Intensification of Biochemical Leaching Process Through Application of Mine Water

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ABSTRACT

Through the investigation of processes of bacteriological treatment of low-grade (out-balance) mineral raw materials, carried out in Institute for Technology of Nuclear and Other Mineral Raw Materials (further: Institute), it is pointed out at the possibilities of utilization of natural mine drainage to this purpose. Utilization of these waters in bacteriological leaching process, after their enrichment with agents that support leaching (bacteria, acidity, iron), the valorization of usefull components (metals) is much more successfull.

The efficiency of bacteriological leaching of copper and uranium ores as a function of a great number of technological parameters was investigated against autochtone bacterioflora separated from mine drainage, on one hand, and against a direct utilization of mine drainage as a lixiviant, on the other. The terrain investigations (analyses of mine drainage and seepages from mine deposits) showed that there exists a correlation between a quality of water (acidity, degree of oxidation, content of metal) and a quantitative presence of hemoautothropic bacteria (of Thiobacillus genus), i.e., that overall oxi-reducing processes determine a degree of natural leaching. The final objective of the investigations presented in this work is utilization of mine drainage in process of bacteriological leaching and a possible implementation of this method into practice.

INTRODUCTION

The years long investigations of bacteriological leaching of low grade ores of copper, uranium, antimony and molibdenum, copper dumps and tailings (i.e., already treated ores), carried out in Institute on laboratory and pilot-plant scales, pointed out at the possibility of practical application of this method. On the basis of our findings and findings obtained elsewhere, nearly all significant parameters that determine the efficiency and justification of application of this method are defined. One general attitude is also established, that each deposit (dump store) has it's own specificities in form of abiotic and biotic factors, that should be investigated in each individual case.

Over the last few years, these general investigations associated with bacteriological leaching of low grade ores took over a more detailed courses, such as relating of microbial leaching with environment protection and intensifying of this leaching process to the maximum, through utilization of all natural and technological factors. Starting with the facts that a natural bacteriological proces (including an "additional" one, too) is relatively slow process that depends on a number of parameters, particularly on the quality of lixiviant (it's acidity and occurance of present bacterioflora), also that mine drainage and seepages originating from the places where natural leaching potential exists are acid, this all should be taken into account and such waters should be utilized to this purpose.

The specificities of deposit planned for a possible bacteriological leaching are in physico-chemical and mineralogical characteristics of ore, topographis and hydrogeological conditions, ecological factors related with possible growth of subsequently introduced bacterioflora, quality and quantity of water and it's flow regime, etc. On this occasion, we would like to emphasize that a term "mine drainage" is used irrespective of way of it's formation, but having in mind that all these waters had passed through an ore deposit (abandoned mines, research mine galleries) or dump stores (tailing), either primary, or secondary ones.

MATERIAL AND METHODS

While investigating the possibilities or increased efficiency of utilization of mine drainage in the process of bacteriological leaching of primary low grade ores or tailings, either in situ or in heap, the results of laboratory leaching of several samples of a primary low grade ores were used, together with the results of investigation of mine drainages from a primary ore deposits of copper, uranium, nickel and molybdenum (abandoned mines and research galleries), and mine drainages, from secondary dump stores.

For laboratory investigation of bacteriological leaching of primary and secondary mineral raw materials, (ores and tailings), the gass columns of various volumes (12,000 cm^3, 800 cm^3, 200 cm^3 and flasks) were used. The parameters of bacteriological leaching were set up and adjusted depending on the objective and material used. In these experiments, (unless specified otherwise), bacterial cultures of hemoautothropic bacteria of Thiobacillus thiooxidans and Thiobacillus ferrooxidans, isolated in the previous years from mine deposits of copper, uranium, molybdenum and antimony by the ordinary techniques [(2,3,4,6)] were used as the standard ones. The number of bacteria in input solution (variant with bacteria) was between 10^7 and 10^8 per cm^3. In variants where a "natural" mine drainage was used, the number of bacteria (of Thiobacillus genus) was determined immediately before leaching proces and the population occurance varied between 10^2 and ^{5} per cm^3. During the laboratory experiments of leaching, a number of bacteria was perminently followed by a method of dilution.[(5)] It has to be mentioned that on utilization of mine drainage (without subsequent intervention), there were also some other bacteria, besides ones belonging to Thiobacillus genus, but in this investigations these were not further identified.

