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Economical Efficiency of Utilization of Allied Mining Enterprises Waste

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Abstract: With the example of underground mine of Sadon lead-and-zinc integrated plant of dolomitic quarry, the researchers proved eco-economic efficiency of combining of their possibilities. The researchers researched economic repercussions of utilization of nonconforming dolomite for production of solidifying mixtures based on mill tailings of polymetallic ores after processing in activators differentially and with integration for each participant. It has been proven that usage of mining waste allows to increase completeness of subsurface use and brings profit depending on completeness and scope of mastering of technologies.

Key words: Mine, dolomite, quarry, economy, utilization, solidifying mixture, mill tailings, ore, disintegrator, subsurface resources, profit, technology

INTRODUCTION

As a result of economic reform of 1990 s most of mining enterprises (which were mainly subsidized) faced the problem of survival in conditions of the emerging market.

One of the ways to guarantee economic security is to combine possibilities of allied mining enterprises in the frame of technologic diversification involving mineral resources which have been regarded as nonconforming earlier, into the production (Kozyrev, 2001).

In some cases, usage of mill tailings of depressed allied enterprises allows to use subsurface resources to the utmost to improve quality or to increase volume of output, to reduce production costs and thereby to raise economic status. Solving of the problems of diversification directions finding requires economic justification.

A very important direction for the development of mining enterprises with ores deep mining is mastering of technologies using filling of cavities with solidifying mixtures (Polukhin *et al*., 2014).

These technologies are aimed at correction of tendency of natural ecosystems degeneracy under the influence of mining which disrupted 40% of land, emits over 30% of gas and dust and discharges 10% of liquid effluents volume and leaving up to 40% of field reserves underground.

A concept of mining technologies environment friendliness includes following conditions:

- Loss of natural resources is a consequence of technologies unreasonableness
- Technologies are judged by quality and amount of mineral resources
- Commercial product's cost includes expenses for environment protection

The main obstacle in the stowing technologies way high price of cement used in them. At the same time at quarries nearly 30% of cement raw material are waste.

For a quarry, the new thing is selling dolomitic waste as a product for making of solidifying mixtures at a mine and for a mine the new thing is using dolomite activated in a disintegrator as a bonding material and mill tailings as a filler in the composition of a stowing mixture after removing metals which are insusceptible for traditional beneficiating methods.

Sadon lead-and-zinc integrated plant had mined over 500 ths. tons of lead and 830 ths. tons of zink from 1843 till 2004. Mine development intensity in 1936 reached 210 ths. tons, reduced to 20 ths. tons in 1943, again increased to 140-150 ths. tons in 1960. In 1970s enterprise capacity reached 745 ths. tons of ore per year.

Valuable components of mineral resource base of North Ossetia-Alania republic are zinc, lead, silver. Development of these ores without government grant is unpromising, because amount of active reserves which satisfy the conditions of lossless mining is only 30% of balance reserves.

MATERIALS AND METHODS

Eco-economic efficiency of enterprises possibilities combination is considered using the example of utilization

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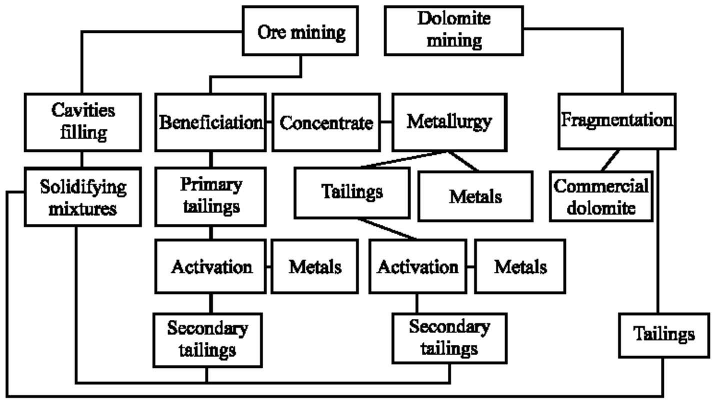

Fig. 1: Integrated scheme of allied mining enterprises waste utilization

of waste of dolomite production and ores beneficiation during underground mining in conditions of Sadon lead-and-zinc integrated plant (Fig. 1).

