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Economic and Technological Aspects of Metal Leaching Metals from Coal Mine Refuses

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Abstract: The utilization problem of metal containing coals was formulated. It was shown that the traditional methods of enrichment promote the formation of technogenic deposits on the earth surface. The results are provided concerning the experimental extraction of metal from the coal mine refuses by mechanical activation method. It was shown that the concept of coal industry development should include the development of innovative technologies for man-made stock utilization.

Key words: Coal, utilization, tails, extraction, mechanic activation, metal, efficiency, leaching, technology

INTRODUCTION

The problem of man-made mineral deposits gained its urgency in recent period due to a sharp increase of mineral production volumes at the lagging of its processing technology level. The reduction of extracted raw material quality at the extraction from the subsoil is not compensated fully by its enrichment processes, so technogenic deposits are formed on the earth surface (Davies and Rice, 2001).

During the process of 1 ton of salable coal extraction and enrichment 3.3 tons of waste are produced. Every year 0.5 billion m^3 of rock mass is extracted from the depths in Russia and about 60 million m^3 of tailings are formed and only up to 10% of this type of resources is used (Fig. 1). Waste recycling problem is particularly acute for the coal-mining regions, including the Russian Donbass. In Rostov region the carbonaceous wastes occupy 1.3 thousand hectares of land and the area of lands disturbed due to the mining of coal reaches 7 thousand hectares (Kornilov *et al*., 2014).

Prior to economic reform of 90-ies up to 19 concentrators were operated on the territory of Russian Donbass. The area supplied up to 1/3 of coking coals in the USSR and about a quarter of thermal coals. Currently, the production of coal is reduced in times, and the problem of mine refuse keeping escalated.

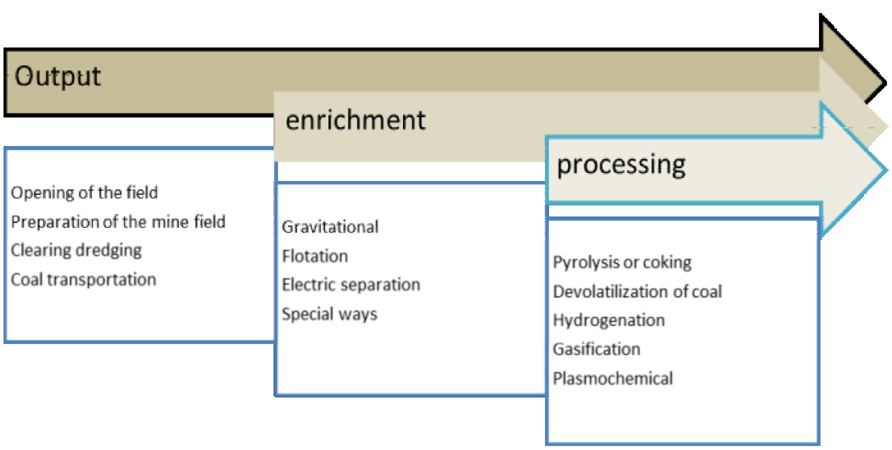

Fig. 1: Production processes of technogenic deposit formation

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MATERIALS AND METHODS

About 450 of mine dumps and concentrators with the capacity up to 280 million m3, including mine dumps with the capacity up to 150 million m3 and factory dumps with the capacity up to 130 million m3 were located on the territory of Russian Donbass. The mine refuses contain up to 20% of coal and up to 2.1% of sulfur. Most dumps are in burning stages.

The tails are characterized by the following content of fractions, %: more than 40 mm from 7-63, 20-40 mm from 8-46, 10-20 mm from 7-27, 5-10 mm from 4-31, <5 mm from 2-34. The chemical composition of tails: Si O_2, from 40-53%, Al_2O_3,from 15-16%, Fe_2O_3-from 4-9%, Ca O, from 1-3%, SO_3,from 0,1-0,8%, K_2O-from 0.4-0.5, Na_2O from 0.1-0,3%, Mn O from 0.3-0.7%.

The effective specific activity $A_{эфф}$ of natural radionuclides Ra-226, Th-232, K-40 is close to the maximum permissible value of 370 Bq/kg. Coal mining and processing wastes contain metals, including, non-ferrous, rare and precious ones. The increased concentration of vanadium and chromium waste is set in the extraction wastes of many areas, making 3.3 on the average.

RESULTS AND DISCUSSION

The metal content in mine refuses is characterized by (Table. 1) (Davies and Rices, 2001). A profound disposal of mine refuses provides profit not only from the sale of by-products, but also due to the environment improvement up to the sanitary level. Traditional processing technologies allow to extract metals from the richest tailings but they do not solve the problem, since, the secondary tailings also contain more metals than PMC allow (Rolf Dieter *et al*., 2009; Bian Zhengfu *et al*., 2012; Golik *et al*., 2014; Golik *et al*., 2015; Golik *et al*., 2015).

