International Business Management 9 (6): 1119-1123, 2015
ISSN: 1993-5250

Evaluating the Effectiveness of Utilization of Mining Waste

Vladimir I. Golik, Alexander N. Doolin, Maria A. Komissarova and Roman A. Doolin
South-Russian State University of Technology, ul. Education, 132346428 Novocherkassk, Russia

Abstract: The estimation was given for methods for determination of environmental costs and criterion to evaluate the mineral potential of the region in the form of discounted earnings with the compensation costs for the preservation of the environment recommended. It is proposed to evaluate the effectiveness of the use of secondary mineral potential, taking into account environmental and economic situation, the cost of goods of recyclable resources and increasing effectiveness of subsoil use. Using an example of a mining company, it is shown how the use of non-traditional technological schemes provides both economic and environmental benefits.

Key words: Mineral, raw materials, potential, region, discount, profit, the environment, ecology, economics, utilization, resource, mineral resources, technology, enrichment, mechanochemistry, disintegrator, effect

INTRODUCTION

The main danger to environment comes from chemicals of natural desalination of mining waste storage facilities. It is determined by the nature and time of contact of solid and liquid media, the ratio of sulfides and carbonates, amount of carbon dioxide and pyrrhotite, etc. (Golik *et al*., 2008).

Reclamation of tailing dumps without tails disposal does not diminish but increases the risk at the expense of manifestations of new, unexplored and unpredictable factors operating indefinitely. Damage from the impact of the tailing dumps may exceed the value of the extracted minerals, especially since the average period of existence of mines is a few tens of years and the tailing dumps-centuries.

The main mechanism of pollution the release of the chemical element from a mineral matrix as a result of natural physical, chemical and bacterial processes. It is opposed to a controlled process of metals technological extraction from tailings with providing security to secondary tails for use without sanitary restrictions (Kaplunov *et al*., 2003).

Valuation techniques as a criterion for appropriate technology use: the cost of production, profit, capital costs, profitability, differential mining rent and other parameters.

Lack of techniques lies in the fact that they do not take into account environmental aspects of environmental destruction with waste which reduces confidence in the economic calculation.

Evaluation of environmental costs requires changes in the methodical approach to the selection of criterion and indicators of the mineral and resource potential of the region (Polukhin *et al*., 2014).

MATERIALS AND METHODS

The efficiency of mining waste utilization is considered on the example of usage of waste of enriching and metallurgical processes of ores during underground mining in conditions of Sadonsky lead-zinc plant.

The existing methodologies for determining environmental costs are analyzed and it is recommended to evaluate the effectiveness of the use of secondary mineral and raw material potential, taking into account the ecological and economic situation using another complex criterion.

The example of a mining company getting both economic and environmental benefits through the use of non-traditional technological schemes is considered. The economic effects of production of substandard raw materials after the change of its properties in activators are studied.

Economic modeling of indicators of technologies with receipt of quantitative parameters of processing is carried out. The statement that the combination of traditional innovative technology can provide both economic and environmental benefits is proven.

Corresponding Author: Vladimir I. Golik, South-Russian State University of Technology, ul-Education, 132346428 Novocherkassk, Russia

RESULTS AND DISCUSSION

Main part: Economic and environmental assessment of the effectiveness of tailings processing in the region that has secondary mineral and raw material potential is proposed to be determined as the sum of effects (Table 1):

$$Э = \sum_{i=1}^{n} Э_i$$

Where:

$Э_i$ = The total environmental, social and economic effect
n = The number of estimated effects

The criterion of effectiveness of waste utilization is represented by the sum of profit or notional income at waste disposal. Its introduction puts companies on an equal footing, since disposal costs depend on their technological capabilities the more correct technology is the lower are the costs for rehabilitation of environment (Shestakov, 2000).

Effective utilization of tailings consists of reducing the amount of environmental damage caused by the storage of tailings, the value obtained in the processing of products, raw materials for the construction industry and corresponding consumable goods (Burdzieva, 2010).

In assessing the impact of the storage of materials usually only tangible aspects are considered: land employment for the tailings, dumps, etc. Even in incomplete form, the damage reaches 50-75% of the production costs. If we assess the damage to environment not only now but also after an indefinitely long time afterwards, its scale will be bigger (Golik *et al*., 2014):

$$\sum_{t=1}^{t} Y_э = \sum_{t=1}^{t} \left(Y_p \times n + Y_э \times m + Y_л \times p \right)$$

Where:

Y_p, $Y_э$, $Y_л$ = Damage during exploration, exploitation and elimination of mines and factories
n, m, p = Existence of enterprises stages duration specific weights