For investigation of effects of autochtone bacterioflora from mine drainage in laboratory processes of bacteriological leaching, the following materials were used:

1. Uranium material
1a. natural sample (PT-1)
1b. natural sample (PT-2)
1c. sample treated by hydrometallurgical method (PUR-1)
1d. sample treated by hydrometallurgical method (PUR-2)

2. Copper-bearing material
2a. ore (NR)
2b. sample, previously treated (PTR)

The concentrations of uranium and copper in this material are presented in Tables 1,2 and 3.

Within the investigations of possibbilities of bacteriological leaching of low grade ores and tailings (both primary and so called "technological" tailing), the terrain investigations were carried out at the localities of Bor-Majdanpek, Avala ("Šuplja Stena"), Bukulja (research operations) and Mačkatica (abondoned mine). From these localities where oxi-reduction was evident, the samples of ores and mine drainages were taken. On these samples, a detailed tests were carried out in laboratory to determine the presence of bacteria (particulary of Thiobacillus genus) and the concentration of anions and cations in water samples. Water samples from these localities were also used in a specific variants of bacteriological leaching of ores from the same localities. The autochtone bacterioflora was used directly in leaching process, or a pure culture was obtained by certain techniques and then used for determination of oxi-reducing capacities of isolated bacteria.

The physico-chemical methods used in this work were carried out according to standards [1,2,7], while the methods of isolation, determination and counting of bacteria were achieved by techiques standard to this purpose [3,5,7].

RESULTS AND DISCUSSION

The effect of bacteriological leaching of primary low grade copper and uranium ores and waste material (previously treated by some of the ordinary methods), aiming at intensification of this process and associated, beside others, with utilization of mine drainage, several samples of copper and uranium material were investigated on laboratory level.

Bacteriological leaching of uranium material (tailing) from locality Bukulja, under laboratory condition, at varying quality of starting solution for leaching, is presented in Table 1. For both samples (PT-1 and PT-2), the highest percentage of extraction was achieved in the first variant, where the spent bacteriological medium by Leathen was used as a solution, somewhat weaker leaching was achieved when a natural mine drainage (without addition of bacterioflora) was used, while the weakest effect was achieved in a control variant.

In Table 2, the results of bacteriological leaching of a primary uranium ore comminuted to a desired granulation, leached by mine drainage, are presented. In this case, the controls used were: solutions of Leathen medium and a variant without bacteria. While samples PT-1 and PT-2 were leached for 34 days, PUR-1 and PUR-2 samples were leached for 65 days and the achieved percentage of extraction was much higher, judged by time only. The best results were achieved in the first and in the second variant (Leathen medium and mine drainage), while the weakest effects were registered in the third, (control) variant.

Bacteriological leaching of copper ore (sample ("NR") and ore that was already treated (technological tailing, sample "PTR) by autothropic bacteria of Thiobacillus genus in mine drainage, with the corresponding controls, is presented in Table 3. In both samples, the highest extraction is achieved in the variant where bacteriological Leathen media was used as solution for leaching, somewhat lower in the variant where mine drainage was used, while the weakest extraction was achieved in their controls (variants 3). The difference in extraction percentage registered between the two samples is significant. This is explained as due to the fact that "PTR" sample was previously treated at a standard hydrometallurgical method by sulphuric acid and, in that way, better prepared for bacteriological leaching, since it provided more favourabe initial conditions for bacterial growth.

During bacteriological leaching of copper-bearing and uranium materials, we monitored the change in number of introduced bacteria. In all samples, considerable increase in number of bacteria is detected in the first half of leaching period, in the first and the second recycling (the curve of bacterial growth is steep), in those variants where mine drainage was used as lixiviant. Towards the end of leaching cycle this difference disappears, so the curve of populations growth is getting the same form, i.e. the increase in number of bacterial units per a unit of time is becoming approximately the same for all variants. This is explained as due to the fact that the initial conditions for bacterial growth and multiplication in the "natural" mine drainage are much more favourable, particulary if bacterioloflora selected from that or the neighbouring water is used, because there is a certain preadaptation of bacteria to the environmental conditions. This phenomenon, expressed in a form of improved conditions for bacterial growth, is also reflected upon the overall conditions that influenced the effect of bacteriological leaching (percentage of extracted metal, adicity of leaching solution, better expressed oxi-reducing process, higher redox potential).

