# Innovative technologies of metal extraction from the ore processing mill tailings and their integrated use

**Vladimir Golik**

*Professor, doctor of Technical Sciences,*
*North Caucasus mining metallurgical Institute (State Technical University)*

**Vitaly Komashchenko**

*Professor, doctor of Technical Sciences,*
*Belgorod State National Research University*

**Vladimir Morkun**

*Vice-Rector for research, Doctor of Science, Professor,*
*Head of Computer Science, Automation and Control Systems department*
*State Higher Educational Institution "Kryvyi Rih National University"*

Abstract
Rock refuses of mining and metallurgical production contain a considerable amount of non-ferrous, ferrous, precious, rare and trace metals and represent the man-made feedstock, that has been stockpiled and accumulated as result of lack of the cost-effective and environmentally appropriate technologies of their processing and recycling. Long-term mining wastes storage causes different geochemical reconversions. All these processes can last for many years, until all the waste metals and chemical species will be dissolved and carried out with water or neutralized by means of insolubilizing.
Key words: METAL EXTRACTION, TAILINGS, ORE PROCESSING, ENVIRONMENTAL POLLUTION

Wastes, being a powerful source of environmental pollution, are valuable raw materials for industry. Reducing the harmful effect of mining on the environment can be achieved by improving technology. A critical condition for intensification of economics and systematic environmental management is the fullness and complexity of use of natural resources. It's particularly applied to man-made mineral arrays and tailing dumps.

It is considered, that integral subsurface use allows to receive additionally 25% more of output. This is achieved by the implementation of enhanced recovery programs [1]. Currently, percentage of wastes utilization at the mining and processing plants even in the technologically advanced countries does not exceed 10%. The only possible way of environmental protection is elimination of waste dumps with comprehensive utilization of products after processing, because their biological recultivation does not solve any ecological problems.

The current theory and practice have the following basic framework: economic efficiency of innovative technology is determined taking into account useful properties of raw materials and its earning power, that define the level of business, enterprise value, reliability, liquidity, economic activity and profitability; mechanism of the innovative technology effectiveness justification is implemented using an economic and mathematical model, describing the correlation of production level, time, input requirements, derived benefit and risks [2].

Good results of extraction of nonferrous metals depending on the method of activation, shown in Figure 1, have been obtained on the basis of previous studies.

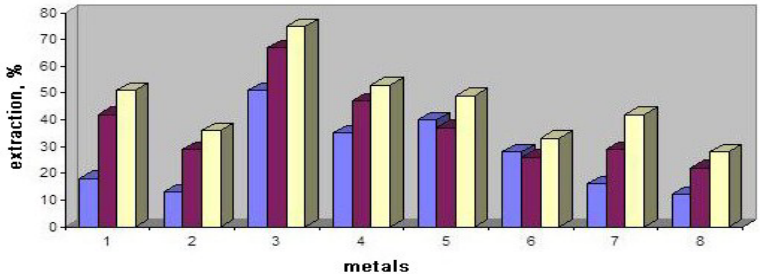
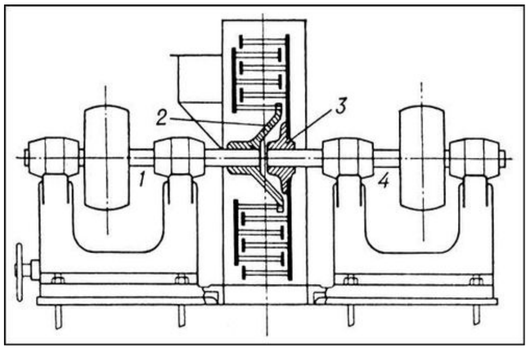



**Figure 1.** Metal extraction depending on the method of activation: 1 – lead from the mill tailings; 2 – lead from the metallurgy tailings; 3 – zinc from the mill tailings; 4 – zinc from the metallurgy tailings; 5 – copper from the mill tailings; 6 – copper from the metallurgy tailings; 7 – iron from the mill tailings; 8 – iron from the metallurgy tailings. First column - hydrochloric acid sprinkling; second column – anolyte; third column – anolyte in disintegrator