Scientists study economic repercussions of production of binding materials made of nonconforming dolomite for making of solidifying mixtures after processing in activators involving obtainment of active fraction (Golik *et al*., 2014).

Economic aspects of diversification of technology at the quarry of dolomite open mining and polymetals underground mining are studied at first on an individual basis and then combining their possibilities.

For certain statistical business environments of allied enterprises we created an economic model of technologies indices with obtainment of qualitative parameters of diversification.

It is proven that dolomitic binding material usage is an economic basis for technology modernization; it allows to increase volume of subsurface use and repay expenditures for waste recycling.

Main part: Ores mining on the Sadon group deposits is possible via alternative technologies (Golik, 2013a, b):

- With open mined-out space and supporting with ore pillars
- Filling cavities with solidifying mixtures, using activated dolomite of a local quarry and active fraction of ores beneficiation as binding materials and coarse fraction of mill tailings (after extracting metals from them) as a filler

To compare possibilities of technologies we calculate their indices according to data of Sadon lead-and-zinc integrated plant and Bosnian dolomitic quarry (Table 1).

Calculation is made for conditions of intensive operation and at costs of 1990. Mine capacity is 500,000 t/year. Content in ore: lead 1.6%, zinc 1.8%. Extraction into concentrate: lead concentrate 91% of lead and 4% of zinc, zinc concentrate 87% of zinc and 2% of lead. Loss of metals in tailings: in heavy suspension: lead 2.6%, zinc 5.3% in floatation tailings: lead 5.2%, zinc 7.5%. Production of commercial concentrates: lead ones 7000 t, zinc ones 10000 t. Price of concentrates: lead one 555 rub., zinc one 360 rub.

Table 1: Modelling of alternative technologies of deposits development

	Technologies	
Parameters (units)	Basic	New
Subsurface use: impoverishment (%)	30	10
Losses (%)	20	5
Underground metal mining (%)	100	115
Production of concentrates: lead (t year)	7000	8500
Zinc (t^{-1}year)	10000	11500
Price of concentrates: lead (Rub.t^{1})	555	555
Zinc (Rub.t^{1})	360	360
Productivity concerning mined rock (t. m^{3-1}year)	170	170
Volume of cavities formed per year (ths-m^3)	220	190
Volume of cavities filled per year (ths-m^3)	-	150
Price of 1 m^3 of solidifying mixtures (rub)	-	5
Expenses for cavities filling per year (ths. rub)	-	750
Additionally concentrates (t^{-1}year)	-	300
	-	600
Concentrates from tailings process (ths. rub)	-	400
Price of building materials made of tailingsths (rub)	-	600
Total cost of utilization products (ths. rub)	-	1382
Results of technologies usage (ths.rub.$^{-1}$year)	7485	8867
Environment damage compensation (ths.rub.$^{-1}$year) (%)	10-748	1-88
Saving per annual output (ths.rub.$^{-1}$year)	-	2039
Saving per 1 ton of concentrate (ths. rub)	-	90
Saving (%)	-	30

Apart from lead and zinc, ore contains the following components: copper 0.29%, cadmium 0.011%, indium 0.0007%, bismuth 0.006%, cobalt 0.0051%, thallium 0.0003%, gallium 0.0004%, germanium 0.00025%, gold 0.06 g t^{-1}, silver 28 g t^{-1}.

Practical effectiveness of a new technology is presented above because calculation does not involve price of metals obtained from tailings via desalinization in disintegrator and actual damage exceeds 10% which are taken into calculation.

