory of the Republic of North Osetiya-Alaniya, Kabardino-Balkaria, Karachai-Cherkessia and other regions: the Sadon lead-zinc enterprise, the Tyrnyauz tungsten-molybdenic complex and others (Kozyrev, 2000).

MATERIALS AND METHODS

Experimental technique: Ecological and economic efficiency of complexification of capacity of enterprises for recovery in economy is considered in terms of consuming rejects and ore dressing in deep-mined output by the North-Caucasus underground mines.

It is explored economic consequences of industrial organization of marketable products of substandard raw materials after treatment in apparatus-activator of disintegrator type with obtaining of active fractions.

Economic aspects of technological diversification are investigated differentially first in terms of consequences for separate enterprises and then in terms of integration of their capacity for the region. For certain statistic conditions of functioning of partner enterprises, it is performed economic modeling of technological indicators with obtaining quantitative variables of diversification.

The objective of investigation is a proof that consuming tails of primary processing forms economic basis for radical upgrading of technology that allows to raise industrial capacity of enterprise and fullness of consuming subsoils and to cover costs on waste treatment.

RESULTS

Mining industry is referred to a number of the most capital-intensive branches with rather long investment cycle lasting for 5-15 years. Specificity of mining industrial sector is that the capacities of mining enterprises after waste courses of ore reserves reduce, therefore, investment process is to be uninterrupted and to provide introduction of new capacities on production in return of the left.

Peculiarity of reprocessing mineral raw material basis of metallurgy in prospect consists in that the reserves of secondary raw resource materials are constantly reproduced in priority rates and become compared with the reserves primary resources. The reserves of many deposits lost in depths make up a half of initial reserves. Formation of technogenic deposits is explained by objective reasons:

- Not always predictable conditional change to merchant ore makes conditional on selective extraction of rich places with retirement of inactive reserves
- Rise of technological level of production, first of all using power large-dimension engineering is provided by growth of reserves of pillars by 20-40% and their reprocessing increases ratio of dilution and losses of ores and output of tailings

Ores with high content of metals are under primary excavation. Then the conditions alter and ores with insufficient high content remain in mines-and-carries. As a result, the ore fields turn into subterranean technogenic deposits, there it is formed technogenic deposits from tailings of dressing and metallurgical redivision of ores on the surface.

In the tailing dumps, there are tails accumulated that contain precious polymetals, rare and noble metals. The volume of utilization does not exceed the first percent of the volumes surfacing. The main drawback for tails utilization is the circumstance that by concentrating and metallurgical redivision the capabilities of traditional technologies do not allow to extract minerals overall. Such "tails" cannot be utilized in form of building and other materials or slopped into the biosphere as book cost of non-extracted metals is comparable and even exceeds cost of already extracted minerals. Especially, it concerns technogenic deposits of noble and radioactive metals.

For each technological form of mining or ore dressing, there exists economically expedient limit of extraction that is set by conditions. Optimal ratio of marginal cost and quantity of metal is a constituent part of efficient and profitable development of the natural resources. Therefore, technologies directed to optimization of nature management and reduction of technogenic wastes at the expense of their reworking will allow to fully use the natural resources to create low-waste variants of technologies.

The importance of economic state estimate of nature management with technological and mining and geological conditions of deposits is explained by non-renewable nature of the natural resources and scanty deposits with favorable conditions of processing and their high capital intensity.

Management of rational use of the resources by means of economic instruments is provided by sequential execution of actions (Khasheva, 2009):

- Substantiation of economic reasonability of re-mining off-grade minerals
- The proof of possibility of reduction of production prime cost to acceptable condition owing to extraction of reserves destined for recurring reserve development
- Minimization of losses of the mining enterprise by capacity expansion at the expense of inclusion of technogenic resources with reduction of product unit in cost into second exploitation
- Estimate of efficiency of investment projects of second field development
- Substantiation of minimized conditions of mineral resources providing complexity of consuming input materials and cost reduction to economically reasonable level

By second development of technogenic minefields poor-balance and off-balance are included into exploitation. In the presence of the power reserves, it is efficient developing guard pillars including of metalliferous laying and off-balance reserves into the processes of mining as they are uncovered and prepared and the costs on their prospecting and mining first workings are allowed for mining primary reserves.

Considerable influence on substantiation of metal cutoff grade in ore is exerted by cost figures of mining and dressing, loss and dilution, metal content in balance reserves and change of engineering-and-economical performance of the applied technology.

