Small-scale and large-scale testing of photo-electrochemically activated leaching technology in Aprelkovo and Delmachik Mines

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Abstract. The paper gives a description of tests and trials of the technology of heap gold leaching from rebellious ore in Aprelkovo and Delmachik Mines. Efficiency of leaching flowsheets with the stage-wise use of activated solutions of different reagents, including active forms of oxygen, is evaluated. Carbonate-peroxide solutions are used at the first stage of leaching to oxidize sulfide and sulfide-arsenide ore minerals to recover iron and copper from them. The second stage leaching uses active cyanide solutions to leach encapsulated and disperse gold and silver.

Success gained in commercial testing and introduction of innovative mining and processing technologies for rebellious ore, based on brand new physical, physicochemical, biochemical and combination processes results in no enhancement in recovery of valuable components from low-grade and impoverished ore and mining and processing waste due to high capital and operating cost involved.

In this respect, it remains of concern to develop, evaluate and substantiate innovative processes to be included in flow charts of different physicochemical technologies, namely, underground (mine and borehole), heap and cuvette leaching. These processes should involve activation of leaching solution, minerals and sorbents by environmentally safe and low power-hungry physical fields and emissions. Combination photochemical and electrochemical treatment of solutions of some reagents allows producing highly active oxidizers at minimum energy input.

The most representative experiments on photo-and-electrochemically activated heap leaching of agglomerated and unagglomerated ore from waste stockpiles at Pogromnoe and Delmachik deposits, with high residual gold content (0.72–0.78 and 0.8–1.1 g/t, respectively), were carried out in Geotechnology Laboratory of the Chita Division of the Institute of Mining, SB RAS, and directly in Aprelkovo and Delmachik Mines. The laboratory tests showed that additional recovery of gold from Aprelkovo Mine waste ore by cyanide solutions prepared based on photo-and-electrochemically activated solutions of sodium bicarbonate with different admixtures, which was actually treatment by water-and-gas emulsions, made 37.3 % without secondary agglomeration and 58.3 % after secondary agglomeration. The concurrent tests of the same material in large percolation filters with the standard cyanide solutions yielded additional gold recovery of 20.1 % without secondary agglomeration and 35.6 % with the secondary agglomeration. After similar experimentations using Delmachik Mine waste ore material, additional gold recovery made 12–17 % as against the standard cyanidation.
circuit. It is noteworthy that the check solutions featured high concentration of cyanides (0.4 %), whereas the testing solutions had cyanide content not higher than 0.03 %. On the joint technical meeting at Aprelkovo Mine, it was decided to use the circuit of activation leaching without secondary agglomeration though it produced much lower gold recovery but its introduction in the process flow chart would require re-excavation of the waste material stockpile. In this regard, the authors suggested minimized drop-like feed of photo-and-electrochemically activated solution at the first treatment stage, which would be sufficient to soak the material, with the stage of ageing for 2–3 days before spraying the material with the high-concentration cyanide solution with pH = 10.5–10.7. For the tests in the mine, two samples were taken from different waste material stockpiles of unagglomerated and agglomerated ore (with the residual gold content of 0.65 and 0.55 g/t, respectively). Each sample was divided into one check and two testing specimens. As follows from Figure 1, the highest recovery was reached with the photo-and-electrochemical activation despite lower content of cyanide in the activation solution as compared with the check solution. In case of the waste material with the higher gold content, additional gold recovery with the activation circuit was 29.0 and 23.3 % in the testing specimens and (curves 3 and 2) and 21.9 % (curve 1) in the check specimen; as for the lower grade sample, additional gold recovery was 19.8 and 20.2 (curves 5 and 6) in the testing specimens and 14.3 % (curve 4) in the check specimen.

Gold yield in the testing pregnant solution takes 2 cycles as against gradual extraction of gold in the check circuit (see Figure 2). This means that activated solutions extract dispersed gold.

![Figure 1. Gold recovery from materials of heap leaching waste stockpiles (3 upper curves for the specimen with the gold content of 0.65 g/t; 3 lower curves for the specimen with the gold content of 0.55 g/t). The check curves for the specimens are the first and the fourth relative to the abscissa axis, respectively.](image1)

![Figure 2. Gold content of pregnant solution versus time in the standard circuit and activation leaching.](image2)
Au leaching from rebellious Delmachik ore using the standard agglomeration circuit ended with the low gold recovery in liquid phase despite the high content of cyanides, namely, 27 % as against the expected recovery of 32–35 %. This could be explained by the increased concentration of copper and antimony in the test ore material, and by solubility of these elements in the high-concentration cyanide solution. The introduction of the photo-and-electrochemical activation with the agglomeration in the circuit of the same sample produced gold recovery up to 57 %. Based on the testing results, management of Aprelkovo and Delmachik Mines decided on commercial testing of photo-and-electrochemical activation in processing of ore from Antimony Site using the flow chart of flotation (with mobile cell) and cyanidation of the flotation concentrate with photo-and-electrochemical activation of input and recycling solutions.

For the commercial tests in Aprelkovo Mine, the present paper authors and the engineers of NordGold company designed a process-and-equipment flow chart of the photo-and-electrochemically activated heap leaching of low-grade oxidized ore and waste stockpiled material. Additional pumps were purchased, and electrochemical and photochemical reactors to process initial solution of sodium bicarbonate were assembled (Figure 3).

![Figure 3. Electrochemical and photochemical reactors for activation of process solutions at Aprelkovo Mine.](image)

The sequence and parameters of feed of the process solution on a stockpile composed of leached and low-grade ore are developed.

Spraying is executed by unit section (a unit section is 30 000 thousand tons of ore, total area of 2206 m$^2$). Parameters: height—8 mm, bulk density—1.7 t/m$^3$, pumping capacity—700 m$^3$ per day, maximum capacity of 2 main lines—760 m$^3$/day (reference data), spraying density 700×1000/2206 = 317 l/m$^2$ per day. Capacity of grinding and sorting plant—170 thousand tons.

Commercial testing of process solutions included:

—Stage 1—three-days long feed of photo-and-electrochemically activated peroxide–carbonate solution (without sodium cyanide). Initial moisture content of ore in winter—3 %; moisture content or ore treated with the process solution is 9.7 %; i.e. it is required to feed 2100 m$^3$ of the photo-and-electrochemically activated solution per unit section;

—Stage 2—the solution is added with sodium cyanide up to the concentration of 0.35 g/l. Spraying is carried out for 8 days. Cyanide consumption makes 700×8×0.35 = 1960 kg.

By the time of this paper preparation, the increment in gold content of the pregnant solutions per the test unit sections was not less than 10 %.

References

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