Table 2: Effectiveness of mine's work when using filling technology

Parameters (units)	Technologies Basic	New
Extractible value of ore per year (ths. rub.)	7485	8867
Yield of metal into concentrate (t/t)	0.168	0.271
Expenses for technology modernization (mln. rub.$^{-1}$year)	15.6	82.6
Profit per extent of production (mln. rub^{-1}year)	-	2039
Profit per unit (rub.$^{-1}$t)	-	90

Table 3: Effectiveness of quarry's work given the chance of waste realization for mixtures preparation

Parameters (units)	Technologies Basic	Basic
Extractible value of dolomite (rub.$^{-1}$t.)	115	115
Output of standard dolomite (tt^{-1})	0.7	0.7
Output of fraction for binding material preparation (tt^{-1})	-	0.2
Output of primary activation product (tt^{-1})	-	0.07
Output of secondary activation product (tt^{-1})	-	0.03
Expenses for binding material preparation (rub.$^{-1}$t.)	-	35
Expenses for primary activation rub./t.	-	50
Expenses for secondary activation rub./t.	-	60
Price of binding material made of dolomite rub./t.	-	130
Price of primary activation product rub./t.	-	250
Price of secondary activation product rub./t.	-	320
Expenses for technology modernization mln. rub./year	10	30
Total extractible value rub./t.	115	172
Profit per extent of production (900,000 t) ths. rub.	-	51300

Indices of effectiveness of cooperation between quarry and mine are shown individually for each part in Table 2 and 3.

Results of economic modelling go to prove that combination of technologic alliance parts possibilities provides them with advantages over the basic technology.

Mining technologies optimality criterion is discounted profit in "t" year, rub. Under the basic scenario:

$$D_{tb}=A_b\left(P_b-C_m\right)/\left(1+E\right)^{t-1}$$

Where:

- D_{tb} = A discounted profit of the basic scenario, rub
- A_b = A productive capacity under the basic scenario, t
- P_b = An extractible value of ore under the basic scenario, rub t^{-1}
- C_m = Expenses for mining and beneficiation under the basic scenario, rub t^{-1}
- E = A lending rate for construction credit

Under the new scenario:

$$D_{tn}=A_b\left(P_b-C_m\right)/\left(1+E\right)^{t^{-1}}+A_n\left(P_n-C_n\right)/\left(1+E\right)^{t^{-1}-t^{cc}}-\frac{K_{cc}\left(1+E_{cc}\right)}{\left(1+E\right)^{t^{-1}}}+1/\left(1+E\right)t^{-1}E_i/\left(1+E\right)t^{-1}-t^{cc}$$

Where:

- D_{tn} = A discounted profit of the new scenario, rub
- A_n = A productive capacity under the new scenario, t
- P_n = An extractible value of ore under the new scenario, rub t^{-1}
- C_n = Expenses for mining and beneficiation under the new scenario, rub t^{-1}
- E = A lending rate for construction credit
- t_c = An evaluation time, years
- t_{cc} = A time of construction of stowing complex, years
- K_{cc} = A investments into stowing complex construction under the new scenario, rub t^{-1}
- E_{cc} = A lending rate for credit for construction of new objects
- E_i = A decrease of environmental damage under the filling technology, rub./year

Effectiveness of activation of mill tailings for the purpose of extraction of valuable elements from them, activation of stowage mixture components, reduction of loss and dilution of ore is described by the model in "t" year, rub:

$$E_a=\frac{A_b\left(P_b-C_m\right)}{\left(1+E\right)^{t^{-1}}}+K_t\left(1+E_t\right)^{t^b}+Y_t\left[A_t\left(P_t-C_t\right)-K_t\left(1+E_t\right)^{t^t}\right]$$

Where:

- A_b = A productive capacity under the basic scenario, t
- P_b = An extractible value of ore under the basic scenario, rub t^{-1}
- C_m = Expenses for mining and beneficiation under the basic scenario, rub t^{-1}
- γ_t = A tailings output
- t^b = A time for construction of mill tailings activation base, years
- t^t = A time for construction of tailings pond, years
- K_t = A investments into tailings pond, rub
- A_t = A productive capacity of mill tailings process plant
- P_t and C_t = A tailings' extractible value and expenses for tailings process, rub t^{-1}
- K_t = Expenses for construction and mastering of tailings activation objects, rub
- E = A coefficient of discounting of expenses and profit through time, fr.unit
- E_t = A lending rate for credit for construction of new objects, fr.unit