The ore industry develops the technologies, using the phenomenon of useful component transfer into soluble compounds-leaching (Petersen, 2015; Sinclair and Thompson, 2015; Golik *et al*., 2015). The effectiveness of these technologies is determined by the parameters of a leaching solution movement through the leaching material and prevented by the clogging the spaces between the fine fractions of minerals (0.1-0.2 mm).

In order to activate the process the mineral and solution pulp is stirred, but it also does not provide the extraction of metals within economically acceptable terms. The leaching of metal-containing raw materials in activators and disintegrators combines the possibilities of activity increase by the processing in a disintegrator with the extraction of metals by leaching (Golik *et al*., 2015; Golik *et al*., 2015; Golik *et al*., 2015).

The difference of this method from the known methods is the combined use of mechanical activation and leaching with a reagent delivery deep into a particle under pressure (Fig. 2). The completeness of metal recovery from coal mine refuses is characterized by Table 2.
Leaching modes differ in sequence and a place of metal extraction in solution (Fig. 3). The regression models obtained after the experiment with a confidence level of 95%, show that the success of leaching is determined according to their importance: the composition of a leaching solution, the ratio of a solution and raw materials and leaching time. During leaching in a disintegrator they are added by disintegrator rotor speed and the number of leaching stages in a disintegrator.

The best option of studied material leaching is determined by the comparison of metal extraction calculated values under the varying parameters of leaching.

A correct determination of quantitative parameters concerning metal transition in solution is provided by solution evaporation and the sedimentation of complex gel from soda solution up to pH 9.0 with the transfer metals into an insoluble form and with the subsequent evaporation. The initial content of metals in coal mine refuses is characterized by Table 3.

Samples were treated in the oven at the temperature of 60°C to with the obtaining of the evaporated concentrate of metals. The other samples of each batch were added with soda solution with the pH value up to 9.0 in order to convert metals in an insoluble form and prepare a complex gel.

After the evaporation and drying, the reduced samples were calcined at the temperature of 300 °C for the removal of crystalline-bound water with a dry concentrate obtaining (Tables 4-6). The experimental data support the possibility of metal leaching from coal mine refuses with the bringing of the

Table 1: The metal content in mine refuses

	Maintenance of elements, g/t										
Dressing-works	Mn	Ni	Co	V	Cr	Mo	Zr	Pb	Zn	Be	Sr
Donetsk	640	74	17	124	222	5	113	74	149	3	175
The Hookean	989	39	14	79	148	5	99	49	83	4	594
Sholokhovskaya	324	55	24	242	242	6	104	55	263	2	356
Nesvetayevskaya	790	49	10	99	198	3	99	39	148	3	151

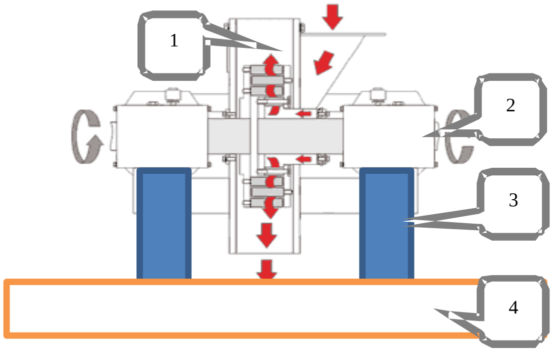

Fig. 2: Disintegrator components: 1; working body; 2- electric motor; 3- vibration damper; 4- basis

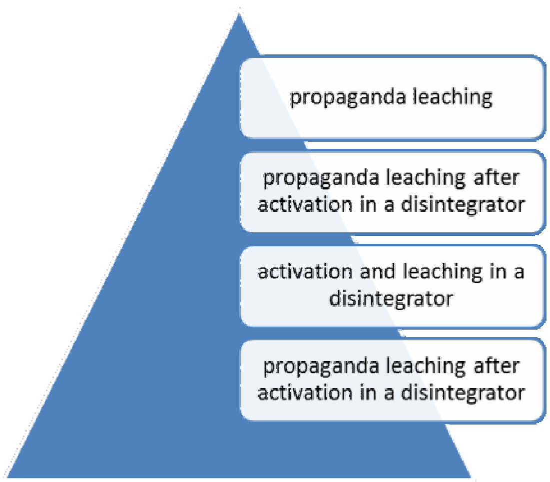

Fig. 3: Schemes of mechanical and chemical energy combination in the course of metal leaching

