Prospects of mining waste use

Sergey Stradanchenko

Director, D.Sc. in engineering, Prof.
Don State Technical University in Shakhty,
Russia
Email: ssg72@mail.ru

Stansilav Maslennikov

Deputy director of scientific and innovative work,
PhD in Technical Sciences
Don State Technical University in Shakhty,
Russia
Email: maslennikovsa@mail.ru

Vladimir Dmitrienko

PhD in Technical Sciences, associate professor
Don State Technical University in Shakhty,
Russia
Email: vadmitrienko@rambler.ru

Irina Kokun'ko

PhD in Technical Sciences, associate professor
Don State Technical University in Shakhty,
Russia
Email: kokynek@rambler.ru

Irina Kapralova

Senior teacher
Don State Technical University in Shakhty,
Russia
Email: dsp_2007@bk.ru

Abstract
The problem of technogenic waste recycling - mill tailing of metal ores beneficiation was considered. The way of metals extraction from waste was suggested, experimental researches results were presented. The dependences of metal extraction on the content of sulfuric acid, sodium chloride in the leaching solution, intensity of mechanical impact and ratio of liquid and solid phases were obtained.
Key words: ORE MINING INDUSTRY, TAILINGS, DESINTEGRATION, RECYCLING, METAL EXTRACTION

There are about 100 billion tons of solid waste in culm banks, storages of slimes and tails of mining and metallurgical complexes of Russia. Annually, about 15 million tons are added, and no more than 10% of them are recycled. The storage of mineral raw materials, which are not accessible for recycling, threatens with ecological disaster; therefore, the radical recycling of tailings by technological means is only one possible measure for danger reduction [1,2].

The works on decrease in harmful effect of mining industry waste on the environment are being conducted for many decades in the countries of North America and Western Europe. The great means were expended for carrying out of technical, biological reclamation, development of ways of waste long-term isolation on surface or underground, their processing, and activity reduction. This allowed us to make significant progress in the specified areas and to get competitive advantages in the markets of both developed and developing mining countries. But burial of metallic tails at small depths, including biological reclamation without extraction of dangerous components is dangerous palliative.

The research project implemented with authors participation is based on fundamentally new approach to mining industry recycling. Instead of waste long-term storage with application of expensive measures for reduction of their harmful effect on environment, the technology of complete recycling including extraction of dangerous components from waste to safe level with absolute involvement of processing from waste in economic circulation is suggested. There is an experience of use of mining waste as mineral fillers. This solution leads to constantly operating reactors of chemical pollution, as the metals containing in waste under the influence of natural leaching migrate in gydro- and atmosphere causing serious consequences. There is an experience of metals extraction from mining waste by mechanical activation and the subsequent leaching. Such solution will lead to accumulation of fine secondary products of processing. Their storage presents considerable difficulties, it is almost impossible to prevent demolition of substance with the particles size of a few microns [3-5].

The problem of waste accumulation is also intensified by the fact that mining by underground way grows constantly [5-7], the content of metals is reduced and mining-geological conditions are complicated. It causes the ores dilution increase with growth of formation of primary processing tails containing heavy metals and posing danger to the environment when storing on surface. For example, the average content of copper in ore fell from 0.95% to 0.7% from 1987 to 2013 that at the equal volume of a commodity product leads to increase in waste by 30-40%; it leads to waste increase by 30-40% at the equal quantity of marketable product.

Average values of waste formation at a stage of production and processing are given in Table 1.

Meeting the time challenges at the Chair of "Building" of SRSTU (NPI) within the federal target program "Researches and Development in the Priority Directions of Development of Scientific and Technological Complex of Russia for 2007-2013", the research project, which was intended to develop technology of extraction of metals from waste of mining production, was developed. Obtaining of additional products in the form of zinc and lead, and also complete use of production waste after bringing of the metals content in them to norms of admissible concentration limit were tasks of the project.

Table 1. Average values of waste formation *

Useful product (1 ton)	Waste	
	in the course of production	in the course of beneficiation
Steel	5-6 tons	0.5-0.7 tons
Non-ferrous metals	100-150 tons	30-60 tons
Rare, precious and radioactive metals	5-10 thousand tons	10-100 thousand tons

*Data of Academy of mining science

The implemented project is based on basically new approach to advanced processing of solid minerals with complete recycling. The suggested technology includes extraction of dangerous components from waste to the safe level with absolute involvement of secondary products of processing to the economic turnover. The increase in completeness of metals extraction is based on the fact that when processing on desintegrating technology with impact velocity of 250 m/s, the substance takes on the new technological properties, and the leaching solution is pressed in the microcracks appearing during activation. The properties, which are appeared during dispergation of solid bodies, are used for involvement of secondary waste to the economic turnover. Thus, the larger the surface of the substance participating in process is, i.e. the less the particles size of obtained product is, the quicker and more complete the processes in the activated substance proceed.

The developed technology underwent experimental testing. Experiments included:

1. Agitation leaching of metals by reactive chemicals.

2. Leaching of metals by reactive chemicals combining with activation in desintegrator.

According to the first experiment stage, variable factors varied on the following levels.

1. The content of sulfuric acid and sodium chloride, X_1, X_2 (changed on levels respectively: X_1 -1 - 2, 0 – 7 and 1 – 12 g/l, X_2 -1 – 20, 0 – 100 and 1 – 180 g/l).