Therefore, it is justified that mechanical activation of the tailings provides opportunities for re-treatment of the tailings and out-of balance ores. Activation of the tailings allows to enhance by 10-20% the recovery of zinc, lead and iron from the wastes, thus improving their properties and creating conditions for their use as construction and backfill materials. On the basis of technical and economical analysis of options it is determined, that the most effective is mechanochemical technology of the mining waste treatment process, which combines methods of mechanical and chemical activation in desintegrators (Fig. 2).


a)




b)

**Figure 2.** Desintegrator: a — general view; b — design (1,2 — work discs (baskets)); 3, 4 — driven shafts.

In terms of design, disintegrator comprises two counter-rotating rotors (baskets), mounted on the separate concentric shafts. The rotors are disposed on the one geometric axis, each with the separate drive unit. On the rotor discs in a view of concentric circles are disposed the rods rows (beater rods) so, that each set of the one rotor freely enters between the two rods sets of the other [3].

The wet magnetic separation mill tailings of the iron formations are represented by finely-divided mineral flour, containing 40 - 70% of size division less than 0,071 mm. Chemical composition of the tailings: $SiO_2$ – 64%, Fe – 8%,

$Al_2O_3$ – 5,2%, Mn – 3,2%, $K_2O$ – 0,7%, P – 0,1%, Ca – 0,8%, MgO – 0,2%, Cu – $5 \cdot 10^{-3}$%, Ni - $4 \cdot 10^{-3}$%, Zn - $5 \cdot 10^{-4}$%, As, Ba, Be, Bi, Co, Cr, Li, Mo, Nb, Pb, Sb, Sn, Sr, Ti, V, Y – of around $(30\text{-}50) \cdot 10^{-5}$%. At head grade of iron in the test sample of 8%, by single leaching it’s extracted about 1% of iron, and after three-time disintegrating of the tailings – 3% of iron. By further multiplying of processing cycles it is possible to reach a safe grade of iron concentration (according to the sanitary requirements). Mechanochemical activation by a single-shot processing enhance extraction of metals into solution - as compared to the reference level - up to 25% and has contingency for the further increasing by enhance of the number of processing cycles. On the basis of the regressive dependence it was drawn a graph that displays the variance between metal extraction and content of sulfuric acid and salt. The factors "Ratio of L:S" and "Disintegrator rotor speed" are established in this case at zero-point (Fig. 3) and a graph of variance of metal extraction vs the factors "Ratio of L:S" and "Disintegrator rotor speed", at zero level content of the sulfuric acid and salt (Fig. 4).

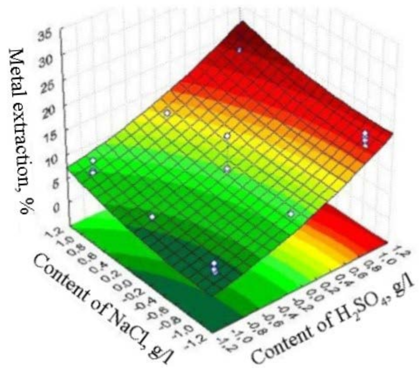



**Figure 3.** Fitted surface of variance between metal extraction, %, and content of H2SO4 and NaCl

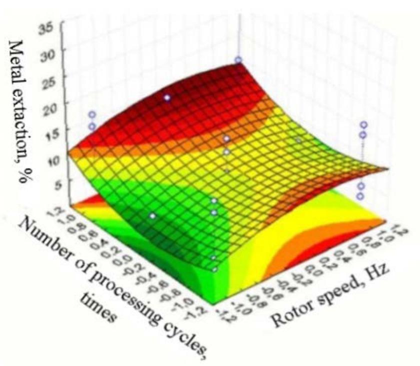



**Figure 4.** Fitted surface of variance between metal extraction, %, L:S ratio and disintegrator rotor speed

Activation in disintegrator without leaching increases the strength of the mixture with cement additive from 1,30 to 1,52 MPa, or by the ratio of 1,17.

The mixtures, activated in disintegrator without addition of concrete can be used for flushing of overwhelming majority of the stopes: concrete strength, made on the basis of the mill tailings increases upon their activation in disintegrators; activation in disintegrator without leaching increases the strength of the mixture with cement additive from 1,30 to 1,52 MPa or by the ratio of 1,17; mechanochemical activation in disintegrator reduces the strength of the mixture with cement additive as compared to dry activation by means of a subsequent gain in moisture of the mixture, but it is offset by increasing the number of processing cycles.