At the exploration stage, it is not possible to organize active waste utilization, so the damage caused by the storage of waste and tailings:

$$Y_p = \sum_{t=1}^{t} \sum_{n=1}^{n} \sum_{k=1}^{k} M_e \times Ц_M + \sum_{t=1}^{t} \sum_{r=1}^{r} \sum_{f=1}^{f} QЦ_q \rightarrow \max$$

Where:

t = Time of tailings storage
n = Number of leachable components
k = The number of self-organization effects
M_e = Quantity of metals entering environment from tailings
$Ц_M$ = The price of useful components
r = The number of direct factors of environment abuse
f = Number of secondary factors of environmental violations
Q = The number of beneficial effects lost during violation of useful effects ecology
$Ц_q$ = The cost of lost effects and quality

When processing waste disposal hazard for environment does not decrease. It increases due to manifestations of new, unexplored and unpredictable factors. It increases by the fact that access to the hazardous waste is terminated (Golik, 2013a). Environmental damage from reclaimed without utilization tailings dumps:

$$Y_{p.x} = \sum_{t=1}^{t} \left(\sum_{n=1}^{n} \sum_{k=1}^{k} M_e Ц_M + \sum_{r=1}^{r} \sum_{f=1}^{f} QЦ_q + \sum_{q=1}^{q} Q_r Ц_r \right) \rightarrow \max$$

Where:

q = The number of factors of the global impact of tailings and waste
Q_r = The number of effects of global destruction of the environment
$Ц_r$ = Price of environment destruction factors compensation

Table 1: Technological solutions of environmental character are typed by us on the basis of their level of implementation

Hierarchic level	Management type	Realization level
Global	Raw material types decrease	International agreements
	Concerns cooperation	Concerns cooperation
Regional	Enterprises cooperation	Enterprises enlargement
	Cooperation of complexes	Regional complexes creation
	Participants' cooperation	Planning and coordination
Local	Dilution minimization	Setting up with empty hardening mixtures
		Geotechnological ways of extraction
	Improvement of technologies of enrichment	Hydrometallurgy
		Mechanochemical technology
	Extraction of metals from waste	Traditional technologies
		Innovational technologies
	Complex processing	Non-waste production

Directions to reduce the negative impact of tailings dumps over the environment (Golik, 2013b):

- Reducing the number of mining units at concentration of operations
- Reducing the time between exploration and exploitation
- Filling in voids with hardening mixtures and tails of leaching
- The use of non-waste methods of ore processing

Ecological and economic models of effective utilization of tailings on the criterion of maximum profit taking into account ecology of the region has the form (Golik *et al.*, 2013a, b):

$$П = \sum_{p=1}^{P}\sum_{o=1}^{O}\sum_{n=1}^{П}\sum_{t=1}^{T}\sum_{f=1}^{F}\sum_{n=1}^{N} \begin{Bmatrix} \left\{\left(M_{еу}Ц_{Му}+Q_{у}Ц_{qу}\right)\right\} - \\ \sum_{з=1}^{З}\left[K\left(1+E_{Ну}\right)+E_{ч}+E_{х}\right] - \\ \left[\left(M_{е}Ц_{М}+QЦ_{ч}\right)+Q_{г}Ц_{г}\right]K_{с}K_{у}K_{Т}K_{б}K_{г}K_{Вр}K_{ч} \end{Bmatrix} \rightarrow \max$$

Where:
P = Utilization products
O = Types of waste, involved in processing
П = Processes of waste processing
T = Time of waste processing
F = Phases of mine and factory existence
N = Stage of waste disposal
З = The cost of waste disposal
K = Capital investments in organizing disposal site
K_c = Coefficient of dumps self-organization

The risk of incomplete verification of projects is characterized by a degree of risk:

$$r = \frac{K_б}{K_и + K_б}$$

Where:
$K_б$ = Expandable part of the investment in recycling costs
$K_Н$ = Used part of investments

The economic effect of manufacturing products from enrichment tailings:

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

Where:
P = Production from waste, weight units
Ц = Production unit price, monetary unit
$З_а$ = Given costs of activation, monetary unit/ weight unit
t_0 and t = Time of the beginning and end of the work
A = The volume of tailings disposal

The model of tailings disposal costs optimization:

$$C = (C1, C2, ...Cn) \rightarrow \min$$

Where:
C = The cost of the final disposition of the product
C1, C2,...Cn = Cost manufacturing processes

Ecological and economic efficiency is characterized by indicators:

$$K_{э.э.э} = \int_1^n f \times \left(dx_1, dx_2, ...dx_n\right) = Q_и : Q_у$$

Where:
$Q_и$ = An amount of material extracted on surface, m^3
$Q_у$ = Amount of utilized materials m^3
$x_1, x_2, ... x_n$ = Process parameters

Enhancement of land creates economic benefits. Productivity and value of the crops cultivated in the region and their gross value per year is determined by calculation (Table 2) (Ermishina, 2011). Remediation of land, including decrease in mineralization, makes profit (Table 3).