Table 2: Dry concentrate composition from coal mine refuses

Metal,%	Burned tails	Not burned tails
chrome	0.10	0.15
Iron	2.75	3.06
Nickel	0. 30	0.17
Manganese	0.10	0.10
Cobalt	0.10	0.12
copper	0.40	0.30
Lead	0.1	0.1
Zinc	0.30	0.14

Table 3: Metal content in coal mine refuses, g/t

Element	At least	At most	Average
Manganese	310	330	320
Nickel	10	40	25
Cobalt	5	10	5
Vanadium	60	130	95
Chrome	50	140	85
Molybdenum	1	2	1.5
Zirconium	60	90	75
Lead	20	90	55
Zinc	10	40	50
Beryllium	2	2.6	2.3

Table 4: The extraction of metals from burned coal mine refuses

Metal	Evaporated concentrate, (%)	Dry concentrate, (%)	Δ, time
Chrome	0.01	0.10	10
Iron	0.85	2.75	3
Nickel	0.03	0. 30	10
Manganese	0.01	0.10	10
Cobalt	0.02	0.10	5
Copper	0.03	0.40	13
Lead	0.01	0.1	10
Zinc	0.04	0.30	7

Table 5: The extraction of metals from unburned coal mine refuses

Metal (%)	Evaporated concentrate, (%)	Dry concentrate, (%)	Δ, (time)
Chrome	0.03	0.15	5
Iron	1.3	3.06	2.4
Nickel	0.026	0.17	6
Manganese	0.015	0.10	8
Cobalt	0.03	0.12	4
Copper	0.03	0.30	10
Lead	0.01	0.1	10
Zinc	0.02	0.14	7

Table 6: Dry concentrate composition from the tailings of different grades

Metal (%)	Evaporated concentrate, (%)	Dry concentrate, (%)	Δ, (time)
Chrome	0.10	0.15	+ 0.05
Iron	2.75	3.06	+ 0.31
Nickel	0. 30	0.17	-0.13
Manganese	0.10	0.10	0
Cobalt	0.10	0.12	+ 0.02
Copper	0.40	0.30	-0.10
Lead	0.1	0.1	0
Zinc	0.30	0.14	7

residual content to the sanitary requirements by repeated processing. The tails of mechanic-chemical activation for coal mine refuses are presented by dispersed mass composed of the particles the size of which makes about 0.1 mm with a uniform structure, which improves its quality during further use, for example, by 15-20% increase of concrete strength produced on the basis of activated tailings in a disintegrator. The effectiveness of tailing storage facility management:

$$? = \sum_{t=1}^{T}\left(\sum_{1}^{n} C_{?} - \sum_{1}^{n} C_{o}\right)\cdot Q$$

Where:

$C_б$ = And
C_o = Are the basic and new costs associated with the storage of tailings
Q = The volume of recyclable tailings

$$\Pi_X = \frac{\sum_{1}^{n}(C_T - ?_o - ?_M)Q_y}{t_y} + ?_w$$

where:

$П_x$ = The profit from tailing processing, rub./t
C_T = The cost of recycled products, rub./t
$З_o$ = The costs of enrichment, rub./t
$З_M$ = The costs on metallurgical processing, rub./t
n = The amount of extracted components
Q_y = The amount of utilized tailings, t
t_y = Utilization period, year
C_w = Fines for tail storage, rub./year

The prospects of coal mine refuse deep processing by the leaching of metals make the part of the global problem concerning the humanization of society attitude to nature (National Energy, 2013; Wang, 2009).

CONCLUSION

The tailing storage facilities of coal companies make the promising mineral resource base of precious metal production. The development of deep processing innovative technologies for industrial resources is an urgent task of coal mining enterprises. The complex solution of issues for the deep processing of coals and coal extraction wastes improves the environmental situation in the coal-mining regions.

The concept of coal industry development should include the development of innovative technologies as a component for the utilization of man-made stocks which form the infrastructure of a high-tech cluster.

The problem of man-made mineral deposit development exacerbated during new period by the continuing lagging of processing technology level at the continued increase of mineral extraction volume. The accumulation of waste is the most dangerous for coal-mining regions, where mining production is adjacent to the agricultural development. Prior to the economic reform of 90-ies at the enterprises of coal mining and processing the concentrators were operated, resulting in the formation of technogenic deposits of substandard raw materials for traditional technologies.

Nowadays, in many regions of coal mining production the volumes of coal production decreased several times, but the problem of the mine refuse keeping became worse due to the backlog of substandard raw material enrichment methods, and the negative effects of the coal industry restructuring. The implemented concept of weakly active reserve write-offs instead of their cost-effective use technology development and the depersonalization of technogenic deposit tail belonging create the conditions for environmental complications with global consequences.

In these circumstances the specification and the development of the proposed technology concerning the leaching of valuable components from coals with the involvement of secondary tailings in the production deserve some attention and implementation.

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