Optimal balance point, correlating the content of metal in ore, extraction of metal into concentrate and mining cost can be defined by means of analytical methods which are currently in use. Estimated total sum of the generalized results of production processes is done by means of methods of multivariate comparative analysis for integrated assessment of rating results of variable engineering-and-economical performance.

The solution of tasks of the prospective use of technogenic deposits is connected with the study of production potentials of the mining companies and revelation of their capabilities to react flexibly to requirements of the market. In complex production system of enterprises with variety of functions the flexibility is determined by the totality of internal and external factors.

Economic aspect of the development of off-balance ores is metals growth in the course of introduction of the mechanism of mining operations by leaching with minimization of production processes and stages of extraction and processing to receive final marketable products with using of the available infrastructure of enterprises. Technological reservoir engineering has advantages:

- Minimal losses of geological reserves
- Checking feature of stock turnover in the process of extraction
- Possibilities of product quality control

Technological reservoir engineering has disadvantages:

- High labour-intensity and prime cost of technological processes
- Ore dilution (up to 30% and more) with product appreciation
- Maximum effect on ecological status

Leaching in place has advantages:

- Minimized labour-intensiveness and prime cost
- Possibilities of automation and robotization of production
- Release of facilities of hydrometallurgical plants
- Reducing pollution of ecological environment at liquidation of dumps

Leaching in place has disadvantages:

- Low metal extraction from ores (extraction coefficient 0.6-0.8)
- Difficulties in control of the process of leaching
- Building facilities on solvent processing
- Content of considerable ore areas in work

Heap leaching has advantages:

- Possibility of extraction of metals from offgrade reserves
- Possibility of control of leachable rock stock
- Favorable conditions for product automation and mechanization

Heap leaching has disadvantages:

- Costs on drawing unconditioned ores and stack forming
- Release of ground off turnover for stack forming
- Environmental pollution at breach of technoques

When comparing technologies with various fullness of extraction from the bowels of the earth it is needed estimate of metal loss in the compared units. The estimate of loss is done on the lost value of the mineral component defined by threshold price of the branch. It enables to arrive at common criterion profit subject to loss damages of the mineral resource (Fig. 1) (Golik *et al*., 2013a).

Technology of leaching in comparison with traditional technology excludes 5-10% of the losses by extracting and 2-2.5% of the losses by dressing. Transparent coefficient of extraction by traditional technology for mean metal content in the block reserves will not exceed 0.865.

At iron and steel plant there will be reclaimed 40% of metal of recovery efficiency 0.93. It will be obtained 39% of balance reserves from 50% per underground leaching of the remained balance reserves with recovery efficiency 0.8 and subject to losses by processing of solutions. With gold content in off-balance ores 1g t^{-1} it will be recovered 2.3% of metal from them and transparent efficiency of recovery will account for 0.88.

By underground leaching the access to treated reserves is limited, therefore, ambiguity of information about condition is more than by traditional technology.