When returning contaminated land to usage with the cost of land 895,000 thousand rubles profit will reach 11,650,000$/ha^{-1}. The damage to biosphere caused by impact of tailings desalination products (Golik, 2009):

$$y_{тм.тм} = \sum_1^m \left(A_p \ldots A_d - C_p \ldots C_d\right) + \Sigma$$

Where:
m = The number of species of flora and fauna
A_p and A_d = The number of flora and fauna before and after the implementation of new technology
C_p and C_d = Price of flora and fauna before and after the implementation of new technology
Σ = The cost of damage reduction

Ecological and economic efficiency of utilization of mine refuse is confirmed by the calculation for the conditions of the North Ossetia.

Table 2: Productivity and value of some crops cultivated in the Republic of North Ossetia-Alania

Crops	Productivity (dt ha^{-1})			Price per item (\$ dt^{-1})	Production amount (\$ ha^{-1})		
	Max.	Average	Min.		Max.	Average	Min.
Wheat	35	24.0	15	14.30	500.5	343.2	214.5
Corn	75	55.0	37	12.50	937.5	687.5	462.5
Oats	33	20.0	15	10.70	353.6	214.0	160.5
Barley	34	19.5	14	10.70	363.8	208.7	149.8
Rye	25	18.5	11	14.30	357.5	259.0	157.3
Buckwheat	7	4.0	3	28.60	200.0	114.4	85.8
Sunflower	18	15.0	12	16.10	289.3	241.5	193.2
Beetroot	550	350.0	250	7.15	3932.5	2502.5	1785.5
Potato	200	160.0	140	14.30	2860.0	2288.0	2002.0
Cucumber	90	75.0	60	10.70	963.0	802.5	642.0
Tomato	175	160.0	140	17.90	3132.5	2864.0	2506.0

Table 3: Gain on reduction of land contamination

Crops	Production amount (\$ ha^{-1})	Recultivation (\$ ha^{-1})	Field expenditures (\$ ha^{-1})	Areas (ha)	Profit (thousand \$ year^{-1})
Wheat	343.2	50	150	4.488	642.682
Corn	687.5	65	235	4.488	1739.100
Oats	214.0	50	130	4.488	152.592
Barley	208.7	50	130	4.488	128.806
Rye	259.0	50	150	4.488	264.792
Sunflower	241.5	50	170	4.488	96.492
Beetroot	2502.5	50	170	4.488	10243.860
Potato	2288.0	60	170	4.488	9236.304
Cucumber	802.5	60	210	4.488	2389.860
Tomato	2864.0	60	210	4.488	11641.872

Annual income from the processing of mine refuse and metallurgy taking into account environmental damage:

$$\Pi_X = \frac{\sum_{1}^{n_0}(C_{T.O} - З_{0.0} - З_{0.M}) \times Q_0}{t_0} + C_{Ш}^{0} + \frac{\sum_{1}^{n_M}(C_{TM} - З_{мM} - З_{MM}) \times Q_M}{t_M} + C_{Ш}^{M}$$

Where:

- Π_x = Annual income from the processing of tailings (rub./t)
- C_{TO} = The value of sales of products of tailings processing (rub./t)
- $З_{OO}$ = The cost of mill tailings treatment (rub./t)
- $З_{OM}$ = The cost of metallurgical redistribution of mill tailings (rub./t)
- n_0 = The number of extracted components from mill tailings
- Q_0 = Mass of mill tailings (t)
- t_0 = Time of processing of mill tailings
- C_m^0 = Penalties for possession of mill tailings (rub./year)
- C_{TM} = Sales of metallurgica lmill tailings products (rub./t)
- $З_{OM}$ = Costs for metallurgical tailings treatment (rub./t)
- $З_M$ = Expenses for metallurgical redistribution of metallurgy tailings (rub./t)
- n_M = The number of components extracted from metallurgy tailings
- Q_M = Weight of metallurgy tailings (t)
- t_M = Time of metallurgy tailings processing
- $C_{Ш}{}^{M}$ = Fines for metallurgy tailings storage (rub./year)

The results of modeling the efficiency of utilization of tailings for conditions of the Republic of North Ossetia-Alania are summarized in Table 4 (Golik *et al*., 2013a, b).

The use of non-traditional technological schemes that protect the environment from the adverse effects of natural tailings desalination disintegration at involving them in the production with combined mechanochemical activation and chemical desalination in the disintegrator, can provide substantial economic effect.

Summary: It is proved that the efficiency of metallurgical and treatment redistributions waste utilization during underground polymetallic ores extraction should be assessed taking into account the ecological and economic situation using complex criterion of efficiency which is the discounted profit.

The possibility of obtaining by a mining company at the same time both economic and environmental impact during production of products of nonconforming raw materials after the change of its properties in the activator.