This technology can be considered as non-waste, as far as the essential components (iron, precious and rare metals and platinum group metals) are extracted into the end products, and the secondary tailings are involved into the nature's cycle. Preliminary technical and economic estimate prove its high economic attractiveness and ecological efficiency [4].

Combined activation in acidic conditions at high rotor speed continues for 60 minutes. Leaching in disintegrator increases the metal extraction from the mill tailing almost twice. A feature of combined activation is that the metal extraction is carried out synchronously with crushing of the crystals.

The best results are obtained when agitation leaching of the mill tailings of iron formations at the moment of their activation with solutions in disintegrator.

Selection of production turned out simultaneously with the metals leaching as well as selection of directions of production complexity upgrade for the presently environmentally hostile raw materials can be derived from the sale of metals produced from the tailings and additional products [5].

Today's theory and practice adopts the basic provisions: economic efficiency of innovative technology is determined taking into account the useful properties of the raw material and its earning power, that characterizes the level of business, enterprise value, reliability, liquidity, economic activity and earning power; mechanism of justification of the innovative technology efficiency is implemented using an economic and mathematical model, describing the relationship of output, time, costs, and risks of assimilating innovations [6-10].

**Conclusions**

Thus, the most important directions in reducing anthropogenic impact of mining and processing of iron ores, are: development of a framework concept of environmental protection from process contamination; development and implementation of the reasonable criteria of drilling and blasting operations; development of integrated non-waste closed dressing and end-product yielding systems as well as tailings re-treatment; creation of radically new technologies of recovery of minerals from the man-made solids. In such a way the recommended technology provides metal recovery in a range from 50 to 80% of the initial content in the tailings, decreasing residual content down to the MPC (maximum permissible concentration) standards [10]. The investigations and adoption of modern innovative mining and processing technologies enable to reduce man-made load of the mining enterprises on the environment and to improve geo-ecological conditions in the mining regions.

**References**

1. Golik V.I., Komashchenko V.I., Leonov I.V. Mining engineering and environment . Moscow, Academic project. Culture, 2011, 295 p.
2. Komashchenko V.I., Golik V.I., Drebenstedt K. Environmental ipacts of prospecting and mining. Moscow, KDU, 2010
3. Golik V.I., Komachshenko V.I., Drebenstedt K. (2013). *Mechanochemical Activation of the Ore ind Coal Tailings in the Desintegrators*. p.p.1047-1057.
4. Golik V.I., Komashchenko V.I.,Rasorenov Y.I. (2013). Activation of Technogenic Resources l Disintegrators. *Switzerland: Springer International Publishing*, p.p. 1001-1010.
5. Komashchenko V.I., Komashchenko S.V., Erokhin I.V., Burdzieva O.G. Development of effective methods of integrated and complete metal extraction from man-made raw materials for the purpose of recreation of geology and mining environment. Voronezh, November 20-22, 2013, p.p. 330-333.
6. Morkun V., Tron V. (2014). Ore preparation multi-criteria energy-efficient automated control with considering the ecological and economic factors, *Metallurgical and Mining Industry,* No5, p.p. 4-7.
7. Morkun V., Morkun N., Pikilnyak A. (2015). Adaptive control system of ore beneficiation process based on Kaczmarz projection algorithm, *Metallurgical and Mining Industry,* No2, p.p. 35-38.
8. Morkun V., Morkun N., Tron V. (2015). Identification of control systems for ore-processing industry aggregates based on nonparametric kernel estimators, *Metallurgical and Mining Industry*, No1, p.p. 14-17.
9. Morkun V., Tron V. (2014). Automation of iron ore raw materials beneficiation with the operational recognition of its varieties in process streams, *Metallurgical and Mining Industry,* No 6, p. p. 4-7.
10. Morkun V., Tron V. (2014). Ore preparation energy-efficient automated control multi-criteria formation with considering of ecological and economic factors, *Metallurgical and Mining Industry*, No5, p.p. 8-11.