Depending on time and place of sampling, the samples of mine drainages used in tests of bacteriological leaching varied both in chemical composition (concentration of anions and cations) and bacteriological composition (number of bacteria of Thiobacillus genus). In certain samples of mine drainage collected after the abandoned mine research activities, the concentration of uranium varied up to 0.1 g/l, that of iron - up to 5 g/l, while the acidity was mainly between 2 and 3. Mine drainage from abandoned mercury mine contained about 0.3 - 1.1. g/l of nickel, up to 0.1 g/l of cobalt, up to 5 g/l iron (over 80% in two-valent state), between 9 and 12 g/l of sulphate ions, while the acidity was about 2.5. The concentration of copper in mine drainage (seepage from tailing and "blue water") was occasionally above 0.2 g/l (the average value was about 0.03 g/l), while the concentration of cations in these waters was about 3 g/l. It is worth mentoning that the concentration of cations in these waters was directly dependent on it's acidity, while this all was dependent on qualitative and quantitative composition of hemoautothopic bacteria.

Autochtone hemolitic bacteria of (of Thiobacillus genus), selected from mercury mine drainage ("Šuplja Stena) were used in our laboratory experiments as convenient

Table 1. Leaching of uranium (samples "PT-1 and "PT-2)

Content of uranium	Sample "PT-1"			Sample "PT-2"		
	variant			variant		
	1	2	3	1	2	3
initial content (g/t)	97.00	97.00	97.00	141.00	141.00	141.00
total weight extracted (g/t)	49.65	44.23	6.38	48.78	46.53	5.78
remained in ore afterleaching (g/t)	47.35	52.77	90.61	92.21	94.47	135.22
% of extraction	48.20	45.60	6.20	34.60	33.00	4.10

Table 2 . Leaching of uranium (samples "PUR-1" and "PUR-2")

Content of uranium	Sample "PUR-1"			Sample "PUR-2"		
	variant			variant		
	1	2	3	1	2	3
inital content (g/t)	320.00	320.00	320.00	364.00	364.00	364.00
total weight extracted (g/t)	270.72	257.28	40.35	313.00	263.54	33.48
remained in ore after leaching (g/t)	49.28	62.72	297.65	50.60	100.46	330.52
% of extraction	84.60	80.40	12.60	86.10	72.40	9.20

Table 3.Bacteriological leaching of copper

	Sample "NR"			Sample "PTR"		
	1	2	3	1	2	3
a. concentration of Cu material before leaching, g/t	1140	1140	1140	280	280	280
b. concentration of Cu in leaching solution, g/l:						
- after I cycle	0.0735	0.0850	0.0050	0.0350	0.0410	0.0050
- after II cycle	0.0910	0.0560	0.0065	0.0215	0.0185	0.0040
- after III cycle	0.0435	0.0245	0.0050	0.0200	0.0100	< 0.0020
- after IV cycle	0.0190	0.0480	0.0070	0.0170	0.0080	< 0.0020
c. taken for the analyses, g/l	0.0120	0.0100	0.0024	0.0064	0.0050	0.0001
d. total (b + c)	0.2390	0.2234	0.0290	0.1008	0.0826	0.0094
e. left in ore, after leaching, g/t	656.6000	693.1000	1080.7000	78.1000	114.8000	261.2000
f. total copper extracted, g/t	483.4000	446.9000	59.3000	201.9000	165.2000	18.8000
g. % of extraction	42.4000	39.2000	5.2000	72.1000	59.0000	6.7000

Note: Sample "NR" -ore, Sample "PTR" -sample previosly treated by a standard hydrometallurgical process,
1 - Test with bacteria, 2 - Test with mine drainage, 3 - Control.
Experiment carried out with 5 kg. of ore, terated by 10 1. of lixiviant

oxidizers of iron contained in this water, in order to facilitate the subsequent extraction of nickel from it.

On the basis of investigation of bacteriological leaching process, occurance of bacteria in mine drainage and their physicochemical characteristics, the following conclusions can be derived:

- introducing of process of "additional", subsequent valorization of usefull components from mine drainage is greatly improved if combined with bacteriological leaching
- such a valorization and the further investigations are necessary also because of simultaneous support of the environment protection
- intensification of natural leaching process through the application of bacteriological leaching should be techologically solved together with the efficient extraction of metal from the leaching solution
- the investigations presented in this paper did not regard the amounts of mine drainages, which certainly is of relevance to for a possible practical use.

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