Table 4: Indicators of mill tailings and metallurgy processing

Articles	1 month	Treatment 1т	Treatment Total	Metallurgy 1т	Metallurgy Total
Processing (tons)	3000	-	5000,000	-	3000,000
Products: metals	400	0.13	650,000	0.20	600,000
Stones	300	0.10	500,000	-	-
Sands	1500	0.50	2,500,000	0.50	1,500,000
Silt	800	0.27	1,350,000	0.30	900,000
Production (thousands rubles)	2600	1.07	5,350,000	2.00	6000,000
ROF expenditures (thousands rubles)	700	0.3	1,500,000	0.50	1,500,000
MZ expenditures (thousands rubles)	1100	0.5	2,500,000	1.00	3000,000
Profit (thousands rubles)	800	0.27	1,350,000	0.50	1500,000
1 complex (thousand tons/year)	-	-	200	-	200
Complexes (items)	-	-	2	-	1
Processing term (years)	-	-	12.5	-	15
Profit (thousands rubles/year)	-	-	108,000	-	100,000
Penalties (thousands rubles/year)	-	-	15000	-	15000
Profit taking into account ecologh (thousands rubles/year)	123,000	115,000			

Technology realization total profit 238,000 thousands rubles/year

CONCLUSION

Correct assessment of environmental costs requires changes in the method of selection of criterion and indicators of the mineral and raw material potential conditions of the region.

Economic and environmental assessment of the efficiency of the processing of tailings in the region that has secondary raw material potential is proposed to determine, taking into account environmental and economic situation, the cost of goods of recyclable resources and completeness of mineral resources use.

As a criterion for the efficiency of mining technologies it is logical to use discounted profit taking into consideration compensation costs for the conservation of environment ecosystems.

The use of non-traditional technological schemes provides both economic and environmental effect which is especially relevant during development of upland minefields.

REFERENCES

Burdzieva, O.G., 2010. The criterion of effectiveness of utilization of tailings. Regional Interdisciplinary Conference of Young Scientists “Science-society” VSC RAS, Vladikavkaz, pp: 56-61.

Ermishina, E.B., 2011. Ways of diversification in the economic system of North Ossetia-Alania. Ermishina, E.B. (Eds.), Herald of Adygeya State University, Ser.: The Economy, 1: 95-100.

Golik, V.I., 2009. Rohstofbasis des Nordlichen Kaukasus. Rohstofbasis Russland. Technische Universitet Bergakademie Freiberg, pp: 76-80.

Golik, V.I., 2013a. Conceptual approaches to the creation of small and non-waste mining production on the basis of a combination of physical-technical, physical and chemical geotechnology. Mining J., No. 5, pp: 46-52.

Golik, V.I., 2013b. Mechanochemical technology of metals extraction from ore coal washery. Proceedings of XV Balkan Mineral Processing Congress Sozopol Bulgari, pp: 263-271.

Golik, V.I., A.A. Ermolenko and V.F. Lazovsky, 2008. Organizational-economic problems of use of natural resources in the Southern Federal District. UMO. Universities. Krasnodar. YUIM, pp: 323.

Golik, V.I., V.I. Komashshenko and K. Drebenstedt, 2013a. Mechanochemical Activation of the Ore ind Coal Tailings in the Desintegrators. Springer International Publishing Switzerland, pp: 163-167. DOI: 10.1007/ 978-3-319-02678-7-101.

Golik, V.I., V.I. Komashshenko and Y.I. Rasorenov, 2013b. Activation of Technogenic Resources l Disintegrators, DC 10.1007/978-3-319-02678-7_107, Springer International Publishing Switzerland, pp: 116-120.

Golik, V.I., Y.I. Rasorenov and A.B. Efremenkov, 2014. Recycling of ore mill tailings. Applied Mechanics and Materials. Trans. Tech. Publications, Switzerland, 682: 363-368. DOI: 10.4028.

Kaplunov, D.R., M.V. Rilnikova, E.A. Blum and A.V. Krasavin, 2003. Scientific aspects of geotechnological strategy selection for the development of ore deposits in a combined way. GIAB. Moscow: Moscow State Mining University, pp: 36-40.

Polukhin, O.N., V.I. Komashcenko, V.I. Golik and C. Drebenstedt, 2014. Substantiating the possibility and expediency of the ore beneficiation tailing usage in solidifing mixtures production. Technische University Bergakademie Freiberg, Germany Publisher: Medienzentrum der TU Bergakademie Freiberg Printed in Germany, pp: 402-413.

Shestakov, V.A., 2000. Optimization of the production capacity of the mine, storage processing order. V.A. Shestakov S.O. Versilov, A.V. Doolin (Eds.)., Mining Information-analytical Bulletin, No. 9, pp: 68-72.