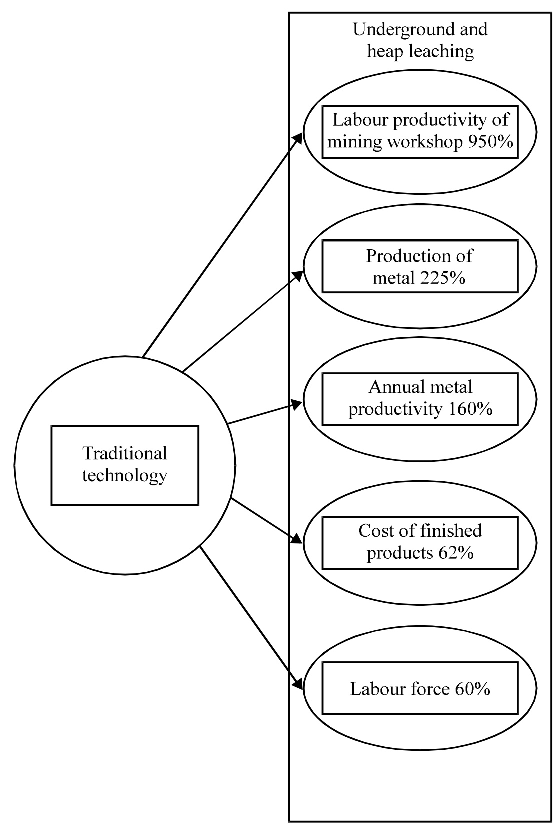

Fig. 1: Efficiency of uranium leaching in comparison with traditional technology

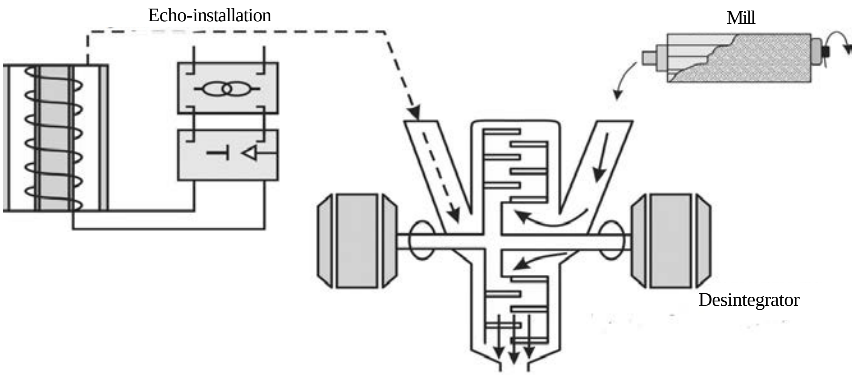

Fig. 2: The scheme of leaching metals in disintegrator: ECHO-installation apparatus for preparation of reagent

Therefore, decision making about reserves treatment by means of mixed technology is great risk-bearing: from 0.6-0.9.

Low-grade and poor ores, rejected onto the surface as a result of gross winning are reprocessed by heap leaching. Finished low-grade ores are stacked and dressed ores are sent to plants.

Improvement of quality of ore, produced from compensation space to 10%, increases efficiency of technology to 3-5%. It enables to broaden the scope of application of the mixed technology. If 40% of ore is rejected to the surface, a 60% of ore leached underground at equal rock productivity the metal productivity is 2 times greater than by tradition approach. Metal production productivity of mining workshop raises 1.5 times. By increase in productivity of metal mines to 1.5 times and equal quantity of the workers the productivity of the mine on rock production amounts to 40% of the indicator of the traditional approach.

Estimated figures are amounts of minerals reprocessing, metal content in ore, extraction of metals, metals prices, capital and operating costs on construction of production objects.

The important stage of calculation of finance total of realization of production development variant is forming finance totals equal for mining projects per year. Pay for risk at $\beta = 1$ amounts to 5 and 8%. Actual norm of risk in concordance with market requirements:

$$r = r_i + \beta(r_m - r_i)$$

Where:

r = Required profit rate profit rate
r_i = Profit rate free of risk
r_m = Average market premium

Estimate of variants of inclusion of metal-containing waste products in reprocessing embraces determination of finance totals of realization, values of profit rate, present value of future outcome, analysis of financial sensitivity of the variant in relation to parametric variation of the financial outcome and value of discount.

Efficiency of leaching rises when applying technology of leaching in disintegrator, providing metal extracting to the norms of MPC in a time, shorter by factor of 2 as compared with agitation leaching (Fig. 2) (Golik *et al*., 2013b).

By recovering metals from processing wastes coproducts are created: metals and nonmetal in form of salts and oxides, secondary tails of processing with safe content of ingredients, desalted water, chlorine, hydrogen and oxygen, strengthening the economy.

Range of application of products manufactured after extracting of metals: tanning and construction industry, agriculture, heat and power engineering and other branches of the economy.

Technology characteristics of metal extraction is determined by decision of the economic and mathematical model enabling to find optimal parameter values. The model reflects individuality of current task and provides successive approaching to optimum by optimization of each system element.

Economic model of efficiency of tails utilization on the criterion profit maximum with consideration for ecology of the region (Shestakov, 2000):

$$\Pi = \sum_{p=1}^{P}\sum_{o=1}^{O}\sum_{n=1}^{\Pi}\sum_{t=1}^{T}\sum_{f=1}^{F}\sum_{n=1}^{N}\left\{\left(M_{ey}Ц_{My} + Q_y Ц_{qy}\right)\right\} - \sum_{З=1}^{З}\left[K\left(1+E_{Hy}\right)+E_q+E_x\right] - \left[\left(M_e Ц_M + QЦ_q\right)+Q_Г Ц_Г\right] K_c K_y K_T K_б K_Г K_{Bp} K_ч \rightarrow \max$$

Where:

P = The products of utilization of rejects and low-grade ores
O = Types of wastes included into processing

П = Technological processes of waste treatment
T = Time of waste treatment
F = Phases of existence of the mine and plant
N = Stage of wastes utilization
K = Costs on waste processing
З = Capital investments for area of utilization
K_c = Coefficient of self-organization of dumps

Economic effect of obtaining products from rejects:

$$Э = \sum_{t_0+1}^{t} \left(\frac{P \times Ц - З_a}{1.08^{t-t_0}} \right) A$$

Where:

P = Products obtained from utilization, weight per unit
Ц = Price of products, currency unit
$З_a$ = Reduced costs for activation, currency unit/unit of weight
t_0, t = Time initiation and end of works
A = Volume of utilization of tails

Gain on extraction of metals from the rejects and metallurgy with consideration for ecological damage:

$$П_X = \frac{\sum_{1}^{n_0} \left(C_{T.O} - З_{0.0} - З_{0.M} \right) \times Q_0}{t_0} + C_?^0 + \frac{\sum_{1}^{n_M} \left(C_{T.M} - З_{0.M} - З_{M.M} \right) \times Q_M}{t_M} + C_?^M$$

Where:

$П_X$ = Profit on processing tails, ruble/ton
$C_{T.O}$ = Cost of realization products of processing tails, ruble/ton
$З_{0.0}$ = Costs on beneficating redivision of the rejects, ruble/ton
$З_{OM}$ = Costs on metallurgical redivision of the rejects, ruble/ton
n_0 = Quantity of extracted components from the rejects
Q_0 = Mass of the rejects, T
t_0 = Processing time of the rejects, year
$c_ш^0$ = Fines for storing rejects, ruble/year
C_{TM} = Realization of the processed products of the tails of metallurgy, ruble/ton
$З_{OM}$ = Costs on the rejects of metallurgy, ruble/ton
$З_{MM}$ = Costs on redivision of the tails of metallurgy, ruble/ton
n_{MM} = Quantity of the extracted components from the tails of metallurgy
Q_M = Mass of the tails of metallurgy, ton
T_M = Time for processed tails of metallurgy, years
$c_ш^M$ = Fines for storing the tails of metallurgy, rouble/year

Dynamic problem statement of linear programming with regard to stochastic character of system modification restricts discrete interval of time by 10 years with subsequent correcting of statement of a problem.

Storing tails in the dumps includes compensation for ecological damage on revegetation and payment of fines (Khasheva, 2014). Reclaiming of the tails radically improves the state of ecological system. Therefore, the costs on construction and use of complexes of metal extraction should be compared not only with the value of the extracted metal and compatible products but with the total sum of negative effects of waste impact.

The decision about reasonability of extraction of metals from wastes is made with complex consideration for technological, economic and ecological factors: value of the obtained materials, products reduction in cost, cost cutting, increase of competitiveness, decrease of risk, rise of rhythms and stability of production and economy.

DISCUSSION

It has been proved that utilization of the tails of first reclaiming forms economic basis for radical modernization of technology, raises plant capacity and fullness of the use of minerals and enables to cover the costs on reclamation in certain conditions.

The main problem of preserving and strengthening mineral base of the North Caucasian plants is in decrease of efficiency of the process of reproduction that is characterized by ratio of the derived value of the incremented reserves to the costs on production and by ratio of labour inputs.

The use of the tails of first reclamation is necessary here as mineral raw material complex as compared to the other sectors of economy processes the most comprehensive facilities in increasing a budget acting as a donor for development of allied industries, employment and growth in prosperity of population.

The analysis of profitability shows that traditional way in view of considerable costs on transport and treatment of diluted ore mass in working low-grade ores does not compensate the lost value of metals in the depths by technological reclamation.

Optimal ratio of volumes of reserves, reclaimed by mixture of traditional technology and technologies of underground heap leaching, increases the efficiency of exploitation of deposits as compared to each of the ways separately.

Inclusion into exploitation of tailings of the first stages of mining that did not have commercial value earlier, exerts considerable influence on volume of the produced minerals and content of metal in ore mass. It cuts operating costs and improves rates of use of capitals and production assets.

Financial plant prosperity on production of metals from processing wastes is provided if income from sales of metal with the exception of operating costs is sufficient to cover costs on mining and processing gold-containing minerals.

CONCLUSION

Recovery in the economy of the depressed mining enterprises of the North Caucasus is possible by using innovation methods, for example, leaching in complex with traditional technology for fuller utilization of resources at the expense of inclusion into exploitation of earlier lost ores and ore-processing wastes.

The main factor of economic efficiency of mixed technology consists in the fact that by compared costs it is extracted from the depths far larger volume of metal at the expense of profitable prospecting of off-balance reserves and rejects of prior field development stage.

Impact of innovation technologies on the growth of return of the resources occurs in two directions: volume gain of mining providing increment of output and increase in capital return thanks to effective resource using, stock addition, introduction of scientific and technical progress and rise in labour productivity.

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