2. Solid to liquid ratio, X_3 (changed on levels: X_3 - 1- 4, 0 – 7 and 1 - 10).

3. Time of agitation leaching, X_4 (changed on levels: X_4 -1 – 0.25, 0 – 0.625, 1 - 1 hour).

According to second experiment stage:

1. The content of sulfuric acid and sodium chloride, X_1, X_2 and L:S ratio, X_3 changed on the same levels as in the previous series of experiences.

2. Rotation speed of desintegrator rotors, X_5 (changed on levels: X_5 -1 -50, 0 - 125, 1 – 200 hz).

Experiments were conducted with the use of methods of experiments design according to $3^{(k-p)}$ factorial design with 27 experiments and 3 central points [1]. 5 experiments were set up in each point of the design. The determined values were averaged for the lots under investigation; that allowed reducing of mistake.

Mathematical processing of experiments results was carried out by means of the Statistica 6.1 program. The model was in the form of regression dependence considering linear and square effects and their interactions in the form of equation:

$$\varepsilon_{Zn,Pb}=a+a_1\times X_1-a_2\times X_2+a_3\times X_3+a_4\times X_4+a_5\times X_1^2+a_6\times X_2^2+a_7\times X_3^2+a_8\times X_4^2+$$
$$a_9\times X_1X_2+a_{10}\times X_1X_3-a_{11}\times X_1X_4+a_{12}\times X_2X_3+a_{13}\times X_2X_4+a_{14}\times X_3X_4$$

where X_1 – content of H_2SO_4, g/l;

X_2 – content of NaCl, g/l;

X_3 - solid to liquid ratio;

X_4 – time of agitation leaching, h;

for the second stage experiments X_4 is substituted by X_5;

X_5 - frequency of rotation of desintegrator rotors, hz.

The values of the determined regression coefficients are given in Table 2.

Table 2. Regression coefficients

	For the regression equation (ε_{Zn})			For the regression equation (ε_{Pb})		
	Regression coefficient	Confidence limit		Regression coefficient	Confidence limit	
		-95,%	+95,%		-95,%	+95,%
a	69.11	62.4	75.8	-37.9	-56.1	-19.8
a_1	7.57	6.93	8.2	7.13	5.42	8.85
a_2	-0.239	-0.273	-0.205	-0.395	-0.487	-0.304
a_3	-0.851	-0.889	-0.813	0.956	0.855	1.06
a_4	0.0023	0.00217	0.00243	-0.0035	-0.0038	-0.0031
a_5	-2.19	-3.62	-0.762	3.28	-0.602	7.16
a_6	0.0343	-0.0594	0.128	-0.0823	-0.336	0.172
a_7	-0.117	-0.163	-0.0709	-0.0522	-0.177	0.0729
a_8	-0.00048	-0.00063	-0.00033	0.0001	-0.0003	0.0005
a_9	-0.00319	-0.00482	-0.00156	-0.0032	-0.0077	0.0012
a_{10}	-0.207	-0.25	-0.163	-0.275	-0.393	-0.156
a_{11}	0.00499	0.00325	0.00673	-0.0013	-0.0061	0.0034
a_{12}	0.00915	0.00643	0.0119	-0.0039	-0.0113	0.0034
a_{13}	0.00111	0.00100	0.00122	-0.0001	-0.0004	0.0002
a_{14}	0.0187	0.0158	0.0216	0.0034	-0.0045	0.0112

Mean-square deviations for the first and second equations are 0.837 and 0.811 respectively.

The importance of the influencing factors is visualized on Pareto map for the standardized effects (Fig. 1), linear effects are designated by the sign (L), square ones by(Q), 1L on 2L, etc. – combinations of the corresponding factors.

The regressional dependence of zinc extraction on two most significant factors is presented by the three-dimensional graphics in Fig. 1. The percent of zinc extraction reaches the maximum values in the considered range of independent factors at the maximum content of H_2SO_4 in solution and the minimum NaCl content. Frequency of working body rotation of desintegrator increases zinc output significantly and gives maximum at X_5=200 hz. The lead output reaches the greatest values in the case of content of H_2SO_4=3.94 g/l and NaCl=127 g/l.

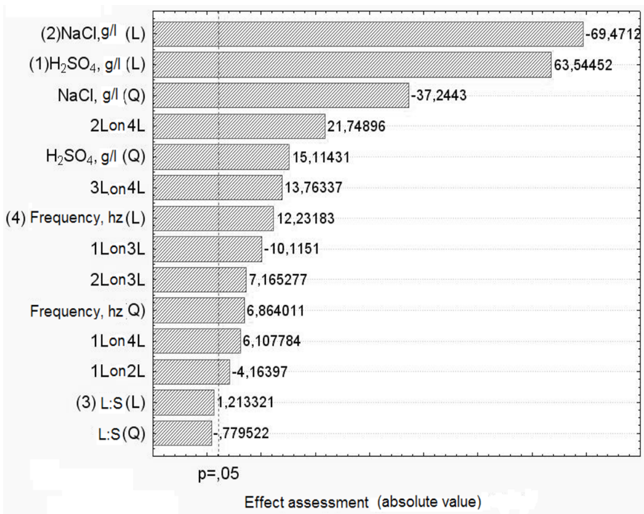

Figure 1. Influence of prime factors on objective function

Conclusion

Experimental researches confirmed that combination of mechanical and chemical impact on metallic minerals increases percent of metals extraction significantly (up to 1.22 times). Thus, better extraction of metals in solution is provided in desintegrator in time, which is by 2 times less, than when leaching without activation.

Indicators combined mechanical-chemical-activation process of metals extraction can be improved due to increase in time of activation by a repeated passing of pulp through the desintegrator.

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