Saving due to technologies integration in comparison with the basic scenario consists of growth in production with minimum expenses for reequipment:

$$E_p = A_n(P_n - C_n) - A_b(P_b - C_m) - K_t(1+E_t)^{t^t}$$

where, A_{bt} enterprise's productive capacity under the basic scenario in "t" year, t rub^{-1}; d_{bt} and C_{db} extractible value of ore mass and expenses for mining and beneficiation under the basic scenario in "t" year, rub t^{-1}. Expenses for mining and processing of ore (Shestakov, 2000). Under the basic scenarios without stowing:

$$C_{b1} = \frac{1-T_b}{1-D_b}(A_1 + A_2 + A_3) + A_4 + A_6$$

with stowing

$$C_{b2} = \frac{1-T_b}{1-D_b}(A_1 + A_2 + A_3) + A_5 + A_6$$

under the new scenarios:

$$C_n = \frac{1-T_n}{1-D_n}(A_1 + A_2 + A_3) + A_4 + A'_5 + A'_6$$

Where:

- T_b D_b = Correspondingly loss and dilution under the basic scenario, fr. unit
- T_n D_n = Correspondingly loss and dilution under the new scenario;
- A_1, A_2, A_3 = Expenses for geological exploration, amortization and mine preparation work, allocated to 1 t of balance reserves under the basic scenario, rub t^{-1}
- A_4, A_5, A_5 = Expenses for subsequent processes, stowing operations and beneficiation under the basic scenario per 1 t. of obtained ore mass, rub t^{-1}
- A'_5, A'_6 = Expenses for stowing operations and beneficiation under the new scenario per 1 t. of ore mass, rub t^{-1}

Stowing on the dolomitic base provides minimum dilution and considerably greater extraction during beneficiation. Capital expenditures for stowing complex construction are not a part of cost of mining and processing; they come into account in different scenarios of stowing. For instance, during stowing with cement, breakstone production quarry should be used (Golik, 2013a, b).

Activity index or ratio of active class output to throughput can be increased with repeated and subsequent activation in disintegrator (Fig. 2).

Resume: Eco-Economic Model of watse usage effectiveness describes economic and ecological effects of combination of possibilities of underground mine and dolomite quarry.

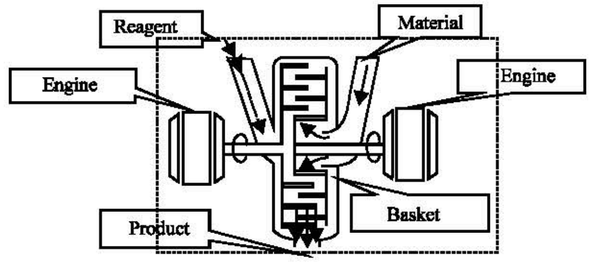

Fig. 2: Scheme of disintegrator-activator

Mining technologies effectiveness criterion is a discounted profit inclusive of compensatory expenditures for environmental ecosystems preservation.

The major role in effect creation belongs to usage of solidifying mixtures made of activated waste of dolomite production and mill tailings.

Mechanism of interaction of factors taking part in processes is characterized by correcteness and that allows to implement it in the production management system.

CONCLUSION

It has been proven that using of mining technology with solidifying mixtures filling of cavities is by 30% more saving than the basic technology which leaves cavities open. The major role in effect creation belongs to usage of solidifying mixtures made of activated waste of dolomite production and mill tailings. Filling of technologic cavities with mixtures drastically reduces technologies detrimental effect on ecosystems which does not seem possible to be evaluated yet (Golik *et al*., 2013).

It has been found that operating expenditures and environmental damage can be reduced due to activation of mill tailings and extraction of metals from them (Golik, 2010).

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